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B-01-02, Jalan SS7/13B, Aman Seri, Kelana Jaya
47301, Petaling Jaya, Selangor Darul Ehsan, MALAYSIA
Tel: +603 78770637 Fax: +603 78779636 Email: mip@mip.org.my
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# DEVELOPING PRELIMINARY FRAMEWORKS FOR CHALLENGING ADJUDICATION DECISIONS: A CASE STUDY OF CONSTRUCTION INDUSTRY PAYMENT AND ADJUDICATION ACT 2012

**Nurul Afiqah Fairul Amir[1], Mohd Suhaimi Mohd-Danuri[2], Mazura Mahdzir[3], Zul Zakiyuddin Ahmad Rashid[4], Mohd Hanizun Hanafi[5]**

[1,2,3]*Centre for Building, Construction & Tropical Architecture (BuCTA),*
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UNIVERSITI MALAYA
[4]*School of Housing Building and Planning,*
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[5]*Faculty of Architecture and Ekistics*,
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## Abstract

The Construction Industry Payment and Adjudication Act 2012 (CIPAA 2012) helps provide a speedy remedy to the cash flow of a project due to payment disputes during the construction phase by providing an interim binding decision through adjudication. However, the challenge for adjudication decisions in court have been continuously reported in the CIDB Construction Law Report (CCLR), thus could potentially defeat the whole speedy and cheaper concept promoted by CIPAA 2012. This paper aims to explore the extent to which the adjudicator's decision can be challenged under section 15 of CIPAA 2012. It presents the trends on challenges raised under section 15 of CIPAA 2012, and the frameworks for challenging adjudication decisions. Case study approach on CIPAA 2012 has been drawn upon the analysis of court cases reported in the CCLR spanning from 2015 to 2020. The frameworks encompassing 4 main issues under section 15(b), 4 main issues under section 15(d), and 1 main issue under each of sections 15(a) and 15(c). The findings offer the parties in adjudication, a necessary understanding of the pertinent issues and to re-evaluate their claims before coming to court in the event if they wish to challenge the adjudication decision.

***Keywords**:* adjudication decision, challenge, section 15 of CIPAA 2012, CCLR

[2] Associate Professor at UM: Email: msuhaimi@um.edu.my

## INTRODUCTION

The Construction Industry Payment and Adjudication Act 2012 (CIPAA 2012) has been enacted in Malaysia, establishing a framework for statutory adjudication within the construction sector. Adjudication, as elucidated by Rajoo and Singh (2012), encompasses a process where an unbiased third party holds the authority to issue interim judgments on contractual disagreements among involved parties. Guided by the principle of "pay first, argue later," adjudication delivers an interim legally binding judgment, promptly alleviating payment concerns for affected stakeholders throughout the construction process (Che Haron & Arazmi, 2020; Yan, et al., 2023).

However, it is essential to acknowledge that adjudication, while offering temporary relief, may not always lead to the comprehensive resolution of disputes, as indicated by Mohd Bashah (2016). In the interim, unless the decision is overturned through an application to the High Court as stipulated in section 16 of CIPAA 2012, the parties are obligated to abide by the adjudication decision and fulfill the disputed payment. To have an adjudication decision set aside, the aggrieved party must initiate the process by applying to the High Court based on any of the grounds outlined in section 15 of CIPAA 2012. Subsequently, the challenging party is required to substantiate the existence of such circumstances as per the legislative framework, adhering to the general-civil standard of evidence, as expounded upon by Rahmat (2018) and the works of Rajoo and Singh (2012).

## OVERVIEW OF CIPAA 2012

Due to the expedited nature of decisions under the CIPAA 2012, sometimes referred to as "rough justice", the outcomes of adjudication can occasionally leave the aggrieved party dissatisfied. This rapid resolution process, while designed for efficiency, can lead to discontentment with the decisions rendered. It was reported that a notable portion, specifically 54.3 percent, of adjudication rulings end up being brought to court or subjected to arbitration (Wong, 2018). Furthermore, a study conducted by Mazani et al. (2019) explored the trend of adjudication challenges brought before the courts between 2014 and 2018, drawing from The Malayan Law Journal Unreported Journal.

The literature review indicated a rising trend in the submission of adjudication challenges throughout these years. However, despite the increase in challenges, as depicted in Table 1 of the study, only a relatively small portion of cases, namely 15 out of 62 cases, successfully managed to contest and overturn the decisions made by adjudicators. This data suggests that despite the push for swift resolutions through adjudication, a considerable number of cases still find their way into litigation or arbitration proceedings, possibly due to the perceived

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limitations of the "rough justice" nature of adjudication decisions. Hence, the rapid and binding nature of adjudication decisions mandated by CIPAA 2012 can lead to discontent among parties, prompting a significant percentage of decisions to be further contested in court or through arbitration (Mazani et al. 2019).

**Table 1:** Court's ruling on challenge to adjudicator's decision from 2014 to 2018 (Mazani et al. 2019).

| Year | Ruling by The Court | | | |
|---|---|---|---|---|
| | Stay of Adjudication Decision | Dismissed Adjudication Decision | Partially Dismissed and Allowed Adjudication Decision | Total Cases |
| As of Feb 2018 | 5 | 1 | 1 | 7 |
| 2017 | 25 | 7 | 3 | 33 |
| 2016 | 11 | 0 | 1 | 12 |
| 2015 | 7 | 1 | 1 | 9 |
| 2014 | 1 | 0 | 0 | 1 |
| Total no of cases | | | | 62 |

Specifically, challenges to set aside such decisions can be pursued under section 15(a) of CIPAA 2012 if it can be proven that the adjudicator engaged in fraudulent activities or bribery during the adjudication process, if there is evidence to demonstrate that the adjudicator failed to uphold the principles of natural justice during the adjudication proceedings as per section 15(b), if it can be established that the adjudicator exhibited bias or partiality in the conduct and judgment of the adjudication as stated in section 15(c), and if it can be demonstrated that the adjudicator went beyond their jurisdiction or authority as defined by the applicable laws and regulations under the provisions of section 15(d) of CIPAA 2012.

Realizing the significance of providing justice to an aggrieved party is fundamental to upholding fairness, this paper aims to explore the extent to which the adjudicator's decision and jurisdiction can be challenged under section 15 of CIPAA 2012. This can be achieved through the following objectives; (i) to study the trends on challenges raised under Section 15 of CIPAA 2012, and (ii) to propose preliminary frameworks for challenging adjudication decisions under the respective sections 15 of CIPAA 2012.

## METHODOLOGY

Case study research is a widely used methodology across various disciplines due to its ability to provide in-depth insights into complex phenomena within real-


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world contexts (Creswell, 2009). The flexibility of case study research allows researchers to explore processes, experiences, and behaviors from multiple perspectives (Cope, 2015). Case study represents a methodological approach where researchers delve deeply into a program, event, activity, process, or individuals to gain thorough understanding. Case study also defines by specific timeframes and activities, and researchers gather detailed information through various data collection procedures over an extended period (Stake, 1995; Yin, 2014; Merriam, 1998; Baxter and Jack, 2008).

Document review is a valuable method for collecting data in case study research. It involves gathering information from existing documents such as policies, reports, and other written materials (Creswell and Poth, 1997). This method allows researchers to access a wide range of data without the constraints of time and space (Xie et al., 2022). Document review can be particularly useful when studying complex real-world situations, as it enables a systematic analysis of written content (Akan et al., 2023). Additionally, document review can provide background knowledge, descriptions, and data that may not be obtainable through other means due to various limitations (Xie et al., 2022). A case study approach can also indeed be utilized to develop a framework. Verma and Sinha (2002) employed a case study methodology to develop a framework explaining the role of resource interdependencies, technology interdependencies, and business unit pull in driving project performance. Furthermore, the process of developing a framework from a case study involves identifying pre-defined themes and categories that shape the data collection and analysis (Frempong et al., 2018).

Hence, a case study approach serves as a valuable research method to explore and provide comprehensive understanding on the challenges raised under section 15 of CIPAA 2012. Chynoweth (2008) has also suggested how qualitative research via case study approach could complement a research about law which concern about interdisciplinary methodology in legal research. This paper presents, a case study focuses on the specific sections of the CIPAA 2012. The methodological approach utilized in this case study, conducted between January 2022 and April 2022, relies on data collection via document review by analyzing a compilation of court cases documented in the CIDB Construction Law Report (CCLR) from 2015 to 2020 (CCLR, 2016; CCLR, 2017; CCLR, 2018; CCLR, 2019; CCLR, 2020; CCLR, 2021).

## RESULTS AND DISCUSSION

The case study results and discussion are divided into the following two parts:

**The trends on challenges raised under Section 15 of CIPAA 2012**

Table 2 presents a comprehensive overview of 112 court cases associated with CIPAA 2012 that have been featured in the CIDB Construction Law Report. Among these cases, a specific subset of 53 cases has been meticulously examined for this paper. In essence, this study has selectively focused on these 53 cases to delve into the intricacies of challenges against adjudication decisions under section 15 of CIPAA 2012. The analysis of this subset aims to shed light on the various nuances and outcomes associated with disputes arising from adjudication decisions within the context of CIPAA.

**Table 2:** Number of reported court cases related to CIPAA 2012 from 2015-2020.

| Year | Number of Adjudication Cases featured in CIDB Construction Law Report from 2015-2020 | Number of Cases on Challenge to Adjudication Decision Under Section 15 of CIPAA |
|---|---|---|
| 2015 | 8 | 4 |
| 2016 | 12 | 7 |
| 2017 | 25 | 17 |
| 2018 | 29 | 14 |
| 2019 | 31 | 9 |
| 2020 | 7 | 2 |
| Total | 112 | 53 |

Table 3 provides an insightful depiction of the patterns observed in challenges raised under section 15 of CIPAA 2012. This section encompasses four distinct grounds, each attributed to a specific set of circumstances: fraud and bribery, denial of natural justice, not acting independently or impartially, and acting in excess of jurisdiction. A comprehensive analysis of these trends reveals noteworthy insights. As gleaned from Table 3, it becomes evident that challenges primarily arising under section 15(d), which pertains to the excess of the adjudicator's jurisdiction, stand out as the most prevalent. This suggests that many instances involve disputes that hinge on whether the adjudicator had exceeded their jurisdiction, thereby warranting judicial review. Following closely, challenges stemming from section 15(b), related to the denial of natural justice, also emerge as significant in number. This trend indicates that disputes linked to procedural fairness and equitable treatment of parties during the adjudication process have captured considerable attention.


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**Table 3**: Challenges raised under section 15 of CIPAA 2012

| Challenges raised under Section 15 of CIPAA 2012 | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total |
| S15 (a) : Fraud and Bribery | - | 1 | 1 | - | 1 | - | 3 |
| S15 (b) : Denial of Natural Justice | 4 | 5 | 13 | 10 | 5 | - | 37 |
| S15 (c) : Not Acted Independently or Impartially | 1 | 4 | 2 | - | - | - | 7 |
| S15 (d) : Acted in Excess of Jurisdiction | 2 | 5 | 14 | 13 | 8 | 2 | 44 |

Table 4 demonstrates a notable trend where the number of successful applicants who managed to challenge adjudication decisions remains remarkably low. In the broader context of the data collected, it is evident that out of the 53 challenges brought forth in relation to adjudication decisions, only a mere 10 cases resulted in success. This stands in stark contrast to the larger portion of challenges that ended up being unsuccessful. The data showcased in Table 4 underscores the considerable difficulty faced by parties attempting to overturn adjudication decisions through the legal process.

**Table 4:** Number of successful and unsuccessful challenges in court

| Year | Number of Successful Challenge | Number of Unsuccessful Challenge |
|---|---|---|
| 2015 | 1 | 3 |
| 2016 | 0 | 7 |
| 2017 | 5 | 12 |
| 2018 | 2 | 12 |
| 2019 | 2 | 7 |
| 2020 | 0 | 2 |
| Total | 10 | 43 |

**Preliminary Frameworks for challenging adjudication decisions**

In this case study, all 53 court cases were thoroughly analysed to formulate the preliminary frameworks addressing challenges in adjudication decisions. The ensuing discussion delves into the respective frameworks, aiming to offer a comprehensive understanding of the pertinent issues falling under the grounds outlined in section 15 of CIPAA 2012, where parties can endeavour to challenge

and overturn adjudicator's decisions. In this study, the framework development were guided by pre-defined themes and categories as suggested by Frempong et al. (2018), e.g., the respective section 15(a), 15(b), 15(c) and 15(d) of CIPAA 2012.

**Section 15(a): Engage in Bribe or Fraudulent Activity**

The case of *KPF Niaga Sdn Bhd v Vigour Builders Sdn Bhd and another* [2021] MLJU 229 demonstrated that the term "fraud" as used in section 15(a) of CIPAA does not explicitly mention that the fraud must be committed by the adjudicator or one of the disputing parties in the adjudication process. The case also highlights that deliberately withholding information by one of the parties during adjudication amounts to a deliberate act of deception and, consequently, fraud. The burden of evidence, however, is on the aggrieved party to show that the decision was obtained through bribery or fraud. Figure 1 below outlines the framework to successfully challenge the adjudicator's decision under section 15(a) of CIPAA 2012.

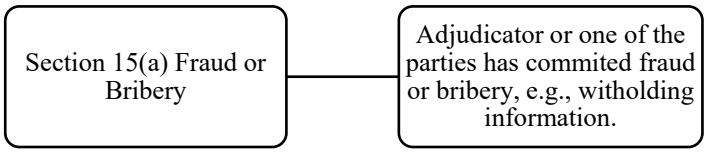


**Figure 1**: Framework outline for s.15(a); Fraud or bribery

**Section 15(b): Denial of Natural Justice**

Figure 2 depicts a range of issues raised in court to challenge adjudicator decisions under section 15(b), which relates to the breach of natural justice. It has been identified that about 4 common issues have been consistently brought to court under the grounds of section 15(b) as follows:

*Payment claim/ payment response*

This issue delves into the intricacies of payment claims and payment responses, shedding light on their relevance to section 15(b) of CIPAA 2012. It can be divided into two (2) separate subheadings which further clarify the issue, namely, failure to submit payment response and defective payment claim. For instance, the Federal Court in the case of *View Esteem Sdn Bhd v Bina Puri Holdings Bhd* [2018] 2 MLJ 22 has decided that the adjudicator is now required to consider all defenses raised by the respondents, notwithstanding that the defense was not raised in the Payment Response or payment response was not filed by the respondent. If the adjudicator fails to do so, he or she can be said to have not acted in accordance with natural justice.


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*Adjudication notice*

An adjudication notice is a formal communication issued by a court, tribunal, or other adjudicative body to inform parties involved in a legal proceeding about important matters related to the case. It typically includes essential information such as the date, time, and location of hearings, deadlines for submitting documents or evidence, and any specific instructions or requirements for the parties to follow. According to the case of *Ban Soon Aik Construction Sdn Bhd v Berjaya Land Development Sdn Bhd & Another Appeal* MLJU 1232, an adjudication notice can be invalid if the notice is not being served properly.

*Unilateral communication*

Unilateral communication, as discussed by Rajoo and Singh (2012), goes against one of the fundamental principles of natural justice, known as "audi alteram partem". This principle dictates that in any judicial proceeding, each party involved should be given a fair opportunity to hear the arguments and evidence presented by the other side. Under the heading of unilateral communication, two sub-issues are highlighted, namely: 1) failure to consider expert reports or allow oral hearings, and 2) failure of the adjudicator to comment on material authorities. For instance, in the case of *Guangxi Dev & Cap Sdn Bhd v Sycal Bhd & Another Case* [2019] 1 CLJ 592, to constitute a denial of natural justice, it would have to be both decisive and potentially important to established that a different decision would have been reached if the witnesses had been allowed to be heard orally. Further, the denial of an application to comment does not necessarily constitute a violation of natural justice. In the case of *First Commerce v Titan Vista* [2021] MLJU 376, the court ruled that the adjudicator has the discretion to seek further explanations or information regarding the matter referred to them, but they are not obligated to do so. It is ultimately the responsibility of the parties involved to present all relevant information and arguments during the adjudication process.

*Right to be heard/ considered*

In essence, the right to be heard or considered is a fundamental aspect of procedural fairness, and it plays a significant role in the context of challenging an adjudicator's jurisdiction under the CIPAA 2012. Under CIPAA 2012, there are various circumstances where the right to be heard may be implicated:

a) Failure to hold an oral hearing: While CIPAA 2012 does not mandate oral hearings, the failure of an adjudicator to hold one could potentially infringe upon the parties' right to be heard, especially if it results in a denial of the opportunity to present their case verbally.
b) Wrongful refusal by the adjudicator: If the adjudicator unjustly denies a party's request for an oral hearing or fails to adequately consider such a request, it could be grounds for challenging the adjudicator's jurisdiction.

c) Failure to consider relevant case law: Adjudicators are expected to consider relevant legal precedents and case law when making decisions. If an adjudicator fails to do so, it may constitute a violation of the parties' right to be heard, particularly if the case law could have a material impact on the outcome of the adjudication.

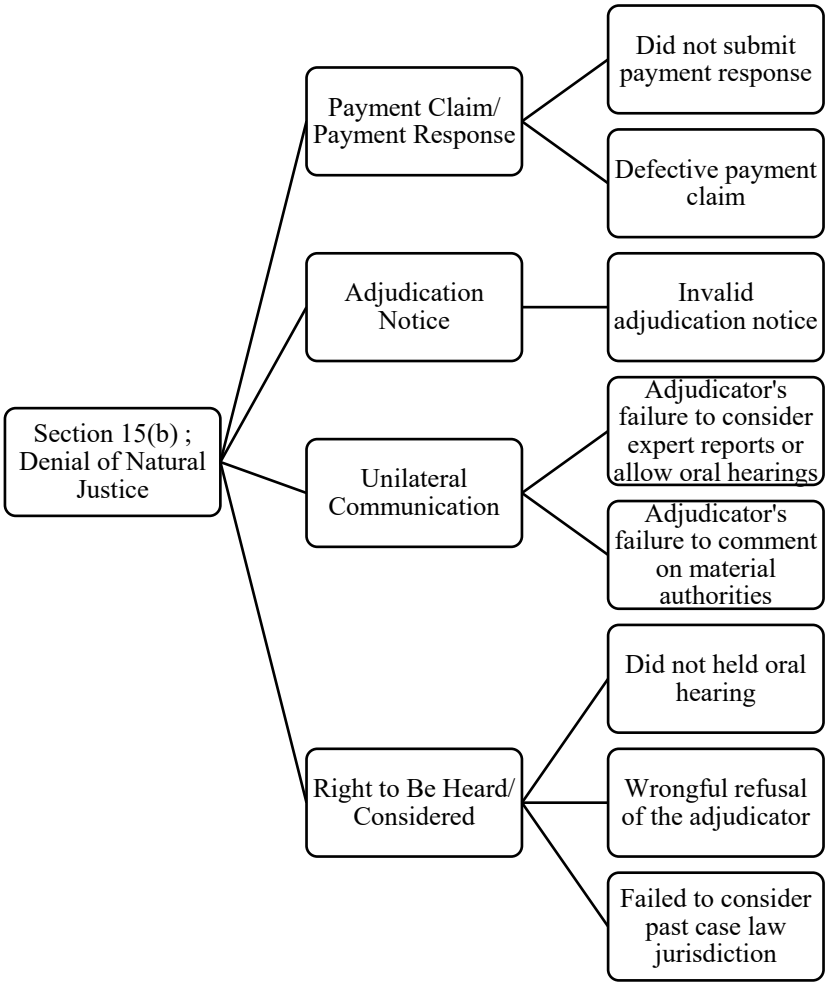


**Figure 2:** Framework outline for s.15(b); Denial of natural justice


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**Section 15(c): Adjudicator Has Not Been Impartially or Independent in His Judgment**

The burden of proof lies with the party making the challenge, and they must provide factual evidence to support their claims that the adjudicator has failed to act independently and impartially. The case analysis shows that this usually include instances where the parties argued that the adjudicator has failed to consider relevant evidence or failed to provide the party with a fair chance to present their arguments. However, simply alleging a misconception about the independence or impartiality of the adjudicators is insufficient grounds for setting aside a judgment. As suggested by Zin and Nik Husain Fathi (2020), challenges based on this ground have been usually unsuccessful due to the high burden of proof required to establish a lack of independence or impartiality. Figure 3 below outlines the framework to successfully challenge the adjudicator's decision under section 15(c) of CIPAA 2012.

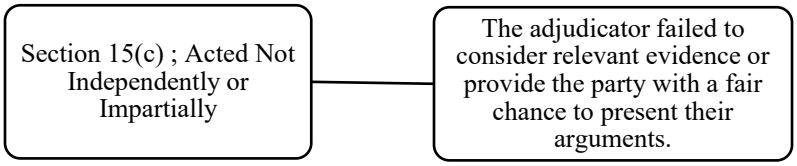


**Figure 3:** Framework outline for s.15 (c); Acted Not Independently or Impartially

**Section 15(d): Excess of Jurisdiction**

Apart from challenges under section 15(b) for denial of natural justice, challenges under section 15(d) for excess of jurisdiction is also one of the most popular challenges in adjudication. Section 25 of CIPAA 2012 grants the abovementioned powers, which appear to be broad, ranging from determining the method to be used and the scope of discovery and production of documents to ruling or declaring on any subject despite the lack of issuance of any certificate in such matter. 4 main issues have emerged from all of the court cases studied. Figure 4 outlines the framework to successfully challenge the adjudicator's decision under section 15(d) of CIPAA 2012 spearhead by the 4 main issues.

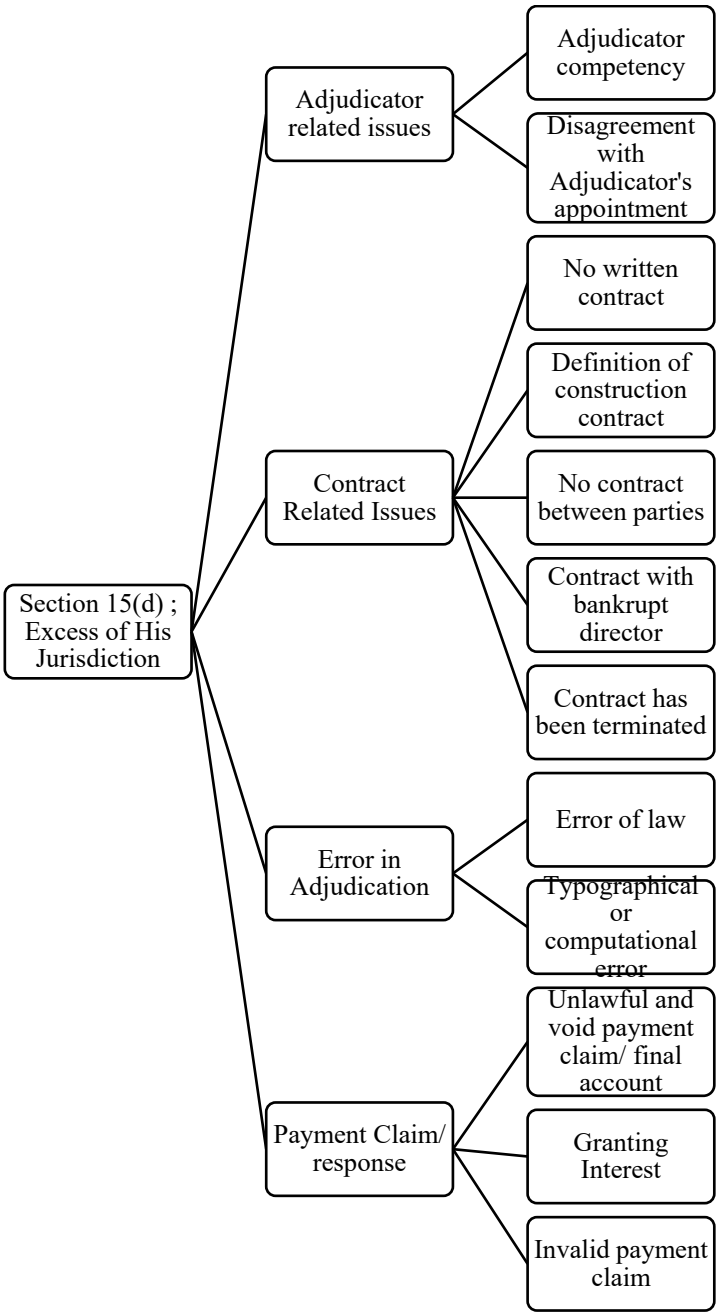


**Figure 4:** Framework outline for s. 15 (d); Excess of jurisdiction


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*Adjudicator related issues*

One of the most popular issues brought to court under this section was regarding matters that related to the adjudicator itself. The issues were related to the adjudicator's competency and the appointment of the adjudicator. The court has recognised that the competency of the adjudicator are regulated by AIAC, via a structured training and courses. Therefore, asserting that an adjudicator had not met the standards and requirements as a qualified adjudicator is indeed a difficult task.

*Contract related issues*

The case study analysis demonstrates 5 contract related issues that are often brought to court to challenge the adjudicator decision under section 15(d) of CIPAA 2012. The related issues are: no written contract between parties, the contract entered is not a construction contract and thus does not fall under the ambit of CIPAA 2012, no contract between parties, the validity of the contract entered with the bankrupt director, and lastly does CIPAA 2012 still applies to contract that has been terminated. Overall, the issues involving contracts in relation to adjudication decision challenges generally cover the validity of the contract and determine whether the statutory adjudication applies to the contract.

*Error in adjudication*

To set aside adjudication based on there is an error of law in the adjudication decision, there is a need to prove that the adjudicator is on “frolic of his own” by his conduct through his wisdom and expertise. For instance, it was emerged from the case study that a flawlessly written decision, or requirement for the adjudicator to subscribe to any particular writing style or a mode of the plaintiff's preference were considered as irrelevant argument to justify the setting aside of the whole of the adjudication decision, as it did not affect the substance of the decision.

*Payment claim/response*

Payment claims and response are essential in the adjudication process, one of the reasons is due to the fact the scope of the adjudication would be determined from the issues that arise in the payment claim only (Zin and Nik Husain Fathi, 2020). Based on *SKS Pavillion Sdn Bhd v Tasoon Injection Pile Sdn Bhd* [2019] 9 MLJ 396, an adjudicator could not cure an irregularity in a payment claim or decide a challenge on jurisdiction due to non-compliant payment claim, as the adjudicator did not have the competence or jurisdiction to do this in the absence of a payment claim that complies with section 5 of CIPAA 2012.

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## CONCLUSION

The Construction Industry Payment and Adjudication Act (CIPAA), 2012 aims to help provide immediate relief to a project's cash flow as a result of a payment dispute during the construction phase. The rough justice and interim binding nature of the adjudicator's decision in CIPAA 2012 have made the process of re-litigation or arbitration of adjudication proceedings under CIPAA 2012 more likely to happen. Respondents in the adjudication process appear to be at a disadvantage because to claimant is the one initiating the adjudication proceeding and the court's role in supporting adjudication decisions unless the reason to set aside is solid, implying that challenges will always be required, undermining the speedy and cheaper alternative promoted by CIPAA. Thus, frameworks for challenging adjudication decisions, is developed to offer the parties in adjudication, a necessary understanding of the pertinent issues related to section 15 of CIPAA 2012. The findings serve as re-evaluate their claims before coming to court, as well as to prevent parties from abusing section 15 of the CIPAA 2012. The preliminary framework also may serve as early reference for the disputant parties to re-evaluate their claims before coming to court in the event if they wish to challenge the adjudication decision. It is also acknowledged that the preliminary frameworks could further be enhanced through expert validation.

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# ENHANCING LEGAL MECHANISMS TO ADDRESS PROJECT PAYMENT ISSUES ENCOUNTERED BY SMALL AND MEDIUM-SIZED CONTRACTORS IN MALAYSIA

**Lee Shi Ting[1], Mohd Suhaimi Mohd Danuri[2], Zul Zakiyuddin Ahmad Rashid[3], Umi Kalsum Zolkafli @ Zulkifly[4], Zulkiflee Abdul Samad[5]**

[1,2,4,5]*Centre for Building, Construction & Tropical Architecture (BuCTA),*
*Faculty of Built Environment,*
UNIVERSITI MALAYA
[3]*School of Housing Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

Persistent payment problems remain a significant obstacle to the financial stability of industry participants, especially small and medium-sized contractors. Initially, the Construction Industry Payment and Adjudication Act 2012 (CIPAA 2012) was introduced with the primary aim of establishing a mechanism for swift dispute resolution through adjudication, while encouraging regular and timely payments. Apart from CIPAA 2012, litigation and alternative dispute resolution (ADR) methods are also available, which are more commonly utilised and familiar to small and medium-sized contractors. Hence, this research endeavoured to explore whether CIPAA 2012 and other legal mechanisms suit the needs of small and medium-sized contractors operating in the Malaysian construction industry. This study has employed qualitative methods, specifically semi-structured interviews, as the means of data collection. These interviews were conducted with contractors who belonged in either the small category (G1-G3) or the medium-sized category (G4-G5). The findings of this study have unveiled various avenues for enhancing the current legal mechanisms. Notably, a compelling suggestion has emerged to establish a dedicated legal tribunal responsible for addressing small payment disputes. The outcomes of this research could significantly contribute to our comprehension of how CIPAA 2012 and other legal mechanisms could positively impact the capacity of small and medium-sized contractors to effectively resolve their payment-related disputes.

***Keywords:*** CIPAA 2012, construction industry, legal mechanisms, payment problems, small and medium-sized contractors, construction project

[2] Associate Professor at UM: msuhaimi@um.edu.my

## INTRODUCTION

Construction activities in Malaysia reached a value of RM24.8 billion during the third quarter of 2021 (Department of Statistics Malaysia, 2021). In the pursuit of becoming a developed nation, it is imperative for the Malaysian government to prioritise and support the construction industry. However, despite its significance, this industry faces various challenges, one of which is the persistent issue of payment problems (Che Haron et al., 2020). Rajoo and Singh (2012) have highlighted that payment disputes, claims, and counterclaims are inevitable in the construction industry. Since the construction industry in Malaysia operates in a hierarchical structure, any payment dispute that arises at the top level can have a significant impact on the cash flow throughout the entire chain (Cheah, 2019). This situation is further exacerbated by the presence of conditional payment practices in construction contracts, which are particularly prevalent in projects involving subcontractors (Hii, 2018). These conditional payment terms, such as 'pay-when-paid' or 'pay-if-paid' clauses, meant that subcontractors will only receive payment from the main contractor, if and when they are paid by the clients. As a result, if upstream players fail to fulfil their obligation of timely payments, downstream players like the subcontractors are left to bear the burdensome and unfair consequences (Tay & Kong, 2018; Yan et al., 2023).

According to the Construction Industry Development Board (CIDB, 2018), contractors registered with the board are classified into seven grades (G1-G7) based on several factors, such as paid-up capital and tendering capacity. Kamal et al. (2012) proposed that contractors can be further categorised into small (G1-G3), medium (G4-G5), and large (G6-G7) sizes. As shown in Table 1, small-sized contractors form the majority among all registered contractors with CIDB, thus, highlighting their significant role in the construction industry and their valuable contribution to the economic growth of this country. However, these small and medium-sized contractors have not received adequate attention from the government, as the current focus still tends to favour larger listed firms (Theong et al., 2014).

To address the previously mentioned payment issues, the Construction Industry Payment and Adjudication Act 2012 (CIPAA 2012) was enacted in Malaysia to promote timely and regular payment, and to provide a mechanism for speedy dispute resolution through adjudication. Apart from CIPAA 2012, litigation and alternative dispute resolution (ADR) methods are also available, which may be more commonly utilised and familiar among small and medium-sized contractors. Hence, this research aimed to explore whether CIPAA 2012 and other legal mechanisms have benefitted the small and medium-sized contractors, with a specific focus on resolving disputes involving small amounts of payment. The findings of this study could be used to generate recommendations for enhancing the legal mechanisms that could better cater the

needs of small and medium-sized contractors in the Malaysian construction industry.

**Table 1:** The Numbers of Contractors Registered with CIDB Based on Sizes and Grades, as of 24 August 2023

| Grade | Paid-Up Capital (RM) | Tendering Capacity (RM) | Size | Number of Contractors |
|---|---|---|---|---|
| G1 | 5,000 | <200,000 | Small | 65,747 |
| G2 | 25,000 | <500,000 | | 22,388 |
| G3 | 50,000 | <1,200,000 | | 17,150 |
| G4 | 150,000 | <3,000,000 | Medium | 5,444 |
| G5 | 200,000 | <5,000,000 | | 7,434 |
| G6 | 500,000 | <10,000,000 | Large | 1,956 |
| G7 | 750,000 | No Limit | | 9,451 |
| **Total** | | | | **129,570** |

*Source: CIDB (2023)*

## OVERVIEW OF CIPAA 2012

Due to the long-standing payment problems in the construction industry in Malaysia, statutory adjudication through CIPAA 2012 was introduced to eliminate the widespread conditional payment practices, as well as to establish a more efficient and cost-effective dispute resolution method through adjudication (Azman et al., 2013). In addition to prohibiting unfavourable conditional payment practices, Section 29 of CIPAA 2012 grants the unpaid party the right to suspend or reduce work progress, if the disputed amount remains unpaid, either partially or in full, even after receiving the adjudication decision. Section 29(4) also explicitly states that the unpaid party who suspends or slows down work or services is entitled to a fair extension of time and can claim any losses and expenses incurred. Moreover, the adjudication process can be conducted concurrently with ongoing projects, which minimises disruptions to activities (Hassan et al., 2019; Yat, 2016).

In general, the CIPAA 2012 offers a considerably quicker resolution process compared to other dispute resolution mechanisms, such as litigation and arbitration. However, despite the positive effect of CIPAA 2012 in addressing payment claims, Singh (2018) argued that the adjudication process has become more complex and has deviated from its original purpose of assisting industry participants, such as small and medium-sized contractors, consultancy firms, suppliers, and laypersons in resolving disputes. Due to the time constraints of an adjudication process, it is believed to provide rough justice, resulting in less precise adjudication decisions (Rajoo, 2016).


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### Other dispute resolution mechanisms

In the context of the Malaysian construction industry, apart from adjudication, other dispute resolution methods are available, such as negotiation, mediation, arbitration, litigation, and legal tribunal. Negotiation is widely acknowledged and generally recognised as a common and preferred approach for resolving disputes, owing to its directness and potential to preserve relationships between the parties involved. Negotiation is a voluntary process where the parties involved would attempt to reach a settlement without the involvement of a third party who imposes decisions (Legal Information Institute, 2021). Likewise, mediation is also a voluntary process, where a neutral and independent third party, known as a mediator, assists the two parties in finding a mutually agreeable resolution (Mishra, 2020). In Malaysia, the Mediation Act 2012 was enacted to promote mediation as an alternative dispute resolution method.

Additionally, the Arbitration Act 2005 governs arbitration processes in this country, with the Asian International Arbitration Centre (AIAC) serving as the governing body. Arbitration involves a neutral third party, the arbitrator, who decides on the dispute. However, arbitration requires a contractual provision or agreement between the parties, although there are some exceptions (Mah, 2016). Despite the availability of various alternative dispute resolution mechanisms in the construction industry, formal litigation remains a commonly used method (Derrick, 2016).

## METHODOLOGY

Given the exploratory nature of this research and its focus on small and medium-sized contractors, a qualitative approach was deemed appropriate. To collect data for this research, semi-structured interviews were conducted. The snowball sampling method was also employed, whereby new interviewees were identified through referrals by the existing interviewees (Neuman, 2017). Lau (2018) discussed the importance of validating qualitative research findings to ensure their quality, precision, accuracy, and credibility. Lau (2018) further highlighted that qualitative research studies are often conducted with a small sample size, which may raise doubts regarding the generalisability of the findings. Several strategies can be used for validating qualitative data, including external auditing, thick description, peer review, and member check (Lau, 2018; Lub, 2015; Mora, 2021). For this study, member check that involved the interviewees themselves was regarded as the most suitable approach to seek their feedback and validate the findings. The interviewees, being familiar with their own experiences and dilemmas in resolving disputes, were able to provide valuable input to validate the findings and enhance the credibility of the qualitative data. The profiles of the interviewees are presented in Table 2.

**Table 2:** Interviewees' Profile

| Interviewee Code | Years of Experience | CIDB Grade | Position Held |
|---|---|---|---|
| 001 | 38 | G5 | Director |
| 002 | 11 | G4 | Managing Director |
| 003 | 23 | G4 | Project Director |
| 004 | 10 | G4 | Director |
| 005 | 37 | G3 | Managing Director |
| 006 | 20 | G2 | Managing Director |
| 007 | 15 | G3 | Director |
| 008 | 15 | G3 | Senior Manager |
| 009 | 25 | G3 | Director |
| 010 | 20 | G5 | Finance Manager |
| 011 | 3 | G4 | Tender Engineer |
| 012 | 15 | G3 | Director |
| 013 | 5 | G5 | Director |
| 014 | 8 | G2 | Director |
| 015 | 20 | G3 | Director CEO |
| 016 | 22 | G4 | Director |
| 017 | 9 | G4 | CEO |
| 018 | 15 | G5 | General Manager |
| 019 | 20 | G4 | Commercial Consultant |

In March 2022, a total of 30,855 CIDB G1-G5 contractors were registered in the Klang Valley region (CIDB, 2022). A total of 1,118 invitations were sent via email to the members of this group, inviting them to participate in a semi-structured interview. The selection criteria for the interviewees included individuals who have faced payment problems and managerial personnel with at least 3 years of experience in the construction industry. Their contact details were obtained from the Centralised Information Management System (CIMS) on the CIDB's website, in addition to the website of their respective company. Those who accepted the email invitations were further filtered to ensure that they fulfilled the selection criteria. Subsequently, 19 individuals accepted the invitation to partake in the interview sessions. For confidentiality purposes, these interviewees were assigned unique labels in an ascending order (001–019) that corresponded to their interview date and time. All semi-structured interviews were conducted either through Zoom or telephone conversations, as the COVID-19 pandemic restrictions were in place during March and April of 2022. Table 3 lists the distribution of interviewees based on the size of their contracting businesses, thus distinguishing between small and medium-sized contractors.


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**Table 3:** Number of Interviewees based on Size of Contractors

| CIDB Grade | Contractor's Size | Number of Interviewees | Total |
|---|---|---|---|
| G1 | Small | 0 | 8 |
| G2 | | 2 | |
| G3 | | 6 | |
| G4 | Medium | 7 | 11 |
| G5 | | 4 | |
| **Total** | | | **19** |

## RESULTS AND DISCUSSION

The responses of nine (47.37%) out of 19 participants, indicated that they were unfamiliar with CIPAA 2012. Remarkably, six of these individuals belonged in the category of small-sized contractors, with four of them belonging in the grade G3 group, while the final two belonged in the grade G2 group, making them the majority within this category. Based on these statistics, small-sized contractors were found to exhibit lower levels of exposure and awareness of CIPAA 2012 compared to their medium-sized counterparts.

Conversely, interviewees who were familiar with CIPAA 2012 accounted for 52.63% of the total participants (10 out of 19 interviewees), with only five interviewees demonstrating a comprehensive understanding of CIPAA 2012, which encompassed its objectives, purpose, and potential benefits for the stakeholders in the construction industry. These interviewees have also acknowledged that CIPAA 2012 offers a relatively quicker, more cost-effective, equitable, and efficient method for resolving disputes compared to arbitration and litigation. In contrast, the remaining five interviewees who have heard of CIPAA 2012 were merely aware of its existence, but lacked a substantial understanding of its essence and how it could be advantageous to them.

The following section presents the findings of this study, as categorised into three parts: perception towards CIPAA 2012; the application of dispute resolution methods and the disputed amounts; and preference for dispute resolution methods when dealing with smaller dispute amounts.

### Perception towards CIPAA 2012

The interviewees, in general, held the perception that adjudication is not a favourable option for dealing with small dispute amounts, especially for small-sized contractors. They believed that adjudication could be financially burdensome for settling small disputes. Additionally, they were concerned that opting for adjudication might not be appealing to small-sized contractors due to various reasons. Another notable concern was the potential for the adjudication decision to be challenged in court, which could further prolong the resolution

process and incur additional costs. This uncertainty and legal complexity surrounding adjudication were viewed as deterrents for smaller contractors. Furthermore, there was a recognition among the interviewees that engaging in the adjudication process could strain the relationship between contractors and the party with whom they were in dispute. These findings were derived from the following thematic analysis of the interviewees' perceptions towards CIPAA 2012.

*Costly for small dispute amounts*

The interviewees generally emphasised that when disputes involve amounts that exceed RM10,000.00, pursuing resolution through the Construction Industry Payment and Adjudication Act 2012 (CIPAA 2012) would be considered a viable and worthwhile option. However, a different approach is often taken when dealing with disputes involving relatively small amounts, specifically those totalling less than RM10,000.00. In such cases, small and medium-sized subcontractors tend to explore less formal means of resolution before considering CIPAA 2012. This is primarily due to the perception that investing more time and resources in navigating the CIPAA 2012 process may exceed the initial losses incurred, rendering it an unproductive endeavour for many parties. The following excerpts exemplify the emergence of this prevailing sentiment:

> "I've calculated before. It is not worth it for disputes below RM5,000, I would rather go through negotiation. For more than RM10,000, it's worth a shot to go through CIPAA." (Interviewee 003)
>
> "I have a friend who is a CIPAA consultant, he told me it's not worth it, if the dispute amount is less than RM10k…" (Interviewee 009)

*Unfair for small contractors*

Larger contractors clearly hold a significant advantage in the adjudication process, as their greater resources and financial stability would substantially increase their likelihood of prevailing in a case.

> "Big companies usually have a professional team of lawyers or consultants; they are more dominant in the industry and may bully the smaller subcontractors who don't understand so much about CIPAA 2012 and take advantage of them." (Interviewee 003)


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*Decision can be challenged in court*

Indeed, the decision made by the adjudicator is, in practice, only temporarily binding. In connection with this, several interviewees have pointed out a significant drawback of CIPAA 2012, which was the ability to challenge the adjudicator's decision in a court of law.

> "...can be challenged in a Court of Appeal and Federal Court, and the defendant still can delay payment even with CIPAA 2012." (Interviewee 005)
> "However, the disadvantage is that it can still be subjected to high court ruling where we still end up not getting a full settlement, even if we have won the case." (Interviewee 018)

*Jeopardised relationship between the disputants*

Subcontractors often encounter challenges when contemplating taking action against the main contractor, as they are inclined to preserve the relationship for the purpose of securing future projects. The following excerpt serves to depict such concerns that CIPAA 2012 might have adverse effects on the relationship between disputing parties.

> "...sometimes it's not about the money but rather about the relationship between the contract parties. I spent so much effort working for you, but you don't pay me." (Interviewee 003)

**Dispute resolution methods applied and disputed amounts**

Interviewees were requested to provide additional details regarding the dispute resolution methods they have employed in addressing their payment disputes and the disputed amounts. The information gathered from their responses are summarised in the following Table 4.

**Table 4:** Thematic Analysis on the Dispute Resolution Method and Disputed Amount

| **Theme** | **Disputed Amounts** | **Interviewee's Quotes** |
|---|---|---|
| Send reminders / negotiation | RM 10k | "Try reminding them..." (Interviewee 014) |
| | RM 20k | "Negotiated with the main contractor for payment by instalment." (Interviewee 008)<br>"...just keep reminding and reminding…" (Interviewee 009) |

| **Theme** | **Disputed Amounts** | **Interviewee's Quotes** |
|---|---|---|
| | RM 50k – RM 100k | "...through negotiation with the main contractor…" (Interviewee 012)<br>"Carry out proper discussion between parties involved. Price rate will be negotiated and agreeable in certain cases." (Interviewee 011)<br>"Through negotiations and proper documentations, such as site diary activities record, certifications of work…" (Interviewee 015) |
| | RM 250k – RM 300k | "Negotiation, keep calling and reminding the client…" (Interviewee 006)<br>"...just keep chasing for payment…" (Interviewee 016) |
| | RM 500k | "...keep sending reminder through email…" (Interviewee 010)<br>"...negotiation to delay payment for a fixed amount of time." (Interviewee 013) |
| | RM 1mil | "...carry out discussions and negotiation process to understand the client's situation and also provide other ways or terms of payment." (Interviewee 002) |
| Adjudication (CIPAA 2012) | RM 30k | "There was also unjustified back charge, so we 'CIPAA them'. In the end, they did pay but we offered a certain amount of discount." (Interviewee 004) |
| | RM 100k | "We sent our CIPAA 2012 consultant to go deal with them. Until the second letter, their lawyer was aware of the issue and I negotiated with the client. In the end, they paid us." (Interviewee 003 |
| | RM 1mil | "…CIPAA 2012…the case was partially resolved by imposing 'hair-cut' initiatives, where the client only offered to pay a fraction of the amount they owed us." (Interviewee 018) |
| Litigation | RM 30k | "...go to court…court gave special order for us to give a discount because we are also afraid the company who owes us money will go bankrupt." (Interviewee 019) |
| Arbitration | RM 100k | "...unless it's a very serious matter, I think if there is a |


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| **Theme** | **Disputed Amounts** | **Interviewee's Quotes** |
|---|---|---|
| | | dispute above RM 300k, then I might consider arbitration…" (Interviewee 013) |
| Legal tribunal | RM 10k | "Once there was a case where the client refused to pay, we asked our lawyer to issue a letter of demand for the money. Instead of paying, the client directly went to the tribunal court for consumers to complain that we didn't do our work properly. We won the case because their accusation of us was unreasonable. Out of good will, we gave a bit of discount of around RM 1k." (Interviewee 017) |

Table 4 highlights that the majority of interviewees prefer to employ other methods, such as sending payment reminders or engaging in negotiations when faced with payment disputes, even when the disputed amount reaches as high as RM 1 million. Only a limited number of interviewees have practical experience with alternative dispute resolution methods, e.g., adjudication (three interviewees), arbitration (one interviewee), litigation (one interviewee), and legal tribunal (one interviewee). Interestingly, none of the interviewees have had any exposure to the mediation process as a means of resolving their disputes.

**Preferred dispute resolution methods for small dispute amounts**

This section outlines the dispute resolution methods favoured by small and medium-sized subcontractors when addressing disputes involving relatively small amounts.

*Negotiation*

Essentially, the consensus among the interviewees was that negotiation stands out as the simplest and most straightforward approach for resolving payment disputes. This preference for negotiation was rooted in the belief that for smaller dispute amounts, to pursue more formal dispute resolution methods would be deemed unworthwhile. The following excerpts have captured this sentiment:

> "I think the easiest one is negotiation, just sit down and talk…rather than spending money to go through complicated processes. We just maybe give a discount and then, get back our owed money…only bigger contractors will go through legal processes." (Interviewee 001)

> "...negotiation… is faster, easier and cheaper…" (Interviewee 002)
> "...for our contracts, usually it's small amounts of around RM 150k, it's not worth it to go through dispute resolution, you spend more time and more money on the legal side." (Interviewee 012)

*Mediation*

Despite the absence of direct mediation experiences among the interviewees, there was a prevailing belief that the impartial nature of a mediator could potentially clarify the overall situation and facilitate the disputing parties in reaching a settlement agreement. The following relevant excerpts captured this perspective:

> "...mediation…is faster, easier and cheaper…" (Interviewee 002)
> "...will consider referring to mediation…which is handier and faster compared to litigation." (Interviewee 011)

*Arbitration*

The interviewees held a perception that arbitration was a less complicated and faster alternative to litigation. They have also indicated that arbitration was better suited for complex disputes and situations involving a significant number of claims.

> "…and arbitration, which is harder and faster compared to litigation." (Interviewee 011)
> "…probably would not occur, since most of our projects don't have big contract amounts that may need to go through that process." (Interviewee 016)

*Legal Tribunal*

While there is currently no dedicated tribunal specifically for construction disputes, one of the interviewees mentioned that a legal tribunal could potentially serve as a suitable dispute resolution method for smaller dispute amounts. This interviewee suggested that the tribunal for consumer claim could provide a cost-effective and expeditious mechanism, unless the parties opted to engage their own legal representation.

> "Tribunal court is useful for very small amounts, it's free as well, unless you hire your own lawyer. However, the one our company went to was for consumers, there is no tribunal specifically for construction." (Interviewee 017)


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## ENHANCING THE LEGAL MECHANISMS

The research findings were sent back to the interviewees for member check validation through a questionnaire survey. Out of the 19 interviewees, only seven of them responded to the survey. These interviewees agreed with the research findings, which indicated a level of consensus among the participants. Their consensus provided further credibility to the research findings of enhancing legal mechanisms to positively impact the capacity of small and medium-sized contractors in resolving their payment-related disputes. Figure 1 illustrates the proposed enhancement.

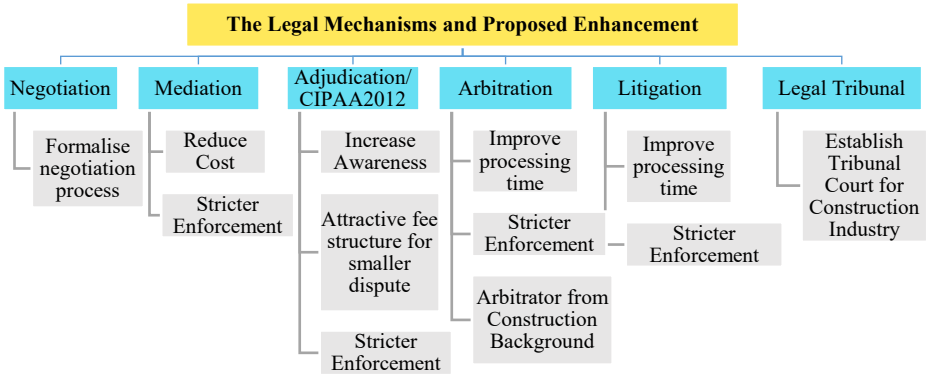


**Figure 1:** Proposed enhancements to the legal mechanisms

The research findings have revealed that many small and medium-sized contractors lacked the awareness and thorough understanding of CIPAA 2012. Raising the awareness of CIPAA 2012 among small and medium-sized contractors would necessitate the involvement of pertinent industry stakeholders, including the CIDB, the Master Builders Association Malaysia (MBAM), and other reputable contractors' associations in Malaysia. By collaborating with the AIAC, these entities can devise a comprehensive plan to educate contractors about CIPAA 2012. The findings also showed that CIPAA 2012 has been perceived as being financially burdensome for smaller disputes, which rendered it unattractive for small and medium-sized contractors. Hence, revising the adjudication fee structure and streamlining the process for smaller disputes could be an option. However, implementing this option necessitates a comprehensive study to ensure its appeal to both disputing parties and adjudicators, without compromising the effectiveness or integrity of the adjudication process, or infringing upon the rights of the parties involved.

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The findings have also indicated that industry stakeholders have predominantly favoured negotiation as their primary method for resolving disputes. However, this approach may be susceptible to misuse by serving as a stalling tactic when one party lacks a genuine intent to resolve the dispute through negotiation due to its non-binding nature (Dani, 2020). Therefore, a legal reform aimed at formalising the negotiation process could improve its effectiveness. This recommendation aligned with the proposal by Mohd-Danuri (2021), who proposed several amendments to existing legislations that could encourage disputing parties to consider negotiation before resorting to adjudication. The suggested reform involves recognising and enforcing settlement agreements by providing robust procedures to ensure adherence to the law and its enforcement.

It is noteworthy to mention an intriguing proposal suggesting the establishment of a specialised legal tribunal designed to address small project payment claims, specifically tailored to meet the requirements of small and medium-sized contractors. This idea could also be expanded to encompass small project payment claims involving suppliers and consultants, thereby increasing its relevance and applicability. This suggestion bears resemblance to the Tribunal for Consumer Claims Malaysia, which offers specialised judicial bodies for consumers to seek redress for goods and services purchased (Courts and Tribunal Judiciaries, 2022). However, forming such a tribunal would require a comprehensive study which necessitates essential legal reform.

## CONCLUSIONS

To summarise, the choice of employing CIPAA 2012 for resolving disputes within the Malaysian construction industry frequently depends on the monetary value of the dispute. In instances involving larger disputes, the advantages of being cost-effective and offering swift resolutions make adjudication a compelling option. Conversely, for smaller disputes, concerns about perceived expenses and time commitments may prompt parties to initially explore informal dispute resolution methods before contemplating more structured approaches. Numerous methods are presently accessible for addressing payment disputes within the Malaysian construction industry, encompassing negotiation, mediation, adjudication, arbitration, litigation, and the potential introduction of a legal tribunal. However, these mechanisms for dispute resolution demand ongoing enhancements to effectively address the prevailing problematic payment practices within the industry, particularly concerning small and medium-sized subcontractors. Enhancements to the legal mechanisms may also necessitate crucial legal reforms that are geared towards augmenting both justice and efficiency. The outcomes of this study have the potential to instigate further


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captivating research endeavours within the realm of dispute resolution in the Malaysian construction industry.

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# ADOPTION OF TECHNOLOGY FOR CONSTRUCTION SITE SAFETY MANAGEMENT: UNVEILING INSIGHT FROM PENANG CONTRACTORS

**Teoh Li Ting[1], Izyan Yahaya[2]**

[1,2]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

The construction industry has the highest fatality rate among other industries. In light of this, the pivotal role played by contractors in leveraging technology to enhance site safety cannot be ignored. Despite the emergence of various technologies, little is still known about the extent of their involvement in this regard. Thus, this research intends to explore technology adoption for safety practices among contractors, the influencing factors, and the challenges encountered when implementing this innovative approach. Survey questionnaires were distributed to G7 contractors in Penang, and 53 valid responses were obtained. The findings show that the current level of technology adoption for site safety management is still low. Key factors influencing technology adoption include the initial cost, top management commitment and contractors' awareness of the technology. Contractors' challenges involve high technology expenses, inadequate network connectivity and reduced industry profitability. This research augments the existing knowledge about technology adoption for site safety management. The outcomes further serve as useful information for contractors, policymakers and government agencies in developing initiatives to improve technology adoption among contractors and reduce the occurrence of accidents in Malaysia.

***Keywords***: Technology adoption, site safety management, contractors, Malaysia

[2] Corresponding Author. Email: izyanyahaya@usm.my

# INTRODUCTION

The construction industry poses a higher risk compared to other sectors because it corresponds to 3D behaviour, which is 'dirty, dangerous and difficult' (Ahmad et al., 2018; Nik Him et. al, 2023). Massive hazardous work, particularly on construction sites, has indirectly increased the likelihood of accidents. In the United Kingdom, it is reported that the annual mortality rate per 100,000 workers is 10, whereas it is 13.44 in Malaysia (Yap et al., 2023). Fatality rate appears to be higher in developing countries such as Malaysia, Indonesia and China than in developed countries (Nnaji & Karakhan, 2020). The high frequency of mishaps in the construction industry can be attributed to various factors, including falls from heights, electrocution and environmental factors (Abdul Halim et al., 2020). To mitigate the issues, various safety measures have been implemented. The sector's prolonged poor safety performance has prompted various stakeholders to seek innovative approaches for significant improvement of site safety. According to Nnaji and Karakhan (2020), there is a clear shift towards using technology for site safety management due to the numerous benefits of integrating with traditional safety management. However, little is known about contractors' involvement in technology adoption for site safety management despite the emergence of various technologies in the sector, aligned with Malaysia's Construction 4.0. This research aims to delve further into this aspect while also investigating the factors and challenges that the contractors face. The findings would be significant in finding solutions to foster a safer construction environment.

# LITERATURE REVIEW

## Safety Issues in Malaysia's Construction Industry

The construction industry is widely recognised as the most perilous sector and workplace globally. Each year, approximately 60,000 individuals lose their lives on construction sites worldwide, resulting in a construction industry mortality rate that is three times higher than that of the manufacturing sector (Abu Aisheh et al., 2022). In Malaysia, Zaini et al. (2020) reported that the construction industry had a fatality rate 3.3 times higher than the overall occupational death toll in the country for the year 2020.

The elevated fatality rates can be attributed to the distinct characteristics of the construction industry. Furthermore, ensuring safety within the construction industry is challenging due to its 'transient' nature, where different teams are responsible for various projects. Moreover, the 'labour-intensive' aspect, which has led to the employment of foreign workers, is another factor that makes the construction industry a high-risk workplace. Many of these workers lack adequate training and awareness and may have had no experience in the construction work (Elsebaei et al., 2021). Jaafar et al. (2018) identified two

categories of occupational accidents: direct causes, linked to human actions and worksite conditions, and indirect causes, involving management and external factors. Data from Hamid et al. (2008) highlights that on-site accidents stem mainly from direct causes, notably 'worker carelessness and lack of knowledge,' 'reluctance in using personal protective equipment and complying with regulations,' and 'hiring unskilled labour.'

**Technology adoption in Construction Site Safety Management**

In the construction industry, safety management involves planning, organising, executing and evaluating the work and workforce to reduce accidents on construction sites (Thanaraj & Priya, 2019). However, according to Zhou et al. (2015), achieving perfect safety management is nearly impossible due to unexpected errors (e.g. human errors, weather conditions, later material deliveries and project modification). Traditional safety management, which relies on paper-based information, exacerbates these issues and makes it difficult to adapt to changing circumstances (Alizadehsalehi et al., 2020). To address these challenges, more advanced techniques are emerging to improve site safety, primarily focusing on utilising technology for safety management.

Technology encompasses tools or equipment that address real-life issues (Khudzari et al., 2021). A notable focus has recently been on adopting technology within the construction industry. Several technologies have been introduced to improve final product quality and construction process efficiency, leading to cost savings and increased profits (Nnaji & Karakhan, 2020). Nonetheless, an expanding array of emerging technologies has been integrated into safety and health management within the construction industry over time (Zhou et al., 2013; Tung et.al, 2023).

**Types of Technology Adopted for Construction Site Safety Management**

In managing the safety aspect of construction sites, many safety technologies have been developed over the years, in parallel with the efforts to move towards the era of Fourth Industrial Revolution (IR 4.0). Building information modelling (BIM) is widely adopted to support construction safety management because it integrates interdisciplinary information into a unified model. This facilitates the effective identification and mitigation of hazards during construction (Muzafar, 2021). Unmanned aerial vehicles (UAVs), which are aircraft that operate without the need for a human pilot, are utilised in safety management. They can be remotely controlled from the ground, minimising potential risk exposure to workers (Melo et al., 2017). Another technology used for site safety management is robotics and automation (R&A). R&A can process numerical information and perform analytical tasks in confined and hazardous locations, reducing the risk to workers (Yap et al., 2023). Virtual reality (VR) has also been adopted, enabling


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contractors to visually assess site conditions and identify potential safety issues during the planning phase (Zhou et al., 2012). Augmented reality (AR) is also employed for site safety management, integrating 3D virtual models with real-time footage to enhance the visualisation of job site conditions (Chi et al., 2013). Furthermore, radio frequency identification (RFID) technology enables precise localisation and tracking, effectively reducing potentially dangerous situations and preventing accidents (Kim et al., 2016).

Wearable safety technologies are valuable for monitoring labourers' safety on hazardous construction sites. They are user-friendly and cost-effective. Network cameras are also incorporated into site safety management. They allow contractors to collect and analyse footage of workers' actions, helping to identify factors that may have contributed to accidents. Precautionary measures can be planned and implemented accordingly (Yap et al., 2023). 3D laser scanning is another technology used in safety management, eliminating the need for human intervention in on-site monitoring and measurements in hazardous areas of the site (Schueremans & van Genechten, 2009). Finally, digital signage is implemented for site safety management, as it is more attention-grabbing than traditional safety boards. This makes it more effective in delivering important safety messages at the site (Yap et al., 2023).

**Factors Affecting Technology Adoption in Site Safety Management**

It is beyond important to comprehend the factors influencing technology adoption when attempting to improve the current situation (Khudzari et al., 2021). In accordance with Nnaji & Karakhan (2020), only by having a thorough understanding of the factors influencing technology adoption can effective solutions be taken to enhance technology adoption in site safety management.

**i. Economic Factors**

The initial cost of technology is one factor that influences its implementation. Acquiring technology for projects often involves a high initial cost, and additional expenses for maintenance and training can further increase the overall cost. Additionally, business dynamics play a significant role as an economic factor. The number of technology suppliers and cost structures can impact the decisions of construction stakeholders regarding technology adoption. Furthermore, the level of competition is another factor that affects technology adoption. High competition in the utilisation of technology for projects can lead to increased adoption by companies (Akmam et al., 2018).

**ii. Management Factors**

Management strategy ensures a project's completion and impacts technology adoption. To facilitate the learning and integrating of new technologies, top

management must support the contractors incorporating emerging technology into the current business (Li et al., 2022). Commitment from top management is equally vital in influencing technology adoption, as a strong commitment is essential to encourage the ongoing use of technology (Akmam et al., 2018).

**iii. Behavioural Factors**

Human aspects, such as understanding how to use technology, are critical factors in making decisions about its adoption (Khudzari et al., 2021). Awareness of a technology's significance is crucial in influencing decisions on technology adoption. Furthermore, the attitude towards technology adoption is an important behavioural factor. It has been observed that companies are more likely to adopt a technology when their employees have a positive attitude towards the adoption of technologies (Akmam et al., 2018).

**iv. Technological Factors**

One technological factor is the perceived usefulness of technology. Technologies that offer improved work performance while providing cost or time advantages are more likely to be adopted at a higher rate. Additionally, the perceived ease of technology use is a contributing factor. This factor involves the complexity of mastering the technology and the time and effort required for its implementation. Moreover, the perceived quality of technology also affects its adoption. High-quality technology that efficiently supports work processes tends to have a higher adoption rate (Akmam et al., 2018).

**v. Regulatory Factors**

Government promotion of technology is crucial in affecting technology adoption for site safety management (Akmam et al., 2018). This can be achieved through government agencies offering incentives, such as free participant training (Khudzari et al., 2021). Another regulatory factor is technology policy. As noted by Akmam et al. (2018), adopting technology for site safety management can be enhanced with a comprehensive technology policy that provides clear guidelines on technology implementation. The rules and regulations governing technology also play a significant role. This is exemplified by the study conducted by Li et al. (2022), where incomplete or unclear rules and regulations can hinder companies from adopting technology.

Based on the review, it is agreed by researchers (e.g. Nnaji and Karakhan, 2020; Yap et al., 2022a), that contractors play a pivotal role in leveraging technology to enhance site safety. Considering the emergence of various types of technologies, there is a noticeable gap in current technology adoption among Malaysian contractors, particularly in aligning with national strategic plans.


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**Constraints Faced in Technology Adoption for Site Safety Management**

It is crucial that the constraints faced by contractors who have already adopted a technology are identified for the successful adoption of technologies in the future. This is critical for maximising the use of technology for construction site safety management.

**i. Economic Constraints**

According to Yap et al. (2022a), cost limitations consistently stand out as the primary constraint regarding technology implementation. These costs are primarily linked to the utilisation and maintenance of technology (Nnaji & Karakhan, 2020). Economic constraints include unprofitable worker training, which arises from the extensive training required to enhance workers' competencies in an increasingly automated industry. A low profit margin in the sector is another constraint contractors encounter when implementing technology in construction site safety management (Yap et al., 2022a).

**ii. Sociocultural Constraints**

The decision to use technology depends on the client, which is one of the constraints faced. This constraint often arises because employers may mandate certain technologies while prohibiting others (Nnaji & Karakhan, 2020). Additionally, the ageing workforce tends to be resistant to change. Consequently, when embracing technological changes, individuals may experience a lack of readiness and motivation to adopt new technologies due to the uncertainty surrounding new procedures and concerns about unfamiliar outcomes that could impact their business (Yap et al., 2022a).

**iii. Technological Constraints**

Various factors influence the implementation of safety technologies. One notable challenge is the incompatibility between technology devices, which hinders effective communication and information sharing (Gamil et al., 2020). Fast and reliable internet access is also essential to ensure technologies function at their full capacity. However, contractors often face poor network connectivity, primarily due to the limited connectivity in designated locations. In many cases, network coverage remains a concern (Yap et al., 2022a).

**iv. Regulatory Constraints**

The high frequency of incidents in the construction sector is often attributed to outdated government policies and inadequate enforcement. Edirisinghe (2019) noted that policies promoting or discouraging technological innovation can limit people's freedom of choice between acceptance and rejection. Additionally, a lack of regulations is common in the construction industry. Therefore, it is imperative

to establish appropriate guidelines to facilitate the effective integration of technologies in a wide range of construction operations, including safety management (Yap et al., 2022a).

**v. Security Constraints**

Using the Internet for technology operations poses a challenge for safeguarding connected devices, data and the Internet of Things (IoT)layers from external threats and intrusions (Gamil et al., 2020). The issue of low confidentiality regarding workers' private data is also a security-related concern. The automatic collection and recording of private data, particularly in the context of worker surveillance, monitoring and the management of recorded information, gives rise to various legal and ethical considerations (Yap et al., 2022a).

## RESEARCH METHODOLOGY

For this study, a quantitative research approach was adopted. The target population consists of 360 Grade 7 contractors registered with Construction Industry Development Board (CIDB), Malaysia. Using the formula, the minimum sample size calculated for this study is 175. From the total of 200 invitations sent, 53 completed responses were received, yielding a response rate of 26.5%. The respondents were approached through a combination of two sampling methods that are frequently adopted in construction management studies: convenience sampling and snowball sampling (Bagaya & Song, 2016; Yap et al., 2019). Penang was chosen as the study's focal point because of its high real-estate market, led to large scale construction projects (San et al., 2017). In presenting the data, statistical software SPSS is being used for analysing frequency, mean score and data variability, similar to the approach taken by (Kamarudeen et. al, 2022) who also investigate similar aspects. In addition, the reliability of the collected data was analysed using Cronbach's alpha coefficient (Mohajan, 2017).

## RESULTS

The demographic information of the respondents is shown in Table 1 below.

**Table 1**: Respondent's Demographic Information

| | Demography | Frequency | Percentage (%) |
|---|---|---|---|
| Highest Academic Qualification | High School or Equivalent | 1 | 1.9 |
| | Certificate / Diploma | 7 | 13.2 |
| | Bachelor's Degree | 39 | 73.6 |
| | Master's Degree | 6 | 11.3 |
| | Director | 1 | 1.9 |
| | Manager | 7 | 13.2 |


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| | Demography | Frequency | Percentage (%) |
|---|---|---|---|
| Position in the Company | Site Manager | 8 | 15.1 |
| | Site Supervisor | 5 | 9.4 |
| | Site Engineer | 21 | 39.6 |
| | Safety and Health Officer | 8 | 15.1 |
| | Others | 3 | 5.7 |
| Years of Experience Working as a Contractor | Less Than or Equivalent to 5 Years | 26 | 49.1 |
| | 6 to 10 Years | 20 | 37.7 |
| | 11 to 15 Years | 4 | 7.5 |
| | More Than or Equivalent to 16 Years | 3 | 5.7 |

Table 2 below presents the various types of technology that the G7 contractors used to manage safety aspects at the site. The frequency of technology usage in the management of site safety is arranged and ranked in descending order of their mean value as follows: BIM (2.49), digital signage (1.75), wearable safety technologies (1.66), network cameras (1.66), UAVs, VR and 3D laser scanning (1.32), R&A (1.25), RFID (1.19) and AR (1.13).

**Table 2**: Frequency of Technology Usage for Site Safety Management

| **Types of Technology** | **N** | **Mean** | **SD** |
|---|---|---|---|
| BIM | 53 | 2.49 | 1.353 |
| Digital Signage | 53 | 1.75 | 1.285 |
| Network Camera | 53 | 1.66 | 1.192 |
| Wearable Safety Technologies | 53 | 1.66 | 1.224 |
| 3D Laser Scanning | 53 | 1.32 | .872 |
| VR | 53 | 1.32 | .754 |
| UAV | 53 | 1.32 | 1.034 |
| R&A | 53 | 1.25 | .757 |
| RFID | 53 | 1.19 | .590 |
| AR | 53 | 1.13 | .394 |

Table 3 presents the factors affecting technology adoption for construction site safety management. Each factor affecting technology adoption for construction site safety management is presented in descending order of its mean value.

**Table 3**: Factors Affecting Technology Adoption for Site Safety Management

| Ref. | Factors | N | Mean | SD | Rank |
|---|---|---|---|---|---|
| A1 | Initial Cost of Technology | 53 | 4.49 | .724 | **1** |
| B2 | Commitment from Top Management | 53 | 4.47 | .775 | **2** |
| C2 | Awareness of the Importance of Technology | 53 | 4.40 | .600 | **3** |
| B1 | Top Management Support | 53 | 4.34 | .876 | **4** |
| C1 | Knowledge of How to Use the Technology | 53 | 4.34 | .706 | **5** |
| D2 | Perceived Ease of Use of Technology | 53 | 4.28 | .601 | **6** |
| C3 | Attitude towards the Adoption of Technology | 53 | 4.25 | .677 | **7** |
| D1 | Perceived Usefulness of Technology | 53 | 4.21 | .631 | **8** |
| E3 | Rules and Regulations of Technology | 53 | 4.13 | .833 | **9** |
| D3 | Perceived Quality of Technology | 53 | 4.11 | .670 | **10** |
| E1 | Government Promotion of Technology | 53 | 4.04 | .784 | **11** |
| E2 | Technology Policy | 53 | 4.04 | .876 | **12** |
| A2 | Business Dynamics | 53 | 3.89 | .824 | **13** |
| A3 | Level of Competition in Technology Adoption among the Companies | 53 | 3.79 | 1.081 | **14** |

Table 4 presents contractors' constraints in adopting construction site safety management technology. The constraints here are also arranged in descending order of their mean values.

**Table 4**: Constraints Faced in Technology Adoption for Site Safety Management

| Ref. | Constraints | N | Mean | SD | Rank |
|---|---|---|---|---|---|
| A1 | Extra Costs Related to Technology | 53 | 4.53 | .668 | **1** |
| C2 | Poor Network Connectivity | 53 | 4.13 | .962 | **2** |
| D2 | Lack or No Regulations for Utilization | 53 | 4.02 | .866 | **3** |
| A3 | Low Profit in the Sector | 53 | 4.02 | 1.009 | **4** |
| B1 | Scarce of Client Demand | 53 | 4.00 | .832 | **5** |
| D1 | Lack or No Government Policy for Utilization | 53 | 3.98 | .888 | **6** |
| B2 | Aging Workforce being Reluctant to Change | 53 | 3.98 | .888 | **7** |


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| Ref. | Constraints | N | Mean | SD | Rank |
|---|---|---|---|---|---|
| A2 | Unprofitable Worker Training | 53 | 3.98 | 1.047 | **8** |
| E2 | Low Confidentiality of Workers' Privacy Data | 53 | 3.79 | 1.116 | **9** |
| C1 | Incompatibility Issues between the Technology Devices | 53 | 3.77 | .993 | **10** |
| E1 | No Assurance of Data Security | 53 | 3.62 | 1.113 | **11** |

## DISCUSSION

The results suggest that the level of technology adoption for construction site safety management in Malaysia is still considered low even though the Malaysian construction industry is making progress towards the technology adoption in managing construction site safety. The mean values can be observed in Table 2. The four most frequently used technologies for site safety management are BIM, digital signage, wearable safety technologies and network cameras. This is consistent with the literature by Yap et al. (2022b), who stated that BIM, network cameras and digital signage are among the top five most effective technologies in site safety management. BIM was ranked as the most frequently used safety technology (Yap et al., 2023). This can be attributed to the Malaysian government's active promotion of BIM usage in line with the Fourth Industrial Revolution (IR 4.0), such as making it mandatory for public works costing RM 100 million or more to implement BIM (Ibrahim et al., 2021). Digital signage was the second most frequently used technology. The increased innovative characteristics of digital signage boards, such as the ability to change colour according to weather conditions also enhance the safety management process by contractors (Karakhan et al., 2019). Network cameras and wearable safety technologies ranked equally as the third most frequently used technologies. These technologies provide various functions to manage construction site safety, such as real-time tracking of work progress at a construction site, collecting data for quality checking, and detection of potential hazards at the site (Yap et al., 2022b). The findings also showed that R&A, RFID and AR are the three least used technologies in construction site safety management. The main factor leading to the low adoption rate of these technologies in site safety management is their high cost (Yap et al., 2023). Furthermore, the limited financial capability of companies has restricted them from investing and using technologies to manage construction site safety (Nnaji & Karakhan, 2020).

Data in Table 3 demonstrates all factors affect the technology adoption by G7 contractors in construction site safety management but at different levels. The initial cost of technology was ranked as the main factor, consistent with the findings in previous research by Yap et al. (2022b). This demonstrates that the costing aspect greatly influences the adoption of safety technology, which

indirectly has implications for safety performance at a site. This is supported by Khudzari et al. (2021), who stated that cost has always been the main concern affecting stakeholder investment in technologies. Commitment from top management ranked second, which signifies that it greatly affects the technology adoption in site safety management. This is supported by Yap et al. (2022a), who stated that management factors play a crucial role in affecting technology adoption by contractors. This is mainly because the choice to use safety technology at sites depends a lot on how these leaders think and visioned on their organizational commitment (Khudzari et al., 2021).

Awareness of the importance of technology was ranked third in the factors that affect the adoption of technology. This is because stakeholders like contractor will only consider adopting safety technology as they are aware and understand the importance of using these technologies (Akmam et al., 2018). Top management support was ranked fourth. This is supported by the research findings of Li et al. (2022) and Yap et al. (2022a). Similarly, the how knowledge is equally important influencing factor. Contractors who are knowledgeable and well-trained in handling a specific technology will greatly influence firms to adopt technologies to manage site safety more effectively (Khudzari et al., 2021).

The two factors ranked last within the economic factors category were business dynamics and the level of competition in technology adoption among the companies. According to Akmam et al. (2018), the dynamics of the market to produce safety technologies, which include items like the number of suppliers of technology and its cost structure have the potential to affect their adoption by users. A higher level of competition between the contractor firms will also encourage the technology adoption for a particular project, as excellent productivity is hoped to be achieved by using these technologies for the contractors.

Data in Table 4 presents the constraints of technology usage that are significant to G7 contractors at various levels. Extra costs related to technology was ranked as the most significant constraint. This finding is consistent with the previous studies by Nnaji & Karakhan (2020) and Yap et al. (2022a), who found that high costs are often the primary concern encountered by stakeholders in implementing these technologies to manage site safety. According to Nnaji & Karakhan (2020), there are various costs incurred including the initial purchase, operation and maintenance, training costs and many more. Subsequently, poor network connectivity was ranked the second most significant constraint. This is supported by Yap et al. (2022a), who stated that technology-related challenges significantly limit the implementation of safety technologies. Without reliable broadband connectivity on the construction site, it is difficult for the safety technologies to operate at their maximum potential (Waqar et al., 2023). Low profit in the sector was ranked third. According to Yap et al. (2022a) and Yitmen


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(2007), low profit margins has been a significant issue impeding the adoption of technologies by construction stakeholders. Considering the low profits that could be gained, contractors often tend to stop implementing technologies for site safety management (Yitmen, 2007). The constraint ranked fourth is the lack or absence of regulations for utilisation. This finding is consistent with study by Waqar et al. (2023), who found that regulatory-related limitations significantly affected technology adoption in construction site safety management. According to Yap et al. (2022a), there is often no updated information regarding the standards or regulations on operating the technologies. Scarcity of client demand was ranked fifth among the 11 constraints identified. This is supported by Nnaji & Karakhan (2020). This indicates that the client's intention to use technologies has certain impacts on adopting technologies in site safety management. The two constraints that ranked last were incompatibility issues between technology devices and a lack of data security assurance. In their study, Gamil et al. (2020) also found technology compatibility to be one of the least significant challenges faced by construction practitioners. However, regarding the challenges related to the 'lack of assurance of data security,' the current findings contrast with their research.

## CONCLUSION

In conclusion, this research has sought to provide a comprehensive understanding of technology adoption in construction site safety management in Penang, Malaysia. The study's findings show that the current level of technology adoption for site safety management within the Malaysian construction industry remains relatively low. BIM, digital signage, wearable safety technologies and network cameras emerge as the most frequently employed safety technologies on construction sites. The technology adoption is primarily influenced by several key factors, with the initial cost, commitment from top management and an awareness of the importance of technology being the most significant among contractors. Additionally, the research findings reveal that contractors face three primary challenges: the elevated costs associated with technology adoption, a lack of reliable network connectivity and low profitability within the industry. From the contractor's perspective, this study contributes to advancing knowledge concerning technology adoption for site safety management. The insights obtained regarding influencing factors and constraints faced by contractors offer valuable information for policymakers and government agencies, aiding in the development of initiatives to enhance technology adoption among contractors. A comprehensive training program, coupled with incentivization through government grants or subsidies, would play a pivotal role in encouraging widespread technology adoption among contractors, consequently enhancing safety at construction sites in Malaysia.

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# CONSTRUCTION PROJECT FAILURE: INVESTIGATING CAUSES OF INEFFECTIVE BUILDING INFORMATION MODELLING EXECUTION PLANS

**Mashanim Mahazir[1], Rahimi A. Rahman[2], Nurhaizan Mohd Zainudin[3], Salmaliza Salleh[4]**

[1,2] *Faculty of Civil Engineering Technology*,
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH,
KUANTAN, MALAYSIA
[2]*Faculty of Graduate Studies,*
DAFFODIL INTERNATIONAL UNIVERSITY, DHAKA, BANGLADESH
[3] *Faculty of Industrial Management*,
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH,
KUANTAN, MALAYSIA
[4] *Faculty of Engineering,*
UNIVERSITI TEKNOLOGI PETRONAS, SERI ISKANDAR MALAYSIA

## Abstract

The successful implementation of Building Information Modelling (BIM) is contingent upon effectively executing BIM Execution Plans (BEPs). This study aims to investigate the causes that contribute to the development of ineffective BEPs that ultimately result in construction project failures. Interview data with twenty BIM professionals were collected on causes contributing to the development of ineffective BEPs. The collected data was analyzed using thematic analysis. The analysis revealed three categories contributing to ineffective BEPs: people, process, and technology. There are 11, 6, and 1 causes related to people, process, and technology, respectively. The finding suggests that incompetency, lack of knowledge in BIM, individual attitude, poor data management, and insufficient technology used are the causes that contribute to ineffective BEPs. The outcomes of this study offer substantial insights into the Architecture, Engineering, and Construction (AEC) industry in developing effective BEPs, thereby ensuring the successful delivery of BIM-based construction projects.

***Keywords***: Building Information Modelling, BIM Execution Plan, BEP failure, construction project, thematic analysis

[1] Corresponding Author. Email: anim.mahazir@gmail.com

## INTRODUCTION

Building Information Modelling (BIM) is an adoption of modelling technology and its related set of processes to generate, convey, examine, and employ digital information models over the entirety of a construction project's life cycle. Before integrating BIM into a project, the successful implementation of BIM is contingent upon the effective execution of the BEPs (Panagiotidou et al., 2023). BEP is an essential document within the Architecture, Engineering and Construction (AEC) industry (Ventura, 2021). It outlines the strategic approach and operational procedures for integrating and using BIM on a designated project. During the COVID-19 pandemic, many projects encompass risks that can be categorized as unpleasant risks and positive risks (Zamani et al., 2021; Ahmad et al., 2023; Tung et al., 2021) . The pandemic has inevitably resulted in catastrophic consequences for various industries of the world economy (Tan & Abdul-Samad, 2022). Additionally, it has been shown that a significant proportion of construction firms exhibit a strong desire to expand into global markets in order to optimize their revenue and capitalize on potential advantages (Ogunnusi et al., 2020). Most international AEC industries implemented BIM. The decision of a construction firm to enter global markets relies on good knowledge and understanding of BIM. Hence, a comprehensive BEP in implementing BIM projects becomes compulsory for most local and international projects. Most research focuses on identifying the elements that should be included in BEPs, but there is a scarcity of research investigating how to create effective BEPs. The development of an effective BEP will help to address the unpredictability of performance of BIM projects (Ayerra et al., 2021 and).

A lack of sufficient information impedes the development of an effective BEP. Due to the scarcity of competent BIM specialists, implementing BEPs appears to be more challenging (Hadzaman et al., 2016). In other words, a thorough identification of the underlying factors contributing to the ineffectiveness of BEP is necessary to develop viable intervention strategies. There are issues related to the slow execution of BIM projects. Not having a clear BIM workflow and poor understanding of the BIM process is due to the ineffective BEP developed. The identification of causes is crucial to ensure that the BEP developed includes all the necessary information required for the successful implementation of a BIM project. The developer of BEP must develop an intervening strategy that ensures the successful completion of the BIM project by executing an effective BEP. Therefore, it is crucial to establish a proper model that may serve as a framework for identifying the underlying factors contributing to the ineffectiveness of BEP, which ultimately leads to construction project failures.

This study investigates the causes that contribute to the development of ineffective BEPs that ultimately result in construction project failures. The aim

was established based on a research question: What are the causes contributing to the ineffectiveness of BEP that result in construction project failures? This is the first paper that analyses the causes that contribute to the development of ineffective BEPs. The outcomes of this study offer substantial insights into the AEC industry in developing effective BEPs, thereby ensuring the successful delivery of BIM-based projects.

## LITERATURE REVIEW

Silva and Andrade (2020) mentioned that BEP encompasses a comprehensive document that delineates the framework for the successful integration and adoption of BIM systematic practices within AEC organizations. Meanwhile, according to Teles and Lima (2023), the most comprehensive BEP document proves to be an effective reference for establishing a well-defined BEP structure to guide a new project. Panagiotidou, N. (2023) mentioned, BEP serves as an outstanding example of a mechanism that effectively mitigates waste by fostering responsibilities and deliverables, hence facilitating the establishment of a shared understanding within teams regarding the use of BIM in projects. The usage of BIM to its maximum capacity optimizes project outcomes, mitigates errors, and enhances decision-making capabilities across the entire project lifecycle.

Farah et al. (2019) mentioned that BEP is a preliminary document that must be prepared during the initial phase to improve the probability of a successful project. In order to facilitate the optimal use of BIM during the operation phase, owners must develop effective BEP during the pre-operation phase (Lin et al., 2016). The first phase in the development of the BEP entails the inclusion of the Employer Information Requirement (EIR), Organization Information Requirement (OIR), and Asset Information Requirement (AIR) (CIDB, 2017). The phase is followed by the validation of the outcomes of BIM implementation process to find out if the supply chain effectively fulfils the requirements and capacity of clients to play a leadership role in the BIM implementation process. Abu Bakar et al. (2021) emphasized that the following six elements are essential for formulating a BEP: strategy, process, information, infrastructure, personnel, and standard.

Based on the research conducted by Abbas et al., (2022) and Hadzaman et al., (2016), the primary reason for the ineffective BEP is the need for more detailed guidance for BIM implementers in developing BEPs. Lack of clarity about process coordination also become one of the causes of ineffective BEPs as according to Fosse et al., (2016) and Ayerra et al., (2021). An extensive EIR framework is necessary to ensure effective BEPs, as mentioned by Mayer et al., (2021).

Prior research has identified the challenges of implementing BIM in AEC industry, including coordination of works, understanding the project and the


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need for software, keeping the BEP updated and ensuring the BEP is properly used. However, limited research has addressed the need to develop an effective BEP as a way of overcoming these challenges. Despite the development of a thorough BEP framework, Perera et al. (2021) have found certain difficulties within the AEC industry that contribute to construction project failures, even after the implementation of the BEP. The difficulties include the integration of information from all disciplines and clear direction from client. In other words, there is a need to investigate the causes that lead to ineffective BEPs, which subsequently lead to construction project failures. This study will, thus, address this knowledge gap by identifying the causes of ineffective BEPs.

## METHODOLOGY

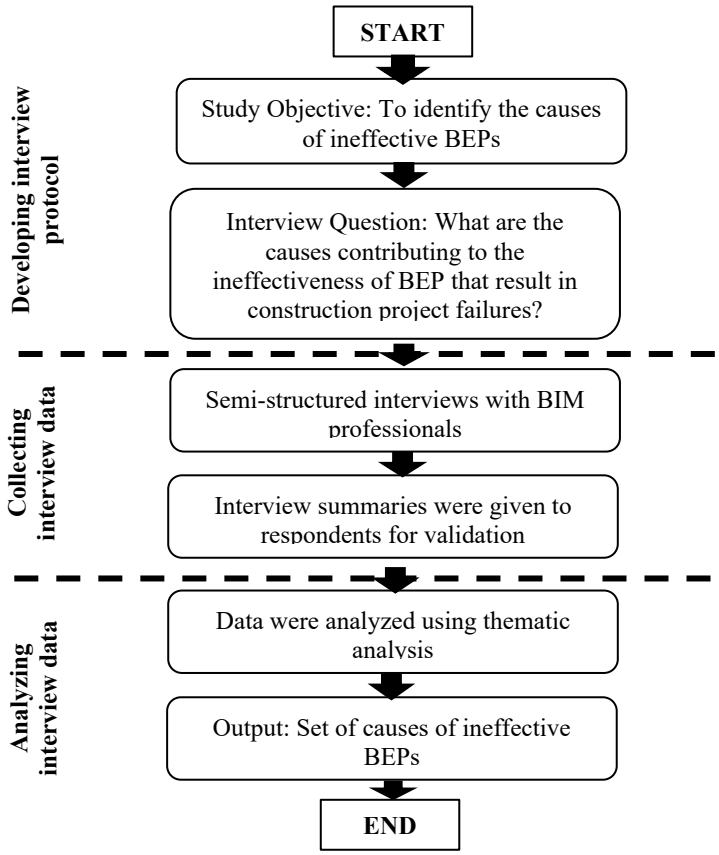


**Figure 1:** Research design flow
*Source from: author's own creation*

The research design follows the sequential process illustrated in Figure 1. Qualitative research method was chosen as it enables the elucidation, enhanced comprehension, and thorough exploration of the perspectives, behaviours, experiences, and phenomena related to the study. Therefore, to achieve the study aim, the data was collected and analyzed. The objective was to identify the causes of ineffective BEPs and analyze thematic patterns within the collected data using a coding process. The thematic analysis was the foundation for various qualitative data analysis methodologies.

**Data Collection**

Semi-structured interview data were collected from 20 BIM professionals in Malaysia. The interviews were conducted in person and via video conferencing. Bekele & Ago (2022) recommended to have sample size of at least 20 interviews. The purposeful sampling method was chosen in finding participants that could offer comprehensive and in-depth details on the subject matter (Cavana et al. 2001). The sampling method was chosen as the respondents possess specific criteria required for the study purpose. A sample of 20 respondents were chosen from varying work experience and professional backgrounds, including BIM managers and project directors. Table 1 shows the respondent profile of the interviewees. The interviewees were selected for having the ability to provide essential information on the subject matter based on their involvement in BIM projects, years of work experience, and expertise in BIM (Farouk et al., 2023).

During the interview, the main question was: What are the causes that contribute to the development of ineffective BEPs? Then follow-up questions were provided with the intention to gather detailed data pertaining to the causes that contribute to the development of ineffective BEPs. A summary of the interview was drafted and sent out to ensure the validity of the data, and validation was obtained from each participant (Zamani et al., 2023; Tan et al. 2022).

**Data Analysis**

Under the qualitative data analysis, thematic analysis was used to analyze the collected data. The method was derived from Braun & Clarke, (2006) and involves six steps in the process of thematic analysis. The steps are illustrated in Table 2.

The analysis comprised a coding technique that incorporated open coding, and selective coding. The first step is open coding, where the data is thoroughly analyzed on a line-by-line basis, using comprehensive interview summaries (Man et al., 2017). The final step involved selective coding, which entailed a thorough analysis of the qualitative data to identify the core category. (Dillon, 2012).


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**Table 1:** Respondent profile

| ID | Gender | Education | | Designation | Experience in construction industry (years) | Experience in BIM (years) |
|---|---|---|---|---|---|---|
| | | Field | Certification | | | |
| R1 | M | Architecture | Degree | BIM Manager | 10 | 8 |
| R2 | M | Construction Management | Degree | BIM Manager | 25 | 17 |
| R3 | M | Architecture | Degree | Construction Lead | 21 | 14 |
| R4 | M | Architecture | Degree | BIM Designer | 7 | 7 |
| R5 | M | Civil Engineering | Master | Director & Project Lead | 20 | 12 |
| R6 | M | Civil Engineering | Degree | BIM Solution Engineer | 7 | 7 |
| R7 | M | Architecture | Diploma | BIM Manager | 15 | 8 |
| R8 | M | Architecture | Certificate | Regional Sales Specialist (BIM) | 12 | 8 |
| R9 | F | Architecture | Degree | BIM Development Senior Manager | 22 | 13 |
| R10 | M | Electrical & Electronic | Degree | BIM Manager | 10 | 10 |
| R11 | M | Civil Engineering | Degree | BIM Director | 27 | 24 |
| R12 | M | Manufacturing | Diploma | BIM Operations Manager | 10 | 7 |
| R13 | M | Civil Engineering | Degree | BIM Lead (Policy Maker) | 23 | 13 |
| R14 | M | Mechanical Engineering | Diploma | BIM Consultant | 16 | 16 |
| R15 | M | Architecture | Degree | BIM Manager | 8 | 5 |
| R16 | M | Architecture | Degree | BIM Strategist | 10 | 10 |
| R17 | M | Architecture | Degree | Managing Director & BIM Lead | 24 | 15 |
| R18 | M | Architecture | Degree | Lead, Group of Technology | 15 | 7 |
| R18 | M | Civil Engineering | Degree | BIM Manager | 23 | 15 |
| R20 | M | Architecture | PhD | Academician | 21 | 4 |

*Source from: author's own creation*

**Table 2:** Six steps of thematic analysis adopted from Braun & Clarke, (2006)

| Step | Description |
|---|---|
| 1. Familiarise the data | The interview data is reviewed and converted into textual form. |
| 2. Create initial codes | The interview data is examined to create preliminary codes. |
| 3. Identify themes | The first themes are reassessed in order to confirm the final themes. |
| 4. Analyse themes | The initial codes and raw data were evaluated to ensure that the themes are consistent with the aims. |
| 5. Establish themes | The themes have been determined and thoroughly reviewed. Adjustment is necessary when the theme's breadth and content are indeterminable. |
| 6. Document the themes | The identified themes were found to be in line with the study's aims. |

## RESULT AND DISCUSSION

### THEMATIC ANALYSIS RESULTS

The study shows findings derived from interviews conducted with 20 BIM professionals in effort to identify the causes leading to the ineffectiveness of BEP. Table 3 depicts the thematic analysis result with the supporting statement of causes leading to the inefficiency of BEP, resulting in construction project failures. There are 3 categories identified under themes and 20 elements are identified as sub-themes.

The themes were categorized under three categories, which are causes related to people, process, and technology, adopted from the People, Process and Technology (PPT) improvement model (Rocha et al., 2015). PPT improvement model was referred as it's integrate people, process, and technology by identifying causes that lead to ineffective BEP hence, improving the performance and outcomes of BIM projects. This comprehensive approach will also assists BIM managers in pinpointing areas for enhancement, prioritising efforts, and aligning resources efficiently.


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## Elements That Cause Ineffective BEP

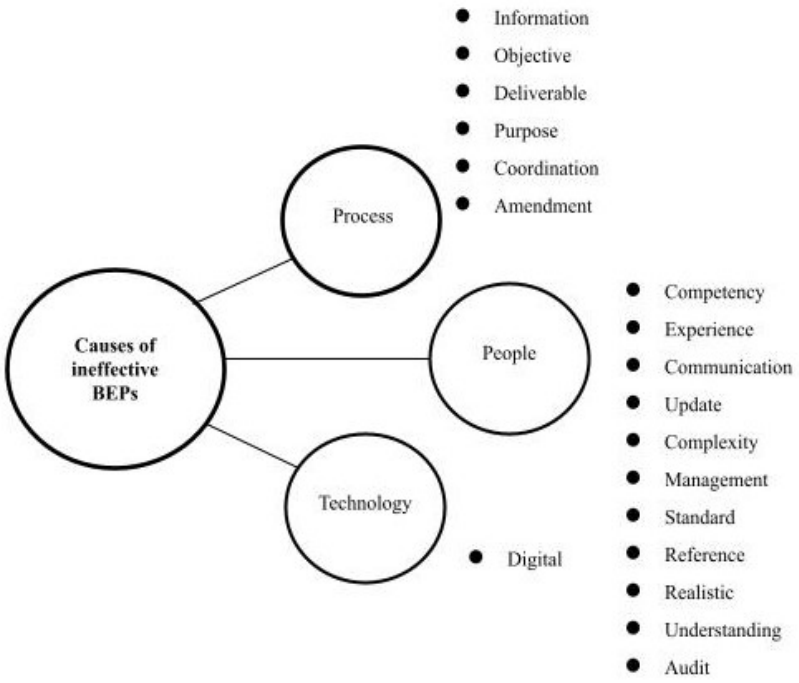


**Figure 2:** Causes of ineffective BEPs
*Source from: author's own creation*

Figure 2 depicts the elements responsible for the ineffective BEP in BIM projects. There were eleven, six, and one causes associated with people, process and technology, respectively.

**Table 3:** Thematic analysis results

| Theme | | Sub-Theme | Description | Respondents | Supporting Statement | Frequencies |
|---|---|---|---|---|---|---|
| **People** | 1 | Experience | Inadequeate experience | R1, R5, R15,R19 | From the beginning of project brief, Employment Information Requirement (EIR) right until as built phase or hand over completed model will lead to obstacle to the entire construction process due to lack of experience. (R1) | 4 |
| | 2 | Manager's Competency | Incompetent BIM manager | R1, R9, R12, R13, R14, R15, R16, R19, R20 | BIM manager was very good in theory but not practically. Practical knowledge is important too besides theory so that BIM manager know exact roles of BIM modeler and BIM coordinator and what should be delivered. (R14) | 9 |
| | 3 | Consultant's competency | Incompetent BIM consultant | R5, R11, R16 | BEP mostly written by consultant but most consultant didn't refer to BEP. Consultant prefer to use traditional method in design and drawing rather than BIM. (R11) | 3 |
| | 4 | Communication | Lack of communication | R10, R13 | BIM manager supposed to guide all team member to follow the BEP. BEP doesn't address everybody's concern due to poor or lack of communication. (R13) | 2 |
| | 5 | Update | BEP not up to date | R6, R13, R14 | BEP stagnates during the procurement stage only. BEP should be developed once the project is awarded, but it became stagnant at the procurement stage. When a project is progressing, parameters will change; hence, BEP needs to be updated. (R6) | 3 |
| | 6 | Complexity | BEP too complex | R18 | People always presume BEP is like a contract document where people lost interest to refer hence complex. BEP should be dynamic where it becomes main reference for all the implementer. (R18) | 1 |


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| Theme | | Sub-Theme | Description | Respondents | Supporting Statement | Frequencies |
|---|---|---|---|---|---|---|
| | 7 | Management | Poor information management | R4, R7, R10, R11, R14, R15 | Poor information management where some of the subcontractors didn't know how to name the file or name the Revit family and where to store the file due to insuffiecient interface to share the information. (R4) | 6 |
| | 8 | Standard | No specific standard referred | R1, R4, R7, R16, R17 | BEP is supposed to be prepared using specific standards. Not referring to specific standards makes the BEP less effective due to lack of understanding of ISO. (R16) | 5 |
| | 9 | Reference | BEP not referred | R9, R11, R13, R14, R16, R17 | BEP was just prepared to fulfil BIM project requirements but not as the main reference to execute the whole project. (R9) | 6 |
| | 10 | Client's competency | Incompetent client | R3, R6, R14, R19 | The client didn't properly define what to include in the BEP example, type of software, type of data storage, level of development (LOD) or detail. During the kick-off meeting, no detailed job description was provided to the contractor and consultant. (R3) | 4 |
| | 11 | Realistic | Unrealistic BEP | R14 | BEP developed was unrealistic making it hard to deliver. Poor milestones set for each stage. (R14) | 1 |
| | 12 | Understanding | Fail to understand the BEP | R2, R4, R8, R10, R12, R16, R17, R19, R20 | BEP was developed but poorly understand by the BIM implementer due to lack of awareness and knowledge in BIM. (R19) | 11 |
| | 13 | Audit | No audit done | R2 | Audit on the BEP should be done at every task's milestone or annually. When the audit is done on the BEP, most of the task team will refer to the BEP to make sure the deliverable is in order. The audit is not just for the appointed party but also the task team to ensure successful project deliverable based on the BEP developed. (R2) | 1 |

| Theme | | Sub-Theme | Description | Respondents | Supporting Statement | Frequencies |
|---|---|---|---|---|---|---|
| **Process** | 14 | Information | Information not detail | R2, R3, R6, R10, R12, R14, R19, R20 | Lack of information in the diagram makes other people don't understand certain information in BEP. BEP must supported with detail wording and illustration. (R12) | 8 |
| | 15 | Objective | Client don't understand objective | R3, R8, R16 | The client was unaware of the project requirements; hence, the BEP developed was based on the incomplete EIR. The EIR is not being amended accordingly. The design model is not taken into account until the Facility Management stage. (R8) | 3 |
| | 16 | Deliverable | Different BEP different deliverables | R3, R7, R16 | Consultant develops own BEP same goes to contractor. BEP should be standardised using the same format for both parties, contractor and consultant. (R7) | 3 |
| | 17 | Purpose | BEP is developed not for main purpose | R3, R6, R16 | Some clients demanded that the contractor create the BEP in order to be awarded the project. The client wanted to integrate BIM in order to stay contemporary. BEP was developed know to fulfil the real purpose. (R3) | 3 |
| | 18 | Coordination | BEP fails to integrate & coordinate | R5, R10, R13, R18 | For instance, a consultant might just concentrate on their area of expertise, failing to consider or make design and modelling compatible with other disciplines. The BEP developed fails to coordinate and integrate with other disciplines. (R5) | 4 |
| | 19 | Amendment | EIR not amended accordingly | R7, R17 | EIR, OIR and AIR were incomplete and it affect the Project Information Model and Asset Information Model. EIR not amended accordingly. (R17) | 2 |
| **Technology** | 20 | Digital | BEP not in digital form | R6, R7, R13 | Only a few referred to hardcopy BEP, such as BIM Manager and BIM Team. Even for consultants like C&S and MEP engineers, only those involved in project deliverables will refer to BEP. (R6) | 3 |

*Source from: author's own creation*



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**People**

Competency took precedence as many BIM managers excellent in theory but lacked practical skills. Incompetent consultants often develop the BEP but fail to refer to it. Clients may also be incompetent if it do not clearly specify what should be included in the BEP, such as the software type, data storage method, and level of development (LOD) detail. This occurred as a result of inadequate experience and a lack of understanding of BEP and BIM projects. BEP should be created according to the precise guidelines outlined in ISO 19650. Once a project is execute, as it progresses, parameters will change. Therefore, BEP must be revised and audited at each milestone or annually. The developed, updated, and audited BEP fails to be referred by the implementer because of inadequate communication. It is also ineffective due its complexity, unrealistic milestones and poor information management, causing a loss of interest among people.

**Process**

Process is the sequence of procedures or actions taken to accomplish a particular objective or target. It includes workflows, procedures, methods, and regulations that dictate how tasks are carried out. Effective processes are essential for maintaining uniformity, excellence, and efficiency in projects. The BEP was ineffectively because the client was unaware of the purpose and objective of the BIM project. The client had little knowledge of the project needs, hence the BEP was created using insufficient information or an incomplete EIR. The client also failed to revise the incomplete EIR as required. The lack of a standardised format for contractors and consultants, as well as different deliverables, makes the developed BEP ineffective. Different deliverables may hinder the coordination and integration with others.

**Technology**

Technology encompasses the tools, systems, and infrastructure that facilitate activities. It encompasses hardware, software, networks, and other technological assets needed in BIM projects. Technology plays a significant role in automating tasks, enhancing communication and cooperation, and enabling data-driven decision-making. Most of the developed BEP is not available in digital format. Only a small number of individuals referred to the BEP, specifically the BIM Manager and BIM implementer. Only consultants who were involved in project deliverables will refer to BEP. Unavailability of BEP in digital format will hinder the effectiveness of the BEP developed.

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## CONCLUSION

In conclusion, this study aimed to identify the causes of ineffective BEPs, which subsequently lead to construction project failures. The study adopted a qualitative methodology and applied thematic analysis on interview data collected from twenty BIM professionals. As a result, three crucial elements that require significant attention contributing to developing ineffective BEPs have been identified. The potential factors that can render the development of ineffective BEPs include people, process, and technology. People bring significant causes that lead to ineffective BEP developed. The four most frequent causes mentioned are: 1. Incompetence BIM manager, 2: Failure to understand the BEP, 3: Poor information management and 4. BEP is not referred to. Regarding the process, the interviewee's responses indicate that information lacking in detail has contributed the highest frequency. The lack of detailed information provided by the client was identified as the primary factor contributing to unsuccessful development of BEPs. Technology has become the least cause of ineffective BEPs. One of the contributing causes is the lack of the BEP in a digital format. The printed version of the BEP is the least frequently used by project stakeholders, resulting in it being the least referred document.

The study findings indicate that BEP developers and BIM implementers must possess sufficient knowledge, competency, and understanding in the development and execution of BEPs. However, to ensure the efficacy of BEPs, the implementers must demonstrate a solid commitment to adhering to and consulting the guidelines indicated in the development. The perspective that views BEPs as an insignificant document that does not require reference needs to be changed. The efficient usage of technology is influencing the effectiveness of BEPs. Ensuring accessibility for all is a crucial aspect of the development of effective BEPs. The identified causes provide a fundamental basis for developing effective BEP that can lead to successful outcomes in BIM projects.

The study outcomes have substantial theoretical and practical implications. For theoretical implications, this study supports researchers in the evaluation of the BIM process through the development of effective BEPs and the examination of their impact on the outcomes of BIM projects. This can lead to increased knowledge and the development of more effective BEPs in construction practices by using the developed model as a reference. For practical implications, this study could be established as the definitive reference for BIM practitioners seeking guidance in developing BEPs. This is crucial for achieving successful BIM execution in the AEC industry. Furthermore, this study aids BIM practitioners in examining the crucial elements that should be incorporated into BEPs. Consequently, it enables them to develop effective strategies to mitigate the risk of construction project failures.


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# QUALITY MANAGEMENT CHALLENGES IN CONSTRUCTION PROJECTS: INVESTIGATING FACTORS, MEASURES, AND THE ROLE OF MATERIAL QUALITY CONTROL

**Chin Hon Sin[1], Ting Sim Nee[2] and Lee Yee Yong[3]**

[1, 2, 3]*Department of Civil Engineering,*
*Faculty of Engineering*,
UNIVERSITI MALAYSIA SARAWAK

## Abstract

In spite of the considerable advancements and enhancements that quality assurance and control have undergone in the construction industry, quality of the products remain an issue. Notable prevalence of poor quality in final products and facilities such as premature defects, repairs and reworks, and overall product failures within construction projects continue to affect both end users and project stakeholders. This study delved into the intricacies of the role of material as a contributor to poor construction quality, specifically in the context of building projects. Results showed that the utilisation of non-compliant and poor-quality materials during construction primarily stemmed from lack of quality assurance/quality control (QA/QC) activities and lack clarity in QA/QC process as prominent factors for poor quality construction material. In addition, the inability of the project supervisory team to identify, rectify by removing or replacing these poor-quality materials at critical work junctures is also a substantial contributory factor. The results underscore the necessity for an enhanced QA/QC framework that possesses the capacity to comprehensively identify, address, rectify, and if required, replace materials that fall short of the stipulated standards and regulations. By resolving the issues of utilisation of poor materials, it is hopeful that substantial improvements to the overarching quality issues of construction projects can be achieved.

***Keywords:*** Construction Material, Quality Management, Material Quality, Quality Control, Quality Assurance

[2] Associate Professor at University Malaysia Sarawak, Corresponding Author: snting@unimas.my

## INTRODUCTION

Over the course of decades, the landscape of construction projects has undergone a profound transformation, becoming progressively more complex, multi components and technologically advanced. Nonetheless, the principal aim within the construction industry remains unwavering and that is to successfully complete projects within the confines of optimal quality, stipulated time frames, and minimal costs. In accordance to Mane and Patil (2015), it is evident that quality stands as a pivotal determinant in the successful execution of construction projects. It is also discerned by Saeed and Hassan (2012) that paramount consideration for construction quality concept is usually directed toward fostering customer's satisfaction, especially in meeting the requirements of the designer, constructor and regulatory agencies as well as the project's owner. In order to uphold and ensure the attainment of superior quality, it is imperative to exercise meticulous quality management (QM) practices through quality planning (QP), quality assurance (QA), and quality control (QC) (Janipha and Ismail, 2013).

Besides implementing an effective quality management system, it is imperative to acknowledge the various determinants that exert influence on construction quality. Pheng and Hong (2005) conducted an insightful study on the factors that significantly contribute to favourable quality outcomes within the construction industry in Singapore. The foremost priority lies in the unwavering commitment to quality, followed by strategic quality management, a customer-centric approach, the elimination of rework, collaborative teamwork, and comprehensive training initiatives. Moreover, the empowerment and respect afforded to individuals within the organisation also emerge as critical factors in fostering a culture of quality. Furthermore, Lam et al. (2008) delved into an examination of the dimensions of quality within large-sized public building contractors in Hong Kong. It was highlighted the paramount importance of focusing initially on strategic planning, effective human resources management, and dynamic leadership to lay the foundation for a culture of continuous improvement to further enhance the overall quality performance.

Despite a comprehensive understanding and knowledge of what measures can and should be implemented to guarantee favourable quality outcomes, the construction industry continues to confront its own set of challenges in relation to quality outcomes. Yaman et al. (2022) with reference to Malaysia Auditor-General Report spanning 2015 to 2018 underscores recurrent issues plaguing the quality of construction projects. In fact, consumers in the real estate sector have borne the brunt of subpar quality, as shown by the National House Buyers Association (HBA) in their record of a plethora of grievances from dissatisfied homeowners who have encountered myriad issues with their newly acquired residences. The terms defects, rework, poor quality, snagging, non-quality, deviation, and noncompliance have all been utilised interchangeably to

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refer to instances or conditions indicative of substandard quality (Olanrewaju and Lee, 2022). A recent study conducted in Malaysia by Yap et al. (2017) yielded a comparable finding, indicating that rework costs ranged between 3.1% and 6.0% of the overall project value. Yaman et al. (2022) highlighted that premature defect, failures and shortfall in the construction constantly plagued end user and owners of project alike. As highlighted above, it is obvious that despite many improvements, adoption and enhancement quality assurance and control has undergone over the decades, there remain many undesirable outcomes in end products in the construction industry.

The problem with poor quality construction work does stem from various causes. According to Olanrewaju and Lee (2022), the use of non-complying materials and poor-quality materials during construction as well as poor material choice during design are noted to be a major cause of poor-quality construction. Janipha and Ismail (2013) went on to emphasise that when organisational management prioritises supplier selection based on the lowest quotations, overall quality within the construction environment will be lowered, as the quality of materials directly influences the final product's quality. In addition, the inability or negligence in supervision to detect and remove this material at the opportune stage and allowing poor quality material to be produced through poor workmanship are also identified as a major contributing cause.

While on the surface, material quality, management and workmanship are deemed equally vital in determining the ultimate quality of the final product, it is not uncommon for the underlying issue to stem from specification error cause mismatch or incompatibility or substandard and nonconforming materials to enter the project (Janipha and Ismail, 2013). The inability to effectively identify and rectify these material discrepancies in the subsequent quality assurance/quality control (QA/QC) processes often leads to quality issues, culminating in escalated costs and budget overruns during the construction phase (Olanrewaju et al., 2021). This underscores the critical importance of rigorous material inspection and adherence to QA/QC protocols in preventing quality-related setbacks and financial overruns.

This study aimed to investigate the significant role played by construction materials in contributing to poor quality outcomes in construction projects. The research also seeks to delve into potential measures for mitigating these issues, with a particular emphasis on bolstering QA/QC processes. It is crucial to prioritise and scrutinise the quality of construction materials, as it forms the cornerstone of this research initiative dedicated to elevating the overall quality of building construction. This strategic focus is anticipated to yield substantial advancements in construction quality.


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# LITERATURE REVIEW

## Causes of Poor Quality in Construction

The following literature review will focus on the pivotal role that construction materials play in influencing the quality outcomes of projects. It will delve into the various factors that contribute to quality issues associated with materials, and subsequently, how the implementation of robust quality assurance/quality control (QA/QC) processes can effectively address and ameliorate these concerns within the construction industry. This review aimed to provide a comprehensive understanding of the interplay between materials, quality, and the critical role of QA/QC processes in ensuring superior construction outcomes.

Janipha and Ismail (2013) stated that many criticisms levied on the industry was due to poor workmanship and construction materials. The issues highlighted are poor workmanship, defects in facilities, non-complying work and low-quality material used in the construction. Daud and Ishak (2018) also stated that the defect or poor quality in works could be contributed by two segments, namely poor workmanship and poor quality of materials. Olanrewaju et al. (2021) pointed that poor quality occurs in >80% of building projects, whereby poor workmanship and poor quality of materials/ components were the dominant causes.

Ahzahar et al. (2011) also identified poor quality material used as a major contributor in poor quality of construction project, particularly seen in building defects and failures for building projects in the northern states of Malaysia Without due attention, the quality of construction materials used could derail the aspiration of the project team to achieve recognised quality in the construction project. Rumane (2018) mentioned that the products and materials used in construction projects, whether raw or processed, cheap and easily available, or expensive and complex will affect the final quality of the project. If they fall short of these standards, it can compromise the overall quality of the construction project, potentially leading to subpar outcomes.

Janipha and Ismail (2013) discovered the influence of construction materials on quality in the construction industry, revealing that a substantial 67% of the survey respondents identified material supply as the primary issue affecting construction quality. This underscores the critical importance of effectively managing and ensuring the quality of materials in construction projects to enhance overall quality outcomes. Yaman et al. (2022) pointed out that the selections of construction material need to be given due attention at the earlier stage of construction phases to avoid low quality. Its significance and impact to quality begin at the earlier stages of construction and right through the construction processes and activities, in comparison with workmanship.

The Chartered Institute of Building (CIOB) (2019) pinpointed eleven major drivers that exert influence over construction quality, one of which is the

procurement, storage, and handling of materials. This underscores the critical need for precise information regarding material requirements to ensure compliance with design specifications. The quality of materials and components constitutes a pivotal element within a comprehensive quality plan, ultimately culminating in the creation of a product that aligns with all specified quality parameters. The success of project delivery on site hinges on the proficiency and application of the workforce, often referred to as workmanship, as well as the calibre of materials employed (Howard, and Greenwood, 2018). Every facet of the construction process is intertwined with the utilisation of materials. Consequently, any lapses in the management of construction materials are bound to have a discernible impact on the project, regardless of its scale or complexity (Song et al., 2018). The quality of raw materials is unequivocally linked to the overall quality of construction projects and is rightly identified as the linchpin of engineering excellence (Yuan et al., 2018).

This collective body of literature unequivocally establishes that when the raw materials utilised in construction fall below the stipulated quality requirements, the final output of the construction project is inevitably compromised. Hence, it is of paramount importance to implement rigorous measures for managing and controlling the quality of raw materials from the outset, before they enter the supply chain that leads to the project site and the subsequent on-site works. The following section continues to explore specifically the definition of poor material quality.

## Types of Poor-Quality Material

### Non-Compliant Materials

As mentioned by Olanrewaju et al. (2021) non-compliant materials are items that do not meet established specific standards or requirements set by project designers and relevant authorities. Non-compliant materials are those that deviate from the stipulated requirements of the construction project, failing to meet the defined criteria. Akinyemi (2016) classified the causes of building collapses into three main categories: types and quality of materials used, operational issues, and personal problems. In cases where the collapse is attributed to concrete quality, the root cause is often linked to the use of inferior aggregates and lower-grade cement.

However, it is also worthy to note that when professionals on the design team responsible for specifying these materials are somehow lack comprehensive knowledge about the functionality and performance of the materials and components they recommend, it may be difficult to comply to the standard and specification stated (Adafin et al., 2011; Folorunso, and Ahmad, 2013). This implied that the established standard, against which the material is being assessed for compliance, may be flawed or inappropriate from the outset.


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**Poor Quality Material**

Poor quality materials are materials that fall below the recognised national, international, or industry standards (Olenwareju and Lee, 2022). These materials are generally of inferior quality on their own and the terms sub-standard or sub-par are often used. Poor quality material may be constructed from cheap raw materials, and/or may have never undergone testing or certification to validate their properties or performance and possess defects or flaws. Wai (2011) pointed out that low quality of material as the first factor causes poor quality of the building. The study uses the finding of an ongoing research project, presenting the important factors that have significant effect on material on the quality of building construction projects in Myanmar. The adaptation of a good material management system helps in improving the quality of the project. It is imperative to identify and rectify instances of poor material quality, as they can significantly impact the overall quality and longevity of a construction project.

Both non-compliant or poor-quality materials can lead to structural issues, safety hazards (Nik Him et al., 2023), and additional costs for repairs or replacements in the long run. Therefore, rigorous quality control measures, including adherence to established standards and thorough material testing, are crucial to ensuring the use of high-quality materials in construction projects.

**Causes of Non-Compliant and Poor Materials Quality**

**Material Selection, Inappropriate Design**

Talib et al (2015) stresses the critical importance of addressing material requirements during the design phase, emphasizing that the selection of materials at this stage significantly influences the potential for subpar material usage. This highlights the pivotal role of careful material selection in ensuring overall construction quality. Adewale et al. (2018) highlighted the need to provide clear and appropriate materials in specification for design, to address building defects or failure. Waziri (2015) found that one of the barriers to quality construction during construction defects is due to specifications indicating the use of new and untested materials, i.e. the design output of the projects. Olanrewaju and Lee (2022) emphasised on how materials can be specified or designed without adequate consideration for the surrounding environment, potentially leading to detrimental issues such as corrosion. This illustrates the necessity of comprehensive environmental assessments when specifying materials to prevent quality-related challenges in construction projects.

Stukhart (2021) noted the critical role of designers during the design stage prior to construction in ensuring quality of materials. Tan and Abdul-Rahman (2011) quoted Abdellatif and Othman (2006) that building construction materials which did not meet the expectations of customers and are not designed to suit the customer's requirements was one of the causes of poor quality of

residential building. Hence, the responsibilities to quality in the construction industry also should be shared by the designing architects and engineers as observed by Dwikojuliardi (2015) as it is noted that of the three contributing factors to the quality failures, 50% of the failures can be attributed to design faults.

**Lack of QAQC**

Various QAQC methods and approaches are adopted in the local construction scene. Amongst others are Project Quality Plan, Quality Assurance Plan, Inspection and Testing Plan, which are very much adaptation from Quality Management ISO 9001 concept (Pheng, and Hong, 2005). The quality control in the phase of project quality plan should be strengthened, and the emphasis on the inspection after completion should be transferred to the planning and process control of pre-construction. Razak et al. (2017) mentioned that project supervision is carried out by inspection, testing and monitoring of materials and workmanship on site. In their study, 67% of respondents also cited that the materials supply by the suppliers was the main issue influencing the quality in the construction environment. Nidal (2021) concluded that the failure to implement a quality control and assurance system is a root cause. Olanrewaju et al. (2021) similarly emphatically concluded that the various quality management systems should be updated to address poor quality in building construction. Therefore, there is a general consensus that there are shortfalls in current QAQC practices which need to be reviewed and revamped, particularly in view of the impact of quality of construction material.

Razak et al. (2017) mentioned that generally, in the construction industry in Malaysia, there is a quality control plan, which spells out the test on material required for a project. Besides, the plan may include also a material approval procedure, method statement approval procedure and a general approval form to proceed with works. The use of these documents depends on the nature of material or works. All these methods are essentially QC activity based, whereby the utilisation relies on the supervision team's experience in enforcing QC on the materials, as and when the contractor would seek for a green light to proceed with works.

Kandeil et al. (2010) mentioned that even though most of the construction companies are ISO certified and some of them have quality management systems and audits, there is still a room for improvement to achieve end customer satisfaction. Cao (2010) stressed that the quality problems in construction can be rooted back to the following aspects, namely, the construction procedures and regulations, for instance, undocumented design, construction without drawing or not according to drawing, delivery of material for use without final acceptance and undocumented construction quality control. Nidal (2021)


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concluded that the failure to implement a quality control and assurance system is a root cause of poor quality in construction.

It is undeniable that poor material quality is part of the impact on a construction project's outcomes (Howard, and Greenwood, 2018) and some may end up as a construction dispute in building projects if not properly managed (Muhammuddin et al., 2023). And poorly made products will eventually drop in strength, durability, lifespan and appearance. It is evident that poor quality remains a persistent concern within construction projects, resulting in end-products and facilities that fail to meet the expectations of stakeholders and end-users. This underscores the critical role played by materials in the overall quality of construction endeavours. The question remains how non-compliance and substandard materials infiltrate construction sites and find their way into end products or facilities. Following an extensive review of the existing body of literature, this study seeks to empirically investigate the practical issues of poor quality within the construction industry, with a specific focus on the pivotal role played by construction materials. The research methodology employed for this investigation is a quantitative survey, which is outlined as follows.

## RESEARCH METHODOLOGY

The study employed an extensive survey method using questionnaires. Survey methods are effective and appropriate for collecting quantifiable data from a broad range of the general population. Survey method is particularly useful to obtain patterns and understand phenomena (behaviours and preferences), which in the case of this study is the occurrences of poor quality in construction works, its causes and the roles of material in contributing to poor quality occurrences. The study first uses random sampling to reach the large population, followed by snowball sampling techniques to obtain responses from any hidden population.

Respondents selected are construction related personnel who have at least 5 years' site experience and have completed projects in their records. A comprehensive set of 300 questionnaires were distributed through platforms like emails, phone calls, as well as social media channels, out of which 109 respondents actively participated, representing a 36.3% return rate. According to Gamil et al (2022), a response rate of 14.1% is deemed satisfactory.

The questionnaires survey was designed to have three (3) Section as follows:

Section A: Demographic and background of respondents
Section B: Causes of Poor Quality in Construction
Section C: Causes of Poor Material Quality Material

Section B and Section C aimed to extract perception and opinions from the respondents on the causes of poor quality in construction of building and the underlying causes of poor material quality being persistently used in projects. Deriving from the literature review, eight (8) causes of poor quality in construction are derived as follows:

i. Poor construction material quality
ii. Poor workmanship
iii. Inadequate design and specification
iv. Poor supervision
v. Time constraint; construction done in haste
vi. Unsuitable machineries used
vii. Restricted by budget; inferior material, workmanship used

In Section B, the respondents were asked to rank the causes from no 1-8 with 1 as the most prominent cause and 8 as the least likely cause. The analysis tool used to rank the causes is the Total Evaluation Score (TES) method as show in Equation 1.

$$TES = \frac{\sum W_i \times A_i}{10} \quad (1)$$

Where:
TES = total evaluation score
Wi = weight (importance) of rank i
Ai = Number of respondents selecting rank i

Each rank is provided with a weightage (Rank 1 as 7 to Rank 7 as 1).

The causes of poor construction materials in projects are as follows. These potential causes, sourced from the aforementioned extensive literature review, are instrumental in discerning the underlying factors contributing to the utilization of inferior quality materials in construction projects.

- Inadequate design and specification
- Lack of clarity of when and how frequently QC is needed
- Inadequate scope of responsibility of supervisory personnel
- Lack of clarity in QAQC process flow/steps
- Inadequate or insufficient QC activities
- Inadequate or ineffective use of material approval procedure
- Ineffective use of approval form/documents


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The questionnaire used a 5-point Likert scale for respondents to indicate how strongly they agree with the stated causes. The Likert scale has 1 – 'strongly disagree', 2- 'disagree', 3 – 'neutral', 4 – 'agree' and 5 – 'strongly agree'.

The selection of sample size for the survey was based on random sampling technique. The method to determine the sample size of an unlimited population is adopted from Enshassi and Al Swaity (2015) to calculate the sample size. Limited population (N) of 250,000 used is based on Construction Industry Development Board Annual Report 2021 on active personnel involved in site management including supervision.

Data collected from Section C were analysed using the Relative Importance Index (RII) based on the 5-point Likert scale on respondents' agreement to the statement. The relative importance index is based on a formula stated in Equation 3:

$$RII_1 = \frac{\sum x_c}{A\ X\ N} \qquad (3)$$

Where,
RII = Relative Importance Index
W = Weight given to each factor by the respondents (scale 1 to 5)
A = Highest weight (scale 5)
N = Total number of respondents

## RESULTS AND ANALYSIS

### Background of Respondents

This section presents the demographics of participants for the study. There are total 109 respondents to the questionnaire survey. Table 1 shows the demographic data of respondents based on their role in construction projects. Highest set respondents came from the on-site related personnel who are directly involved in the QA/QC aspects of construction projects.

**Table 1.** Background of Respondents

| Background of Respondents | Frequency | Percentage (%) |
|---|---|---|
| Owners/End User | 26 | 24 |
| Project Engineer/Construction Site Personnel | 50 | 46 |
| Project Designer | 33 | 30 |
| Total | 109 | 100 |

## Findings

Table 2 presents the respondents' ranking of the causes of poor quality in construction.

**Table 2.** Rank of Causes of Poor Quality in Construction

| Causes | Rank 1 Score (No) | Rank 2 Score (No) | Rank 3 Score (No) | Rank 4 Score (No) | Rank 5 Score (No) | Rank 6 Score (No) | Rank 7 Score (No) | TES | Cause Rank |
|---|---|---|---|---|---|---|---|---|---|
| Poor workmanship | 168(24) | 264(44) | 80(16) | 36(9) | 27(9) | 8(4) | 3(3) | 586 | 1 |
| Poor construction material quality | 210(30) | 132(22) | 80(16) | 68(17) | 24(8) | 18(9) | 7(7) | 539 | 2 |
| Poor supervision | 98(14) | 90(15) | 155(31) | 116(29) | 33(11) | 16(8) | 1(1) | 509 | 3 |
| Restricted by budget; inferior material, workmanship used | 168(24) | 54(9) | 45(9) | 40(10) | 39(13) | 44(22) | 22(22) | 412 | 4 |
| Inadequate design and specification | 77(11) | 36(6) | 95(19) | 76(19) | 63(21) | 26(13) | 20(20) | 393 | 5 |
| Time constraint | 21(3) | 48(8) | 60(12) | 72(18) | 108(36) | 40(20) | 12(12) | 361 | 6 |
| Unsuitable machineries used | 28(4) | 42(7) | 30(6) | 32(8) | 36(12) | 74(37) | 35(35) | 277 | 7 |

The findings of this study unequivocally point to poor workmanship as the primary driver of poor quality in construction, closely followed by subpar quality of construction materials and inadequate supervision. These results are in alignment with the assertions made in prominent literature, as evidenced by (Janipha, and Ismail, 2013; Daud, and Ishak, 2018; Rumane, 2018; Olanrewaju, et al., 2021; Ahzahar, et al., 2011).

With respect to the causes for poor material quality, the analysis of the results is put forward in Table 3.


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**Table 3.** Causes of Poor Material Quality in Construction

| Reasons | 1 = Strongly Disagree% (N) | 2= Disagree% (N) | 3= Neutral% (N) | 4= Agree% (N) | 5= Strongly Agree% (N) | RII | Rank |
|---|---|---|---|---|---|---|---|
| Inadequate or insufficient QC activities | 3.7(4) | 3.7(4) | 13.7(15) | 51.4(56) | 27.5(30) | 0.79 | 1 |
| Lack of clarity in QAQC process flow/steps | 1.8(2) | 8.2(9) | 19.2(21) | 44.0(48) | 26.8(29) | 0.77 | 2 |
| Lack of clarity as of when QC is needed | 3.7(4) | 7.3(8) | 15.5(17) | 57.8(63) | 15.7(17) | 0.75 | 3 |
| Inadequate or ineffective use of Material Approval | 1.8(2) | 8.2(9) | 25.7(28) | 42.2(46) | 22.1(24) | 0.75 | 4 |
| Inadequate scope of responsibility of supervisory personnel | 4.6(5) | 7.3(8) | 23.8(26) | 45.9(50) | 18.4(20) | 0.73 | 5 |
| Inadequate design and specification. | 3.7(4) | 10.1(11) | 27.5(30) | 40.3(44) | 18.4(20) | 0.72 | 6 |
| Ineffective use of approval forms/documents | 2.8(3) | 15.6(17) | 30.3(33) | 37.6(41) | 13.7(15) | 0.69 | 7 |

The ranking provided showed that inadequate or insufficient QC activities with RII of 0.79, followed by lack of clarity in QAQC process flow/steps (RII = 0.77) and lack of clarity as of when QC and lack of clarity as of when and how frequently QC is needed (both with RII = 0.75) are amongst the top contributors to why poor-quality materials are persistently included in construction projects. When quality control (QC) activities are not comprehensive or are lacking in rigor, it creates opportunities for substandard materials to go unnoticed and be incorporated into the construction process. With the lack of clear guidelines and steps in the (QAQC) process, confusion ensues and potential oversights occurs. Without a well-defined process, it becomes challenging to effectively identify and address issues related to material quality. Also, without clear guidelines on when to conduct quality checks, there is a higher likelihood of overlooking critical checkpoints in the construction process.

Other causes are of high importance as well as their RII are more than and close to 0.7. When there are shortcomings in the process of approving construction materials, it creates opportunity for inferior materials to be introduced. Furthermore, when supervisory personnel do not have clear delineation of responsibilities related to quality management, there may be gaps in oversight, allowing poor-quality materials to be used. Lastly, the use of

approval documentation may not be as significant as other factors on the list, it nevertheless serves as the gateway to capture the use of poor-quality materials.

## CONCLUSION

From both an extensive literature review and the gathered survey data, it is evident that the predominant cause of poor quality in construction projects lies primarily in substandard workmanship, closely followed by inferior material quality and inadequate supervision. Remarkably, this pattern has persisted over the past decade, with previous studies substantiating this prevailing trend. The construction quality landscape seems to have seen little variations. Focusing on the issue of poor material quality, it becomes apparent that deficiencies and inadequacies in Quality Control (QC) activities are the foremost factors contributing to this problem. This underscores a shortfall in the planning of Quality Assurance and Quality Control (QAQC) measures to effectively address material QC on construction sites. Moreover, various underlying causes stem from the previously mentioned factors, resulting in inconsistent and incorrect application of QC activities.

It is evident that the construction industry continues to grapple with this issue, even in the face of the introduction and implementation of various QAQC philosophies and methodologies, such as Quality Assurance Plans (QAPs), Inspection Test Plans (ITPs), Approval Checklists, and the like. Despite the industry's increasing adoption of Total Quality Management and the ISO 9001 Quality Management System, the construction sector still contends with shortcomings and inefficiencies in QC activities as a primary cause of poor material quality. This suggests a notable gap in the understanding and application of construction material related QC activities, despite the widespread adoption of QAQC practices. The lack of clarity when executing QC procedures may lead to either the omission or improper implementation of crucial QC measures on materials. Deficiency in existing QA/QC documentation also plays a role in the persistence of poor material quality. This suggested that current QA/QC processes designed to oversee material quality in construction projects may be inadequate or non-comprehensive. Compounded by a lack of comprehension regarding QC processes and the appropriate timing for QC activities, both of which exert significant influence.

Therefore, it is imperative that study and effort be undertaken to address such significant weaknesses in the construction quality management processes over construction material. The QA/QC practices in the construction industry for material is in dire need of revamping and improvement with new measures, or methodology to unplug the worrying trend of poor material quality still being used in the construction industry. The QA/QC process on material needs to be


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further enhanced in order to elevate the quality in construction through adequate and compliant construction materials.

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# ADOPTION OF SOCIAL COST AMONG STAKEHOLDERS IN MALAYSIA CONSTRUCTION INDUSTRY

**Tantish Kamaruddin[1], Thee Chai Shan[2], Nurshikin Mohamad Shukery[3], Fara Diva Mustapa[4] & Mohamad Zahierruden Ismail[5]**

[1,2,3,4,5]*Department of Quantity Surveying,*
*Faculty of Built Environment & Surveying,*
UNIVERSITI TEKNOLOGI MALAYSIA

## Abstract

Social costs are the overall impact of economic activity on the welfare of society. Social costs are the 'invisible' components of building operations, hence are not included in the tender price. However, the people of a nearby construction zone pay the price by enduring disturbed economic activity, pollution, and disrupted health and social well-being; without any adequate compensation. The purpose of this study is to identify the level of understanding of social cost among construction players and to identify the level of importance of social cost consideration among construction players. This research will provide new information for predicting or assuming the link between the level of understanding and level of importance among construction stakeholders. According to the literature, social cost indicators as a result of construction-related negative impacts for construction players include transportation, economic activities, and social, ecological, and health systems. The respondents for this research were conducted among clients, contractors, architects, engineers, and quantity surveyor firms. A quantitative method using questionnaires is applied to obtain data. In terms of social cost understanding, the data shows that different types of construction stakeholders have varying levels of understanding. According to the findings of the study by mean, the level of understanding of social costs for most respondents is road safety problems, followed by construction site water pollution causing irreversible damages. Then, the third highest mean score which is the air pollution of construction machinery produces air emissions that contain carbon and nitrogen oxides, toxic substances, and heavy metals. The finding emphasises that the level of understanding and the level of importance of social costs consideration among construction players are aware that road safety problems are the main reason for missing construction projects. Meanwhile, there is no significant relationship between the level of understanding and the level of importance of social costs.

***Keywords***: Economic, Social Costs, Quantitative Method

[1] Corresponding Author. Email: b-tantish@utm.my

## INTRODUCTION

Multifaceted construction industry accommodates engineering projects of either building new infrastructure or renovation of an existing building involving alterations or maintenance (Behm, 2008). Construction industry contributes to the sustainable development of a country's economy by delivering output as well as generating and redistributing income (Durdyev et al., 2020).

However, it is undeniable that construction projects unintentionally cause negative impacts on their surrounding environment although the completion of a development project positively influences the wellbeing of the society in general. The equivalent monetary values associated with the significant disruptions caused by the negative effects of the construction activities that are borne by the community are referred to as social costs. According to Danku et al., (2020), social costs involved are not limited to poor traffic conditions, pollution of the environment, road user related risk factors, deterioration of road surfaces, and existing infrastructure; it also decreases the adjacent property value and lowers business turnovers. Thus, fits the definition of social cost coined by Johnston et al. (2021) that "Social costs are the overall impact of an economic activity on the welfare of society. Social costs are the sum of private costs arising from the construction activity and any externalities".

Construction industry of the country contributes to depletion of natural resources, dust pollution, soil erosion and sedimentation, flash floods, destruction of vegetation in addition to using construction materials harmful to human health (Abd-Mutalib et al., 2020). Hence, projects should be executed with social responsibility by estimating building construction related social costs at the construction zone (Onubi et al., 2020).

## RESEARCH BACKGROUND

Social costs are 'invisible' constituents of construction activities, hence, was not priced in tenders. However, the price is paid by the residents of the nearby construction zone with affected economic activities, pollution, disrupted health and social wellbeing; without any appropriate compensations (Budayan & Celik, 2021; Çelik et al., 2019).

Road damage is the first-hand effect experienced by communities near a construction zone. According to Çelik et al., (2019) no amount of patchwork will settle a damaged road because once the soil underneath settles it will cause potholes. Excavation decreases pavement life expectancy and subsequent or inadequate periodic road restoration remains an expensive problem. Furthermore, Sarawak Public Works Department assistant director, Awang Mohd Fadilah said seven federal roads frequently used by overloaded construction lorries are severely damaged and require an estimated RM15.8 million for major repair works (News Straits Times, 2019).

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Consideration or quantification of social costs are ignored or goes unnoticed by traditional construction management practices (Yan et al., 2004; Yu & Lo, 2007). Primarily, construction social costs are completely expected to be borne by the public instead of the construction company. Hence, they are not included on the bill of quantities (BQs) of the project. Secondly, since the public is not part of the project planning and management process, their benefits are overlooked during the project lifecycle. Thirdly, it is difficult to quantify visible costs of construction social costs since they are intangible in nature. However, the awareness on the significance of social costs absorbed by the adjacent community not engaged in the contractual agreement is gaining momentum from city planners, municipal administrators, and the engineering community (Saito, 2012). Therefore, developing an understanding on the social cost pertaining to a construction project will highlight the key areas where the organisation can channel the effort to deliver the goal of minimised or zero social cost.

This study aimed to identify the level of understanding of social cost among construction players and to identify the level of importance of social cost consideration among construction players. The study will highlight to the construction players on the need to include social cost in cost estimation of a construction project. This will eventually formulate a way to define nuisance criteria. Hence, the consequences of residing adjacent to the construction zone could be justified to compensate for the social costs to the society.

## SOCIAL COST IN REVIEW

### Social cost definition

According to Johnston et al. (2021), "Social costs are the overall impact of an economic activity on the welfare of society. Social costs are the sum of private costs arising from the activity and any externalities". Private costs are identifiable specific costs related to the activity; contrarily external costs are not estimated by the profit makers but incurred on the third parties. Comparably numerous authors have explained social costs considering construction background. However, the work zone caused negative impacts such as extended travel time, wear and tear effect on the vehicle, accidents due to heavy traffic, or air pollution due to the congested traffic are four types of social or external cost components (Margorínová & Trojanová, 2019).

Therefore, the definition of social cost provided by Gilchrist & Allouche (2005) are the costs stemming from a construction project executed by the parties of the contractual agreement. In other words, negative impacts caused by construction in which the contractor, designer, or project owner are not held accountable are labelled as social costs (Çelik et al., 2019).


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## Consideration of social cost

Social costs associated with the eruption of engineering projects are widely acknowledged but completely disregarded during designing, planning and cost estimation or evaluation (Gilchrist & Allouche, 2005). Furthermore, the norm of making the public the scapegoat to undertake the effect of social cost rather than the project participants or beneficiaries themselves led to conveniently excluding estimation of social cost from contractual bid value. However, Matthews (2010) explained that the lack of a standard quantification method precludes construction associated with social cost from the bid estimation of a tendered project.

**Table 1**: Summary of Social Cost Themes Approached (Budayan & Celik, 2021; Çelik et al., 2017; Danku et al., 2020; Gilchrist & Allouche, 2005)

| | | |
|---|---|---|
| A) Damage on health | A1 | Construction activities produce airborne particles or dust |
| | A2 | Noise and disturb to human |
| | A3 | Road surface and sub-surface disruption due to intercept water flows may affect their volume, velocity and sedimentation rate |
| | A4 | Vibration of pile driving, dynamic compaction, blasting and the operation of heavy construction equipment produce high levels of vibration |
| B) Civil damage rights | B5 | Treating compromised physical and mental health which is the administration costs of the Social Welfare Department to provide assistance to the injured worker |
| C) Transportation | C6 | Increased traffic accidents rate due to improper construction lane changing or merging |
| | C7 | Additional fuel consumption |
| | C8 | Traffic: Utility construction and highway renovation directly impact roads and generate traffic delays |
| | C9 | Loss of parking space |
| | C10 | Prolonged closure of road space |
| | C11 | Detour to secondary roads |
| | C12 | Travel delays due to utility construction and highway renovation |
| | C13 | Road safety problems |
| D) Loss of income | D | Loss of income due to retailers may loss business |

| | | |
|---|---|---|
| E) Loss of decreased productivity | E14 | Productivity reduction due to traffic delay that affect the ability of people to perform their work |
| F) Loss of revenues | F15 | Loss of tax revenues due to reduction in business sales and personal income |
| G) Pollution | G16 | Air pollution of construction machinery produces air emissions that contain carbon and nitrogen oxides, toxic substances, heavy metals |
| | G17 | Construction site water pollution causes irreversible damages |
| H) Resource costs | H18 | Utility cuts due to construction rehabilitation and replacement of buried services |
| | H19 | Restoration cost which uses to replace the damaged environment with a comparable resource |
| | H20 | The material requirement for the new building was chosen to reduce carbon dioxide emissions |
| I) Property damage | I21 | Public property damage due to destruction of the original building |
| | I22 | Lower housing and property values due to construction noise |

Although social costs are subjected as 'non-existent' or 'invisible', it may on modest estimation rise-up to 400% of construction costs in some incidents (Vanier et al., 2004). Therefore, a conscious move to consider social costs during quotation preparation and tendering process will be a big step in moving the construction industry in the direction of sustainability. Furthermore, estimation and consideration of social cost will be advantageous because the magnitude of the social costs is directly proportional to construction time.

**Potential adverse impacts of construction projects**

The social costs generated at the area surrounding the construction are absorbed either directly or indirectly by the public at large (Aizuddin et al., 2023). It either causes monetary or intangible losses such as alterations to the environmental or inconvenient change of lifestyle (Ariff et al., 2023). Whether permanent or temporary, the severity and predictability of the adverse impact may differ. Construction industry associated adverse impacts incurred during the construction phase could be classified as traffic, economic activities, pollution, and ecological/ social/ health. Vibration works during construction is a common source of disturbance that affects people, buildings, and sensitive equipment. Driving of piles, dynamic compaction, blasting, and the operation of heavy


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construction equipment produce high levels of vibration that can cause a public perception of a lack of safety. Construction vibration effects may range from annoyance to visible structural damage (Waddington et al., 2014).

Vibration works during construction can damage structures either directly due to the impact of traveling energy waves or indirectly due to vibration-induced settlement (Waddington et al., 2014; Yu & Lo, 2007). The costs associated with the impact of vibration works on people are not well known.

**Quantification of construction social cost**

Project participants and stakeholders whose constructional activities contributed to the social cost should compensate for the negative impact incurred by the public. This could be achieved by estimation and incorporation of the associated social costs into the contractual agreement during the tendering process. Bartholomew (2022) and Gilchrist and Allouche (2005) highlighted that "Traditional contractual and bid evaluation practices do not account for economic losses resulting from construction-related activities that are borne by parties not engaged in the contractual arrangement". Danku et al. (2020) and Yu and Lo (2007) have identified three reasons for the difficulties involved in measuring the social cost. First and foremost, social costs associated with construction activities are excluded from bill of quantities (BQs) since it is absorbed by the public instead of the project participants. Secondly, social costs caused by construction activities are intangible, hence, quantifying is nearly impossible. Thirdly, society is generally overlooked since they are not active participants during the planning and management phase.

**Recommendation for social cost quantification**

The implementation of a development project, whether it be an urban underground expressway, public utility, residential building, or pipeline infrastructure, will inevitably result in alterations to the current biophysical environment, cultural status, and socio-economic landscape. (Balaban, 2012; Çelik et al., 2017). Hence, Environmental Impact Assessment (EIA) of a development project should be conducted to identify the consequences of an engineering project to the environment (Çelik et al., 2017; Ramírez et al., 2021). However, quality of life will also be equally affected in the neighbourhood adjacent to the construction area by the development project despite of the socio-economic benefits it may generate. Thus, it is advisable to prioritize classification, quantification, and compensation of the social costs beyond EIA approval of a proposed development (Çelik et al., 2017; Ramírez et al., 2021). Automatically, the focus will shift from tender price to emphasis on sustainable construction by adopting social costs consideration.

## RESEARCH METHODOLOGY

Data to answer the posed research questions were collected via quantitative research methodology involving a questionnaire to various construction players in Peninsular Malaysia. Quantitative research methodology allows to examine the relationship among variables by analysing numerical data via statistical tool. In the questionnaire, the 5-point Likert scale is used to determine a respondent's level of agreement with a statement or group of statements (Alabi et al., 2023; Bertram, 2007)

Collected data was arranged and analysed using descriptive analysis via frequency studies. Data analysis is the process of transforming, evaluating, and modelling data to infer information to support decision-making. Data gathered via structured instrument such as questionnaire or interview is classified into categories to visualise the frequency distribution. It is presented in the form of list, table or chart for easier visualisation of frequency of various outcomes in a sample.

A total of 111 questionnaires were returned successfully and for further analysis. The respondents include 18% of architects, 19% civil and structural engineers, 22% of contractors, 18% of developers and 23% of quantity surveyors.

A mean comparison analysis had been performed. To establish the categories of respondents, types of personal values, and conflict elements, a mean score is necessary. The mean score is calculated by adding the entire number of responses and dividing it by the total number of respondents. Then, ranking analysis is used to determine the level of understanding and importance of social costs among building stakeholders.

## ANALYSIS ON LEVEL OF UNDERSTANDING OF SOCIAL COSTS AMONG CONSTRUCTION PLAYER

For the level of understanding of social costs towards construction player in the construction industry, the results show that the top implication chosen by the respondents is “Road safety problems” with the highest mean score of 4.37. The value described as unaccustomed driving conditions and diverted roads with narrow residential streets will increase incidents of road accidents and vehicular traffic disruption due to extended travel period (Çelik et al., 2019).

The second highest mean score is 4.28 which is “Construction site water pollution causes irreversible damages”. This is because previous study shows that construction as the upper hand environmental pollutant causes water pollution, generates solid and liquid waste, emits harmful gases and generates dust (Enshassi et al., 2016). Pollution-associated impacts not only pose health threats but reduce quality of life to those in adjacent neighbourhoods.

Then, the third highest mean score is 4.19 which is “Air pollution of construction machinery produces air emissions that contain carbon and nitrogen


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oxides, toxic substances, heavy metals". According to (Ijigah et al., 2013), construction accounts for 90% of all non-fuel mineral consumption, and all forms of constructions consume electricity.

**Table 2:** Highest Mean Ranking on Level of Understanding of Social Costs

| | Mean | Std. Deviation | Ranking |
|---|---|---|---|
| **Road safety problems** | 4.37 | .841 | 1 |
| **Construction site water pollution causes irreversible damages** | 4.28 | .765 | 2 |
| **Air pollution of construction machinery produces air emissions that contain carbon and nitrogen oxides, toxic substances, heavy metals** | 4.19 | .668 | 3 |
| **Construction activities produce airborne particles or dust** | 4.14 | .784 | 4 |
| **Noise and disturbance to human** | 4.11 | .802 | 5 |

## ANALYSIS ON LEVEL OF IMPORTANCE OF SOCIAL COSTS AMONG CONSTRUCTION PLAYER

For the level of importance of social costs towards construction player in the construction industry, the results show that the top implication chosen by the respondents is "Road safety problems" with the highest mean score of 4.49. According to (Çelik et al., 2019), no amount of patchwork will settle a damaged road because once the soil underneath settles it will cause potholes. Excavation decreases pavement life expectancy and subsequent or inadequate periodic road restoration remains an expensive problem.

The second highest mean score is 4.34 which is "Construction site water pollution causes irreversible damages". Interception flow construction projects may influence the volume, velocity, and sedimentation rate of the flow, resulting in riverbank erosion, floods, disruptions in the usual course of rivers and streams, and aquaculture damage. Dehydration activities that lower the water table can deteriorate green living, limit agricultural water consumption, and cause building subsidence. Precipitation, dust, and fuel leaks can all have an impact on water quality (Gilchrist & Allouche, 2005).

Then, the third highest mean score is 4.15 which is "Construction activities produce airborne particles or dust". Gilchrist and Allouche (2005) mentioned, construction operations can cause particles or dust to be released into the air. Although dust occurs naturally, building dust has been found to cause significant disruption to people within 150 meters of a construction site. Dust

may wreak havoc on electrical and mechanical systems, as well as decrease sight. The societal costs of dust include higher cleaning and maintenance expenses, lower agricultural productivity, and lower environmental aesthetic quality. Civil contractors plan-ahead of time to manage dust pollution and are thus more prepared than building contractors. To reduce dust pollution, civil contractors frequently have their own water wheels and other supplies on-site (Yu et al., 2004).

**Table 3:** Highest Mean Ranking on Level of Importance of Social Costs

| | Mean | Ranking |
|---|---|---|
| **Road safety problems** | 4.49 | 1 |
| **Construction site water pollution causes irreversible damages** | 4.34 | 2 |
| **Construction activities produce airborne particles or dust** | 4.15 | 3 |
| **Air pollution of construction machinery produces air emissions that contain carbon and nitrogen oxides, toxic substances, heavy metals** | 4.14 | 4 |
| **Noise and disturbance to human** | 4.10 | 5 |

## CONCLUSION

In terms of the level of social costs, the findings indicate that different categories of construction stakeholders have different levels of understanding of social costs. From the results of analysis by mean analysis, the level of understanding of social costs for most respondents are road safety problems, followed by construction site water pollution causing irreversible damages. Then, the third highest mean score which is air pollution of construction machinery produces air emissions that contain carbon and nitrogen oxides, toxic substances, heavy metals. Next, the fourth highest mean score of social cost by construction activities is the production airborne particles or dust, and the fifth highest mean score is noise and disturbance to human.

Furthermore, in terms of societal expenses, data analysis from the gathered questionnaires clearly reveals that road safety issues are the most important cause for building projects amongst construction players. The result underlines that all construction professionals, including the developer, contractor, civil and structural engineer, architect, and quantity surveyor, are aware that road safety issues are the leading cause of project delays.

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# BEST PRACTICE OF REPORTING ACCIDENT AND SAFETY CULTURE IN CONSTRUCTION SITE

**Mohd Saidin Misnan[1], Muzani Mustapa[2], Zuhaili Mohamad Ramly[3], Sarajul Fikri Mohamed[4], Farah Nadiah Abdul Rahim[5]**

[1,2,3,4,5]*Faculty of Built Environment and Surveying*,
UNIVERSITI TEKNOLOGI MALAYSIA

## Abstract

Safety and health management system implementation is an important part of the construction projects. This is because working in construction will extremely expose the workers to hazards. This paper discusses the best practices of reporting accidents safety culture in accordance with the laws of Malaysia and the causes of failure in reporting the accident. Many accidents that happen in construction sites fail to be reported to the Department of Occupational Safety and Health, Malaysia (DOSH). The research methodology was conducted through project case studies, document reviews, and interviews. Failure in reporting accidents gives a vague picture about the level of safety and health in the construction industry. Although the construction law requires that each construction site to have a safety and health officer (SHO), yet the law does not ensure that each construction accident was reported to the parties in-charge. Accurate and correct safety procedures could influence the number of accident statistics in construction sites and the improvements made in reducing the number of accidents occurred. Commitment from all parties involved in construction progress play a key role in ensuring that the safety and health at construction sites progresses well. Therefore, the causes of failure to report accidents and the factors affecting safety and health on construction sites are discussed in this paper to outline the best practices in accident reporting and provide guidance to meet the requirements of safety practice compliance at project sites in the future.

***Keywords***: Best practice, Reporting accidents, Safety compliance, Safety culture

[1] Corresponding Author: b-saidin@utm.my

## INTRODUCTION

The construction industry generates 6.0% of the country's economic development (Dehdasht et al., 2022; Rumaizah et al., 2023). Despite the tremendous growth of the construction industry, this sector is not spared from dealing with various problems and challenges such as the issues of accident at the workplace, especially at construction sites. According to Wan Faida and Mohd Saidin (2018), workers in construction sites face one in 300 of the risk of death in a workplace. Risk of disability in the industry is also greater than other industries. Subsequently, procedures in reporting accidents and deaths in construction sites is one of the responsibilities that must be adhered to by the employer to ensure that workers' safety and health are guaranteed. According to Moore et al., (2013), accident reports and investigation reports issued shall be reviewed by the safety and health officer and safety site supervisor so that effective action can be taken to prevent similar accidents from occurring at the construction site. This is so that the rapid growth in the construction industry is in line with the development in terms of the safety and health of employees.

## PROCEDURES IN REPORTING ACCIDENTS

If an accident was reported, the cause of the accident will be known. This can help in reducing the accident rate in the future. At the same time, the data collected is an important database for the Department of Health and Safety (DOSH) to perform analysis and prepare strategic plan to administer and enforce the law. Therefore, it is important for the data to be recorded by the employer to facilitate the analysis and to ensure the validity of statistical results (DOSH, 2004).

According to DOSH (2004), the process begins with the notification of an occurrence of an accident. This notification will activate the accident investigation process. Conclusions and recommendations will be discussed and evaluated upon the completion of the investigation report issued. Planning for this system should be set before the accident and before starting the investigation. Results from the collection of reading materials, procedures to report accidents at construction sites are summarised as shown in Figure 1.

When accidents occur, emergency responses such as treating victims should be performed. Then, an accident report shall be made to DOSH within seven days by using the appropriate forms. Then, the Occupational Safety and Health Committee (OSHC) and Safety and Health Officer (SHO) will discuss whether further investigation should be performed or not. If necessary, then further investigation will be performed and the accident investigation report will


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be written and reported to DOSH for further action (Ismail, 2006; Nur Adila et al., 2017).

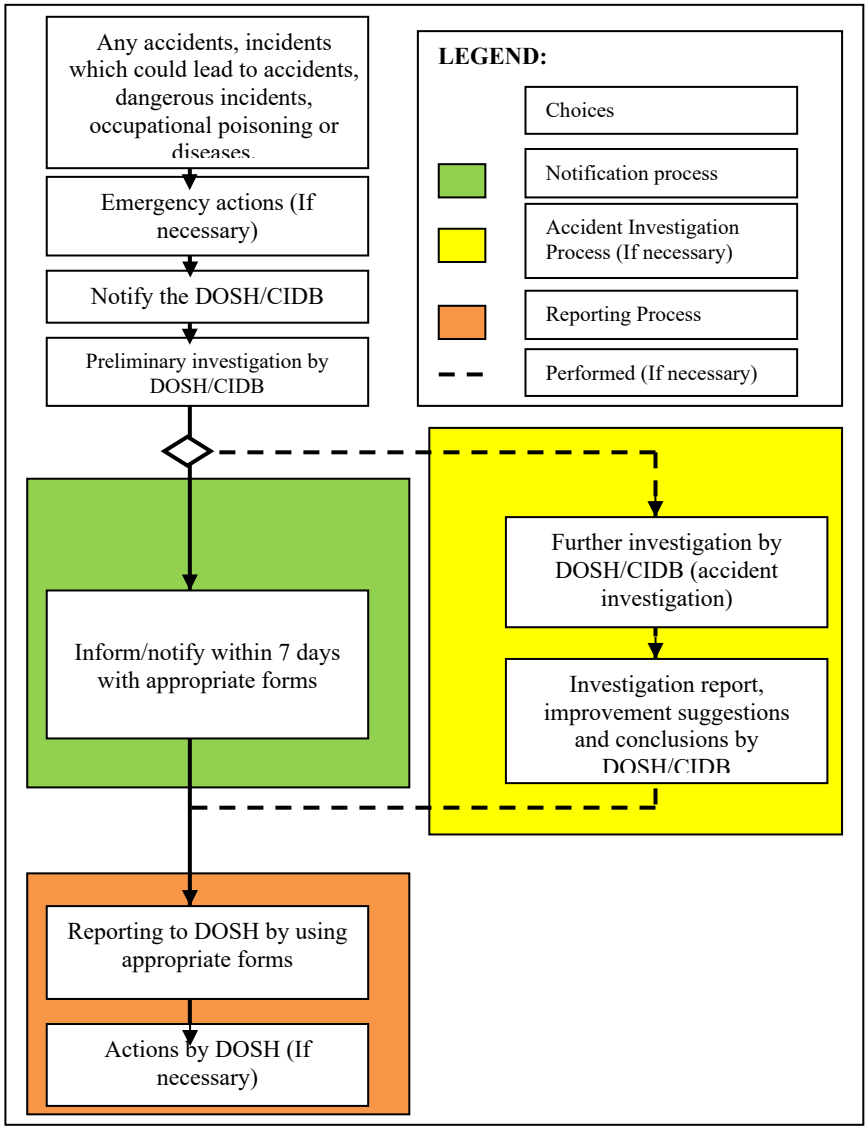


**Figure 1:** Procedures in reporting an accident at construction site
*Source: DOSH*

**Emergency Actions**

Before starting any investigation or notification of an accident, the first step is to give immediate rescue and medical treatment to the injured worker (Manu et al., 2018*)*. If the injury is serious, then the employee must be sent immediately to the nearest hospital. In addition, other workers who are at the accident site must be appeased so that the situation becomes manageable. For major accidents, the likelihood of psychological trauma to the victim is higher. Therefore, counselling should be given to restore the confidence of the victim (Ismail, 2006).

**Notification of Accidents**

According to Ismail (2006), and DOSH (2024) oral or written complaint must be made to the authorities and the organisation as soon as the accident occur. The information provided is usually limited to the type of accident and the effect of primaries. It is limited by what is required in the notification form issued by certain authorities or organisations. This notification does not require a full investigation of the accident because it must be done as soon as possible since the cause of the accident is still unknown. Complaints made can involve:

i. What happened
ii. Location of accident
iii. Parties involved in the accident
iv. Time of the accident

Act 514 requires the employer to make the notification by using the DOSH Form 6 for occupational accidents and incidents involving dangerous death. Serious bodily injuries that prevent the victim from pursuing his normal occupation for five calendar days, and dangerous incidents and accidents that cause him from performing a job for more than four calendar days. While Form JKKP 7 is used for poisoning and occupational disease. If an accident involves death or serious bodily injury resulting in death within one year from the date of the accident, the employer should notify the DOSH as soon as it is known. Failure to make a notification will result in penalties.

**Reporting Accidents**

The action of reporting an accident is defined as the activity of reporting the complete result of an accident systematically and in detail, stating losses and causes of accidents identified and recommendations for improvement. Since a lot of information is needed, the process of investigation and preparation of the


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report require more time as compared with the notification of an accident. This is because the preparation of this report requires more manpower (Ismail, 2016).

According to DOSH (2024) and Ismail (2016), after the emergency action is done, the parties involved in investigating an accident will conduct preliminary investigation of the accident. Further information will be submitted to the authority (DOSH) to make an in-depth and thorough investigation. Further notification will be made to DOSH within seven days after the accident.

**Investigation of Accidents**

According to De Silva et al. (2018) and Williams et al. (2019a) there are several contributors to the accident or dangerous occurrence that occur in construction sites which seem less obvious to the naked eye. Investigation must be carried out not only in tasks such as recording each event, but also in effective planning. A good planning to ensure an effective investigation can be done to prevent the occurrence of the same accidents from recurring. Planning an investigation should include the following criteria:

i. Investigate all accidents or dangerous occurrences which may cause injuries
ii. Procedure to investigate accidents or dangers
iii. Training - the employer must ensure that the investigating team was appointed to perform the duties to investigate the incident
iv. Resources such as necessary equipment (cameras, personal protection equipment, etc.) must be provided by the employer.
v. Accident investigation should be able to answer the questions as follows:
    a. Compare what should happen with what was happening
    b. Determining gap between expectations and actual situations
    c. Determine why the gap exists
    d. Propose ways to prevent accidents from happening again.

## RESEARCH METHODOLOGY

This paper discusses the literature review and case study method has was performed on five construction projects to identify constraints faced by contractors in reporting accidents on construction sites and the factors in ensuring the safety and health practice implementation at construction sites. The result of the literature review obviously revealed that there are three important steps in reporting for an accident at the construction site. Firstly, the staff need to notify the management team on the incident as fast as they can. Secondly, the

management team needs to investigate the cause of the accident. In this stage, they might know how and why the accident happened. Finally, the person who investigates the case needs to report the accident to the authorities so the same accidents could be prevented in the future. Case studies were performed on construction building projects with the presence of occupational safety and health officers (SHO) at all sites.

**Compliance in Reporting Accident Procedures**

Table 1 shows the comparison between the procedures applied in accordance with the allowed provisions of the project. Results showed that one of the five projects has successfully complied with the procedures provided. Meanwhile, the remaining projects failed to comply with all the regulations. There are some projects which comply with the provisions, but only reported accidents if the case involves death to DOSH. Figure 2 is a guidance for Table 1.

**Guidance: -**
√ = Performed x = Not performed ∞ = Performed upon situations

**Figure 2:** Guidance for Table 1

Based on Table 1, Project A is the most critical project because zero accidents were reported to DOSH even though there cases happened at site. It shows that Project A failed to comply with the rules set out in section 32 of Act 514, for all accidents must be reported. This is because the safety and health officer appointed by the contractor would be more favourable to the contractor where the DOSH report was completed only with the permission of the project manager. If the future impact is high, then the accident could be prevented from being reported to DOSH. This clearly shows that the future implication could cause the failure of compliance with the regulations in construction sites.

For Project B, C, and D, the accidents were reported depending on the situation faced and were made only for accidents involving death. According to the respondents, an accident which involves death must be reported to DOSH. Meanwhile, other accidents were not reported because it was reported annually. Respondents in Project B mentioned that only fatal accidents should be reported because it involves many parties and has the greatest impact on the construction project. It is contrary to the guidelines prescribed in the regulations to report the accident, where in rules and regulations of section five and section seven, division two explained that dangerous occurrences, occupational poisoning, and occupational diseases must be reported to DOSH.


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Thus, it can be concluded that knowledge about the types of accidents which should be reported to DOSH remained vague. Similar to the respondent of Project A, the respondents of Project C and D also informed that fatal accidents reported to DOSH must obtain the approval of the client or project manager. Thus, it can be concluded that future implication is the main cause of failure of compliance to these regulations.

Table 1 shows that each of the projects carried out investigations for the accidents that happened. However, not all types of accidents were investigated, and coverage of the investigation was done for the internal use of organisations in improving the safety policy in the construction site. Conflict that occurs is often due to the differences in understanding of the types of accidents that should be investigated. Therefore, it can be concluded that there is a lack of knowledge on the basic guidelines and procedures to report and investigate the accidents. Lack of clear guidelines will result in differences in understanding and at the same time, failure in homogeneity of data. It will be an extremely difficult task to analyse and validate the statistical results of accidents in the construction industry in Malaysia.

**Table 1:** Comparison of the DOSH procedures with the procedure applied by each project

| No | Procedures in Reporting Accidents | JKKP | Project | | | | |
|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E |
| 1 | Accidents took place | √ | √ | √ | √ | √ | √ |
| 2 | Emergency action (if necessary) | √ | √ | √ | √ | √ | √ |
| 3 | Inform PKK or DOSH | √ | √ | √ | √ | √ | √ |
| | Duration of notification (as soon as possible | √ | √ | √ | √ | √ | √ |
| 4 | Preliminary investigation by PKK or DOSH | √ | √ | √ | √ | √ | √ |
| 5 | Notify the accident to DOSH | √ | x | ∞ | ∞ | ∞ | √ |
| | a) Duration of notification | 7 days | 7 days | 7 days | 24 hours | 7 days | 7 days |
| | b) Information provided | | | | | | |
| | i. What happened | √ | x | √ | √ | √ | √ |
| | ii. Location of the accident | √ | x | √ | √ | √ | √ |
| | iii. Parties involved | | | | | | |
| | iv. Time of the accident | √ | x | √ | √ | √ | √ |
| | happened | √ | x | √ | √ | √ | √ |

| No | Procedures in Reporting Accidents | JKKP | Project | | | | |
|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E |
| | c) Types of accident notified | | | | | | |
| | i. Death | √ | x | √ | √ | √ | √ |
| | ii. Major wound | √ | x | x | x | x | √ |
| | iii. Minor cuts | x | x | x | x | x | x |
| | iv. Incidents that could lead to occurrence of accidents | x | x | x | x | ∞ | ∞ |
| | v. Damage to property | x | x | x | x | x | x |
| 6 | Further investigation (if necessary) | √ | √ | √ | √ | √ | √ |
| | a) Types of investigation | | | | | | |
| | i. Death | √ | √ | √ | √ | √ | √ |
| | ii. Major wound | √ | √ | x | √ | √ | √ |
| | iii. Minor cuts | √ | √ | x | √ | x | √ |
| | iv. Incidents that could lead to occurrence of accidents | √ | ∞ | x | √ | √ | √ |
| | v. Damage to property | √ | ∞ | x | x | x | √ |
| | b) Investigation phases | | | | | | |
| | i. Phase 1 : Enclose the accident areas | √ | √ | √ | √ | √ | √ |
| | ii. Phase 2 : Collection of evidence | √ | √ | √ | √ | √ | √ |
| | iii. Phase 3 : Analysis of the factors contributing to accidents | √ | √ | √ | √ | √ | √ |
| | iv. Phase 4 : Investigation report | √ | √ | √ | √ | √ | √ |

## REASONS OF FAILURE IN REPORTING ACCIDENTS

There are several reasons that cause the failure in reporting the occurrence of an accident. Table 2 shows the causes of failure to report an accident at construction sites. Based on Table 2, the causes in failure to report an accident is due to inconvenience and troublesome, adverse effect on contractor's performance, lack of knowledge, fear of being acknowledged as wrongful, no feedback from DOSH, and shame in reporting.


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**Table 2:** Factors of failure in reporting accidents at construction site

| Nos | Factors | Very Low | Low | Intermediate | High | Very High | Total Project respondents | Rank | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | | |
| 1 | Inconvenience and troublesome | | | | 2 | 3 | 5 | 1 | 4.60 |
| 2 | Adverse effect on contractor's performance | | | 2 | 1 | 2 | 5 | 2 | 4.00 |
| 3 | Lack of knowledge | | 1 | 3 | | 1 | 5 | 3 | 3.20 |
| 4 | Fear of being acknowledged as wrongful | | 4 | 1 | | | 5 | 4 | 2.20 |
| 5 | No feedback from DOSH | 2 | 2 | 1 | | | 5 | 5 | 1.80 |
| 6 | Shame in reporting | 4 | 1 | | | | 5 | 6 | 1.20 |

**Inconvenience and Troublesome**

The highest factor for failure to report accidents at construction site is due to the complex procedure of reporting such as a tremendous preparation of paper work, different usage of specific forms, involvement of outsiders at the construction site, appointment of committees to investigate the accident, and other related tasks. It is a difficult task and could hinder the progress of the construction project. Despite the complicated procedures, the worst impact is the effect of closing down the construction site for investigation purposes. The effect of closing the site will eventually cause delays in construction projects. It is accompanied by summons, penalties, or fines imposed by the authorities for the failure in complying with safety compliance. This will result in significant losses for all parties, which include the contractors and the client as well.

**Adverse Effect on Contractor's Performance**

The second highest factor involves the taintment of the contractor's performance. This occurs when the accidents happen at site recorded by the authorities. It will indirectly affect the performance of the contractors. The performance in this context is defined as the difficulty in getting other construction projects in the

future due to the record of accidents owned by the contractor. It will affect the trustworthiness of others in appointing the contractor for any construction projects in the future.

**Lack of Knowledge**

This third highest factor involves the lack of knowledge. Lack of knowledge is referred to as the lack of awareness on the vital components of safety and health procedures and requirements to be followed at construction sites. Knowledge, experience and short courses on the safety and health management are needed in regulating the safety and health at construction sites. This is because safety involves the cooperation of all parties, including the workers themselves. Knowledge can also be obtained by undergoing training organised by the Construction Industry Development Board Malaysia (CIDB). Knowledge on the actual duties of each party is essential to avoid the obstacles in implementing their respective duties. It is important for the organisation to ensure that all stakeholders in a project are exposed with everything related to the practice. Thus, knowledge on safety and work experience plays an important role in decision-making in the near future.

## BEST PRACTICE AND FACTORS OF ENSURING THE COMPLIANCE OF SAFETY PROVISIONS

One of the necessary aspects in ensuring the compliance with safety provisions at construction sites is to ensure the safety, the cooperation by all parties, and the working experience of safety and health officers. Both board members and their senior managers must understand that their role includes both legal and moral obligations. The board and its directors are responsible for setting the broad strategic direction of the company as mentioned by Noorhayatie & Mohd Saidin (2019a).

They should be focussed on the macro situation, like managers looking at the team's performance from the side-lines. Senior managers are responsible for running the business on a day-to-day basis, and this includes the management of the safety and health brief. Managers need to focus on the micro picture, that is, the players on the field. Boards need to understand that their actions (or inactions) can affect workers' safety and health and that they must do all they can to prevent accidents and ill health. They must be aware that accidents at work can affect employees, members of the public, their families, shareholders, and the wider community in which they operate (Abdul-Rahman et al., 2012; Williams et al., 2019b).


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**Emergency Actions**

There are several safety measures that should be focussed on so that the compliance of safety and healthcare can be applied. Compliance of every action is important so that precautions can be taken before any accident in construction site happens. The safety measures can be divided into several sections as follows:

i. Safety information on the notice board
ii. Safety information during "toolbox meeting"
iii. Safety instructions and warnings on each sign board
iv. Application of safety plans at construction site
v. The role of health and safety committees at the construction site
vi. Coordination of safety activities
vii. Safety and induction training for all construction workers
viii. Safety actions such as fines, postponement of works, and not allowed to enter site

**Cooperation of Parties Involved**

Cooperation from all parties play an important role in ensuring the compliance of safety and health rules at construction sites. All parties should work together in ensuring that the safety and health rules at construction sites are applied by all parties (Buniya et al., 2021) and Mohd Ashraf et al., (2023). The parties who play an important role in safety and health at the construction site are:

i. Safety and health officer
ii. Project manager
iii. Client
iv. Contractor
v. Consultant
vi. Sub-contractors
vii. Suppliers

Shouldering the responsibilities of safety and health upon the officers only will eventually cause difficulties for them in monitoring the safety activities. It presents an additional workload and pressure to the officers. At the same time, it will interfere with the work specialisation on the small aspects which are not done and thus, causing a major impact at construction sites (CIDB, 2010). Therefore, all the parties involved play an important role in correcting, discussing, and proposing effective safety methods from their own point of views.

It not only helps in progressing towards the completion of the project, but also promotes benefits to each party involved (Malaysia, 1994).

**Working Experiences of Safety and Health Officer**

Although the safety and health officer is stationed at each site, the safety and health regulations at construction sites are not implemented well. Results showed that a construction site under the supervision of a construction site safety and health officer who has over 10 years' experience is able to comply with the provisions set as compared with other projects with safety and health officer with work experience of less than five years (Noorhayatie & Mohd Saidin, 2019b).

Safety and health officers appointed by the contractor would be in the contractor's side in any decision making whereby in actual work ethic, safety and health officers are supposed to be neutral and their main task is to ensure that the level of safety and health at construction sites was the best. Thus, an experienced safety and health officer plays a significant role in ensuring the compliance with safety at construction sites. This could prevent any external action due to work ethics and bias actions from happening (Williams et al., 2018; Noorhayatie & Mohd Saidin, 2019c).

## CONCLUSION

Failure in reporting all types of accidents at construction sites to DOSH has an impact on the accident statistics at construction sites. It will give a vague picture about the actual safety and health level in the industry. Thus, it will eventually hinder the improvement of health and safety in the industry in the near future. Therefore, compliance with safety reporting procedures is required for an accurate statistical result and it can avoid sacrificing more lives in the process of the construction industry's growth. Causes of failure to report the accident should be reviewed and appropriate action should be taken so that this problem will not be repeated. All parties should have safety awareness and cooperate so that safety culture can be nurtured in Malaysia construction industry.

Health and Safety Authority inspectors must check for compliance with these legal requirements and give advice and information on how to comply with the best practices on safety and health management to prevent accidents and ill health. However, these laws set the minimum standards. Many contractor firms now wish to exceed the minimum legal compliance when setting standards for themselves, so they compare themselves to the best companies that are out there. They wish to apply a professional and best-in-business philosophy to occupational safety and health management, as they do for all other aspects of


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their business. This is what makes such contractor firms industry leaders and successful at business.

They learn from others in their business class and use the lessons learned to continue to improve and ensure no harm to their employees. All businesses must do this to ensure they continue to be successful and have no accidents at construction sites. This guidance now sets out the general principles that should be used by employers to comply with the best practices in safety and health, with the objectives of having no accidents or ill health among employees.

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# MODULAR CONSTRUCTION SYSTEMS: A FOCUS ON DEVELOPING TECHNICAL EXPERTISE IN MALAYSIA

**Mohamad Zahierruden Ismail[1], Tantish Kamarudin[2], Nur Hajarul Falahi Abdul Halim[3]**

[1,2,3]*Faculty of Built Environment and Surveying,*
UNIVERSITI TEKNOLOGI MALAYSIA

## Abstract

The Government has clearly put focus on MCS as the future of construction through the Construction 4.0 Strategic Plan (2021-2025) and National Construction Policy 2030. However, the implementation of MCS in Malaysia is still low due to lack of technical expertise. This study aims to explore the challenges and strategies in achieving sufficient technical expertise to drive construction players in adopting MCS. Exploratory interviews were conducted with MCS experts to obtain multiple views in enhancing technical expertise to implement MCS in construction business. Respondents were obtained through snowball sampling techniques by approaching expert personnel in MCS. Findings were then analysed using thematic analysis, discovering four main challenges that impede adoption of MCS and four aspects of strategies identified to enhance technical expertise in MCS. The exploratory nature of this study provides the preliminary indicators for future actions to drive the adoption of MCS in developing countries.

***Keywords***: Modular Construction System (MCS), Qualitative Interview, Challenges, Strategies

[1] Lecturer at Universiti Teknologi Malaysia. Email: mohamadzahierruden@utm.my

## INTRODUCTION

Modular Construction System (MCS) has emerged as a promising innovation to tackle the long-standing challenges of tight schedules, high costs, poor quality, disjointed supply chains, and limited sustainability practices in the construction industry (Yuslim et al., 2023). The Construction Industry Council (Construction Industry Council, 2018) defines MCS as a comprehensive approach that involves constructing integrated modules in a controlled prefabrication facility. These modules are then transported to the construction site for integration into the building structure. MCS presents a high degree of off-site construction, with as much as 95% of a building's components fabricated in factories (Hwang et al., 2018).

MCS is recognized as a promising solution for providing affordable housing, offering cost-effective and time-efficient alternatives to traditional construction (Khan et al., 2022). It's reliability in maintaining quality due to controlled manufacturing environments positions it as suitable for fast-track projects, addressing the high demand for timely construction (Aziz et al., 2019). Additionally, the adoption of MCS is viewed as a catalyst for a paradigm shift in the Industrialised Building System (IBS) industry, potentially solving affordable housing issues (Sidik et al., 2021). Current literature highlights the dual nature of MCS in Malaysia, emphasizing its potential for addressing housing needs while acknowledging and addressing associated challenges. One of the most commonly cited constraints in the construction sector is the lack of technical knowledge (Mohammad et al., 2016).

Developed nations like the United States, the United Kingdom, and Sweden have made significant policy strides in implementing MCS (Ferdous et al., 2019). Several developing nations, including Malaysia and Singapore, have put in place government regulations and incentive programs to encourage private developers to embrace MCS, as pointed out by Wuni & Shen (2019).

The primary obstacle to MCS adoption is the lack of understanding of the MCS business model (Cheng et al., 2017). This lack of knowledge extends to insufficient skills in MCS project inspection and limited experience in designing and installing modular components (Luo et al., 2015). A crucial aspect of realising the potential of MCS in the construction industry is the development of technical ability.

The successful implementation of MCS depends on the development of technical expertise, which is currently lacking in many developing countries, including Malaysia. This study aims to generate preliminary information to enhance technical expertise in MCS in Malaysia. The objectives are to explore the challenges in developing technical expertise for MCS and to identify the strategies to enhance the adoption of MCS. This study focuses on the Malaysian construction industry while the outcomes can be relevant and applicable to other


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developing countries as well. A qualitative research approach was employed involving construction professionals in the field.

## METHODOLOGY

Semi-structured interview was used for this study. It uses a set of predetermined open-ended questions where order and wording of questions are flexible, allowing for follow-up questions and exploration of new ideas (Mashuri et al., 2022) to strike a balance between the flexibility of unstructured interviews and the focus of structured ones. In this study, MCS contractors in the Malaysian construction market were the subjects of interviews. The interview started in April 2023 and went on for 3 months until it reached 10 respondents. Due to the unavailability of a database on MCS experts or projects in Malaysia, snowball sampling was used to gather respondents. It started by selecting an initial individual that meets the relevant criteria which are designated construction professionals working in an MCS contractor organization and having more than 5 years' experience working in the industry. Respondents were then asked to provide referrals of anyone they know who fits the study criteria. This leads the interview to other respondents, creating a snowball effect as new participants are added to the sample (Mohamed et al., 2019).

As time was of the essence, contractors were selected as the research focus. All respondents had been assured of the confidentiality of their identity and responses. Duration of each interview is set to 30 minutes and researchers stopped collecting data as the result became saturated, where new information becomes redundant, signalling its endpoint. Table 1 provides an overview of respondents' profiles.

To record the analysis of the data, codes are allocated to words and phrases from the data collection. As a result, the topic may be quantified, making it simpler to interpret and summarise the interview data. This study uses inductive coding since predetermined codes could introduce biases.

## RESULTS AND ANALYSIS

### Challenges

Challenges in developing technical expertise are outlined in Table 1. The analysis revealed four distinct themes emerged: (1) Lack of Experience, (2) Lack of Information, (3) High Costs, and (4) Unfamiliar Design.

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**Table 1**: Challenges in developing technical expertise for MCS

| Theme | Challenges | Respondents | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | |
| Lack of experience | Unwillingness to learn | / | | | | / | | | / | / | / | 5 |
| | Uncommon method | / | | | | | | / | | | | 2 |
| | Afraid to take risk | | / | / | | | / | | | / | | 4 |
| Lack of knowledge and understanding | Narrow knowledge among parties | | | / | / | | / | | | / | | 3 |
| Cost | Costly BSI codes | | / | | | | | | | | | 1 |
| | High capital cost | / | | / | / | / | | | / | | / | 6 |
| Complex design | Multiple components and difficult shape | | | | | | | / | | / | | `2 |

As mentioned by Yusof et al. (2023), unwillingness to learn presents a significant challenge. This is attributed to a traditional mindset, lack of awareness, fear of the unknown, and perceived risks associated with this innovative construction method (Wuni et al., 2023). Majority of the respondents established that stakeholders hesitated to invest in training and change management processes required for modular construction. This reluctance had also resulted in missed opportunities for cost savings, increased construction timelines, and limited innovation in the construction sector. The findings significantly tie to the literature by Ismail et al. (2022) that stated MCS requires substantial initial cost in developing human capital before the industry can maximise its benefits.

Two respondents acknowledged that MCS being the uncommon method, significantly hampers the growth of expertise in the area. It then resulted in the lack of local skills, limited supplier base, and regulatory misalignment. The issue had been addressed by Aziz et al. (2022), adding that inexperience can result in cost overruns, project delays, and reduced competitiveness. Wuni et al. (2023) also illustrated the crucial need for experienced personnel as MCS demands such a high degree of accuracy and precision in the assembly of the modules. Respondents further highlighted that the uncommon state of MCS has led to risk aversion attitude among industry players as stakeholders only prefer methods they are familiar with, coinciding with Ambartsumyan et al. (2023).

R3 and R1 added that many stakeholders are not fully aware of the benefits of MCS. Malaysia has a long history of traditional construction methods, and many construction professionals and companies are only confident with traditional practices. The situation is exacerbated by the lack of formal education and training related to MCS, leading to a chain of impacts which are low adoption rate, inaccessible modular material and services as well as rising costs. The issue


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had been discussed eight years ago by Aziz & Abdullah (2015), addressing the significance of focusing on growth of knowledge in MCS. Current study by Yusof et al. (2023) indicated the situation still persists within the industry and stakeholders.

R2 mentioned the high cost of acquiring British Standards Institution (BSI) codes and standards. It is worth noting as the challenge had been discussed in detail relative to other types of construction (Gunasagaran et al., 2022). While some standards are made freely available to the public, many key standards, especially those relevant to specific industries, are proprietary and require purchase. This creates a barrier for smaller businesses, start-ups, or projects with limited budgets, hindering their ability to adhere to best practices in modular construction. The perceived technical incapability has led to some organisations opting not to purchase the standards to avoid non-compliance to the guidelines.

The high capital cost is a well-accepted challenge among respondents. R8 and R10 stated that due to the high initial cost, the MCS has then led to limited market penetration as smaller companies find it challenging to invest in MCS and therefore reducing competitiveness as MCS projects struggle to compete with traditional construction methods in terms of pricing. The findings are parallel with Arowoiya & Oyefusi (2023), which specified that MCS are often used for fast-track projects, therefore client has to put significant investment in starting the project and reap the reward later as the project saves time, cost of labour, overhead, and machineries rental and subcontracting.

R7 stated the complex architectural designs can be challenging to replicate in modular components. The unique designs require customisations that go against the principles of standardisation and repetition inherent in modular construction. It corresponds with the fact asserted by Wuni et al. (2023) that MCS heavily relies on the prefabrication and assembly of standardised building components in an off-site factory, the designs become complex or unconventional and thus pose several difficulties. MCS also has specialised structural requirements, such as heavy loads, seismic considerations, or building heights, which can make modular construction more challenging. R9 stressed on the complicated Mechanical, Electrical, and Plumbing (MEP) systems in MCS. The integration of MEP systems in MCS requires extra effort and customisation compared to conventional construction. R9 also emphasised on the site access constraints. MCS projects often involve tight or irregularly shaped sites which limit the flexibility of the modules to enter, hence, the high transportation cost.

Upon the study of data collected, three significant challenges had been identified: Stakeholders' unwillingness to learn, risk averse attitude, and high capital cost. The findings are positively correlated to multiple latest academic literature especially by Wuni et al. (2023) and Yusof et al. (2023). There are four other challenges that are equally important despite having fewer mentions among the interview respondents.

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**Strategies**

Strategies to develop technical expertise for MCS are outlined in Table 2. The analysis revealed three themes: (1) Education empowerment, (2) Experience enhancement, and (3) Government initiatives.

**Table 2**: Strategies to develop technical expertise for MCS

| Theme | Challenges | Respondents | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | |
| Education empowerment | Increase training/ course | / | | / | / | / | / | / | | / | / | 8 |
| | Upgrade education for next generation | | / | / | | | / | / | | / | | 5 |
| | Increase public awareness | | | / | / | / | | | / | / | | 5 |
| | Strengthen R&D | / | / | | | / | / | | | | / | 5 |
| | Sharing knowledge | | | / | / | / | | / | / | / | | 6 |
| Experience enhancement | Intensify on-site experience | | | / | / | / | / | / | | / | / | 7 |
| | Integrate Players from Different Companies | / | | | / | / | | | / | / | | 5 |
| Government initiatives | Develop Modular Guideline | / | | / | / | / | | | | | | 4 |
| | Provide incentives for Sustainable Practices | | / | / | | | / | | / | | / | 5 |
| | Elevate infrastructure | | | | / | | / | / | | | / | 4 |

Most respondents emphasised the importance of improving training and educational courses as an effective strategy to enhance the skills of various stakeholders in the construction industry. According to Undang et al. (2022), this includes design principles, manufacturing processes, and assembly techniques, to boost the confidence of industry players in practising MCS. Some respondents mentioned the value of providing hands-on experience and sharing knowledge about Building Codes and Regulations, as well as quality management in MCS. A few building regulations had been established to ensure validity building of design and construction, for instance are the Uniform Building By-Laws (UBBL), Street, Drainage, and Building Act 1974 (Act 133), National Building Code (NBC), Environmental Quality Act 1974, Town and Country Planning Act 1976 and Fire Services Act 1988 by the Fire and Rescue Department of Malaysia. Bello et al. (2023) have stated that the laws and regulations need to be in harmony with the MCS growth to ensure productive progress of the necessary expertise. Majority of the respondents agree that offering training and courses focused on MCS can significantly aid its expertise development which coincides with Teh & Zainal (2021).

In addition to training and courses, respondents recommended integrating MCS knowledge into academic curricula. This would expose students


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in universities, technical schools, and vocational institutions to MCS concepts, principles, and techniques. It relates to Liu et al. (2022) about the importance for future generations to understand sustainable practices and the application of modular construction to reduce waste and improve energy efficiency. Respondents also suggested launching mass media campaigns to address misconceptions about MCS quality, safety, and showcase its benefits such as speed, cost-efficiency, and sustainability. Successful MCS projects can be showcased to demonstrate its success as the future construction method. One respondent, R8, even suggested building such projects in prominent locations visible to the public to allow first-hand observation. The goal is to overcome the negative perception of MCS as costly, risky, and resistant to renovation, which hinders its skills growth as illustrated by Cynthia Hou et al. (2023). People need to recognise the global growth of modular systems in building construction and the advantages they offer to motivate investment in developing technical expertise (Loo & Wong, 2023).

Furthermore, five respondents highlighted the importance of contemporary research and development (R&D) in promoting MCS adoption. As per Ribeiro et al. (2022), construction demands vary by country, hence the need for researchers to innovate advanced building materials, digital modelling tools, and automation in modular construction processes. Respondents proposed various other recommendations related to R&D, such as standardising MCS practices, continuous improvement, prototyping, risk identification, case studies, industry-academic collaboration, and quality enhancement, all of which can be achieved through a strong focus on national R&D. The opinions coincide with Ambartsumyan et al. (2023) indicating that design must be adapted to suit MCS implementation.

After acquiring new knowledge, knowledge sharing becomes crucial for empowering individuals and industry players' expertise in adopting MCS. Respondents suggested organising seminars and workshops for industry professionals, including architects, engineers, contractors, and developers. They also emphasised information dissemination through webinars and online resources. Khan et al. (2022) asserted that knowledge sharing programs enable experts to share their insights and experiences with a wider audience. Respondents stressed the importance of gaining on-site MCS experience and involving multiple players from different organisations. The thought conjoins with Feldmann et al. (2022) with the fact that MCS projects are more complex than conventional ones, hence the importance of experience and technical abilities of project parties in making timely decisions. Contractors without experience and technical ability can make costly mistakes leading to project delays and errors.

Overall, respondents recommended on-site learning through demonstrations or pilot modular construction projects, where professionals can

witness the construction process in action. Cross-company training was also suggested as effective for learning best practices in MCS, as proposed by R1. Collaboration between contractors and the government in joint ventures or partnerships for specific modular construction projects was another viable approach. As suggested by Ta et al. (2019), the government could establish skills development centres to facilitate knowledge transfer, resource sharing, continuous improvement, and networking opportunities among industry players.

Government plays a pivotal role in formulating strategies, as it holds the power for policy-making and decision-making in the country (Bello et al., 2023). Four respondents suggested that the government should establish modular guidelines. These guidelines could standardise and ensure consistency in the best modular practices related to design, manufacturing, transportation, and on-site assembly. Such standardisation would enhance quality and safety in modular projects, as per Gunasagaran et al. (2022). The guidelines should align with local building codes and other regulations specific to modular construction, simplifying project approval and permitting processes. To further streamline MCS processes, respondents suggested that the government should provide financial or non-financial incentives to construction stakeholders developing skills and practice of MCS. According to Teh & Zainal (2021), financial incentives may include tax deductions, grants, subsidies, rebates, and low-interest loans, while non-financial incentives could involve expediting project permit, recognition, awards, technical assistance, regulatory streamlining, facilitating networks and collaborations, and supporting R&D. Four respondents also recommended developing infrastructure as a strategic action for developing technical expertise for MCS in Malaysia. This would involve investing in and expanding the infrastructure that supports MCS, such as advancing manufacturing facilities, expanding factories, integrating technology, improving transportation networks, establishing logistics hubs, developing training centers, and providing temporary storage. In line with Ismail et al. (2022), infrastructure development is crucial for paving the way for widespread MCS knowledge and application, leading to more efficient, sustainable, and cost-effective construction practices.

**Proposed Framework**

A framework has been developed to provide a visual representation (Bolhassan et al., 2022) of the seven challenges associated with developing technical expertise in the adoption of Modular Construction Systems (MCS) in Malaysia, along with the ten strategies aimed at promoting the technical expertise related to MCS adoption in the country. It had been observed that the challenges and strategies are specifically directed towards the Government roles. The proposed framework is illustrated in Figure 1.


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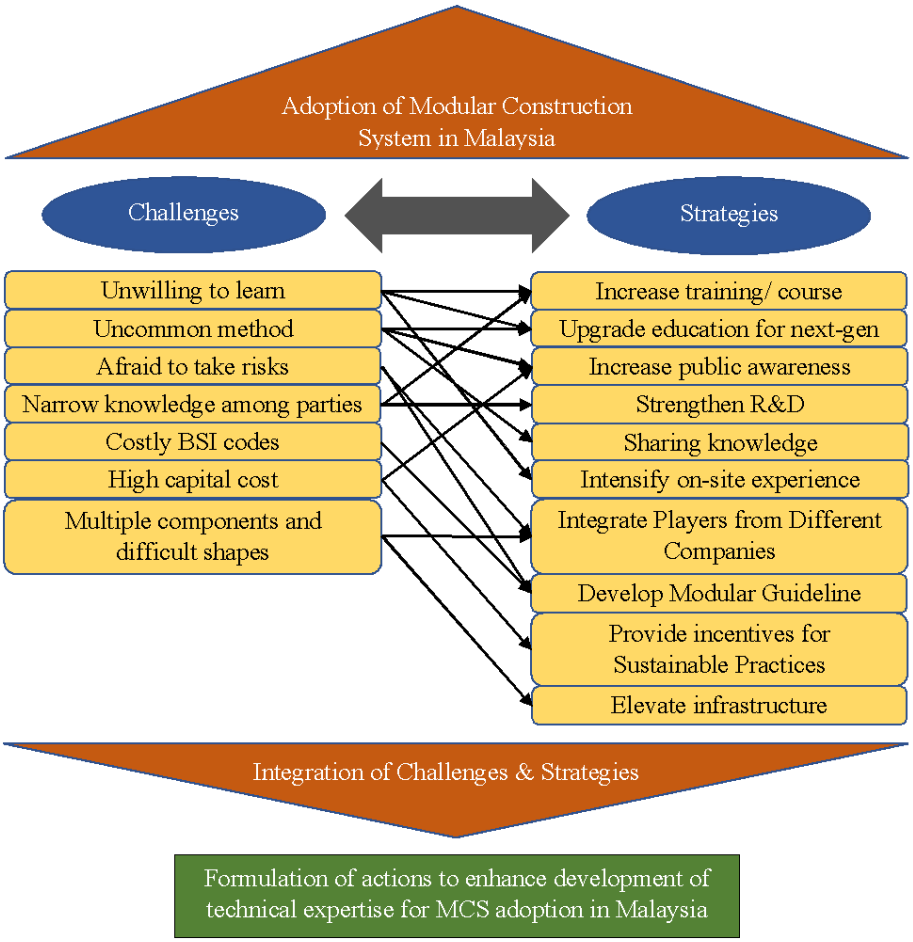


**Figure 1**: Preliminary framework to enhance the development of technical expertise for MCS

The primary goal of this framework is to facilitate a clear and organised understanding of the challenges and strategies in developing technical expertise of MCS adoption within the Malaysian context. The framework aims to assist four key stakeholders in taking effective actions to address the identified challenges and implement the suggested strategies. The challenges encompass various aspects while the strategies outlined are tailored to address these challenges. Recognizing the multifaceted nature of these challenges, the framework outlines how the government, through its regulatory and policy-making capacities, can actively contribute to addressing obstacles and promoting the integration of MCS. By delineating the roles of the government, the framework serves as a comprehensive guide, aligning strategies with governance

mechanisms to optimize the development of technical expertise within the construction sector.

## CONCLUSION

The research has identified significant challenges in developing technical expertise for MCS: experience, knowledge and understanding, cost, and design. Among these, the study revealed that the most prominent challenge is the high capital cost, followed by reluctance to embrace MCS due to perceived investment and risk concerns.

The study also explored strategies to enhance MCS technical expertise in Malaysia. Respondents expressed that conducting training and courses is the most significant strategy, followed by the promotion of on-site experience among industry players, and knowledge sharing to raise awareness. Given the nascent stage of MCS in Malaysia, these strategies require collaboration from all stakeholders in the construction industry, with a particular emphasis on government involvement.

The data gathered were then developed into a preliminary framework that visually consolidates the findings and identifies that the Government holds the major responsibility in this effort. The framework seeks to pave the way for future researchers to navigate their studies more efficiently and achieve more impactful outcomes in the realm of MCS adoption in Malaysia. Despite taking views from contractors only, all parties may reap the benefit of the framework as it indicates the actions of all parties. Further research is encouraged on enhancing the findings by adding the data collection and analysis of views from multiple parties relevant to the development of MCS technical expertise.

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## DISCLOSURE STATEMENT / ETHICAL STATEMENT

Following international publication policy and our ethical obligation as a researcher, we report that we have no conflict of interest.

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# INTEGRATION OF CIRCULAR ECONOMY INTO DESIGN AND CONSTRUCTION OF INFRASTRUCTURE PROJECTS IN MALAYSIA: BARRIERS AND COUNTERMEASURES

**Nor Helmie Shahreen Mohd Ali[1], Yong Siang Lee[2], Ahmad Rizal Alias[3], Rahimi A. Rahman[4]**

[1,2,3,4]*Faculty of Civil Engineering Technology,*
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH
[4]*Faculty of Graduate Studies,*
DAFFODIL INTERNATIONAL UNIVERSITY

## Abstract

Despite the high demands of infrastructures, circular economy (CE) is among the best solution that seeks holistic sustainability goals through a zero-waste culture and to boost economic growth by investing in eco-innovations, secondary raw materials, recycling processes, and industrial symbiosis. Therefore, this study aims to identify the barriers and countermeasures for integrating the CE concept into design and construction of infrastructure projects in Malaysia. For data collection, an open-ended interview has been carried out with twenty-three (23) respondents of clients, contractors, and consultants. Then, the thematic analysis was performed to analyse the data. The findings suggested that the main barriers of CE integration are consisted of internal and external factors; technical, organisational, economic, political, social and environmental aspects. Then, the countermeasures of CE integration are categorized into the hard and soft strategies; raising the awareness of CE, encouraging stakeholder's collaboration and creating financial incentives, and investment opportunities. As a result, the outcome of the findings can serve as a guideline for stakeholders to integrate CE concept into design and construction of infrastructure projects in order to achieve sustainability development goals (SDG). Through the outcome of this study, stakeholders will have a new approach and new paradigm, which will be useful for future decision-making on the infrastructure with the CE concept.

***Keywords***: Circular Economy, Design, Construction, Infrastructure, Barriers, Countermeasures

[2] Corresponding Author Email: leeys@umpsa.edu.my

## INTRODUCTION

Malaysia experienced rapid urban population growth in the last nine decades, particularly during the 1980s and 1990s. The ethnic urban composition is particularly interesting, with over 50% of the population being Malay. The rapid socio-economic development has led to issues such as housing, health, education, and sanitation facilities. (Yaakob et al,.2010).

The high rates of urban growth, natural increase, migration into urban areas, and to some extent reclassifications of the urban areas have significantly contributed to urbanization in the country. In Malaysia, urbanization history ranges from the Straits settlement of Penang, Malacca, and Singapore and the mining towns of Ipoh and Kuala Lumpur. Infrastructure development plays a crucial role in economic growth, with affluent countries having better infrastructure, promoting agriculture, trade, industry, and commerce. In contrast, poor infrastructure hinders urbanization and socioeconomic development (Ng et al,. 2019). Malaysia experienced a fast pace of urbanization between 1990 and 2000, driven by rapid economic growth and transformation.

DOSM (2022) recorded that Malaysia's urbanization rate rose to 75.1 percent (24.4 million) in 2020, up from 70.9 percent (19.5 million) in 2010. Urbanization generated new economic activities and created more employment opportunities, as well as providing greater access to modern social facilities. In a linear economy, resources are extracted, goods are produced, and rubbish is discarded as waste. Malaysia, a country with a linear economy model, is now promoting circular economy principles and practices in various sectors, including manufacturing, waste management, and sustainable development.

The Malaysian government launched the National Policy on Industry 4.0 in 2019, emphasizing sustainable growth through advanced technologies and practices. A circular economy (CE) seeks to reduce waste, increase resource efficiency, and encourage ongoing material usage as opposed to the "take-make-dispose" approach, which creates waste. Utilising a closed-loop system, the "reduce-reuse-recycle" paradigm allows resources to circulate and be recycled. In conclusion, a circular economy emphasises reuse and recycling to minimise waste and maximise resources, whereas a linear economy takes a "throwaway" attitude.

CE is crucial due to the rapid growth in raw material demand and finite supplies. Malaysia, a fast-growing and developing country, faces pollution and sustainability issues due to its rapid industrial development. To transition towards CE, better product and packaging designs, collection, sorting systems, and recycling infrastructure are needed to reduce virgin material use and promote a circular waste path.


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## LITERATURE REVIEW

### Overview of Infrastructure Projects

Infrastructure refers to the fundamental physical systems and structures that are crucial for the smooth functioning of a society or organization. These infrastructures comprise both public and private entities such as (1) transportation including of roads, railways, bridges, tunnels; (2) water supply and sewers including its system and treatment plant; (3) energy such power plant, electrical grids and renewable energy sources; (4) telecommunications for network communication, internet connectivity as well as broadband access, and (5) public facilities including of public buildings, schools, hospitals and any other essential facilities. Additionally, infrastructure encompasses services and facilities that cater to the needs of the economy, households, and businesses. It plays a vital role in promoting economic growth, preserving the environment, and ensuring social well-being.

Sustainable infrastructure is designed with the objective of minimizing its adverse effects on the environment, by lowering greenhouse gas emissions, conserving natural resources, and adopting sustainable construction and operation practices. Sustainable infrastructure initiatives are advantageous to nearby communities in numerous ways. They help to preserve natural resources, reduce the negative effects of climate change, provide better access to financial resources, enhance labour and community relations, and offer long-term benefits to present and future generations. Additionally, they improve water quality and quantity, as well as urban livability through the creation of green spaces and urban forests. Moreover, these projects enhance social cohesion and contribute to economic development.

### Circular Economy in Infrastructure Projects

The promotion of sustainable infrastructure projects is being emphasized by ASEAN and Asia, backed by the ASEAN Connectivity Master Plan and the Asian Development Bank. These endeavors are geared towards fostering economic growth, preserving the environment, and promoting social welfare, necessitating extensive planning and cooperation. The nations that make up the ASEAN bloc are actively working together to advance sustainable infrastructure development through a number of key initiatives, such as Infrastructure Asia, MPAC 2025, ASEAN-ADB cooperation, and Public-Private Partnerships (PPPs). These collaborations are designed to improve connectivity, streamline project preparation, and boost infrastructure productivity, all while tapping into the private sector's expertise to speed up project implementation and meet sustainability targets (Taiwo et. al., 2021).

The construction sector in Asia is adopting circular economy approaches in order to minimize its global impact and preserve natural resources.

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The adoption of circular economy practices is on the rise in the construction industry across Asia, as evidenced by instances such as waste recycling in India (Mistri et al.,2020; Jain et al,.2020; Parida et al,.2023), and circular models of construction in Asia. These practices are geared towards reducing global impacts and conserving natural resources. In Japan, the construction sector is taking steps to develop circular economy practices, identifying any obstacles and providing guidance for advancement (Beng & Matsumoto, 2012; Lacroix & Pioch, 2011; Liu et al., 2019). Kazakhstan's construction sector is also making strides in this direction, pinpointing opportunities and challenges (Tokbolat et al., 2020; Torgautov et al., 2021; Turkyilmaz et al., 2019). Taiwan's circular building design places emphasis on disassembly, material reuse, and recycling (Huang & Hsu, 2003; Ping Tserng et al., 2021; Yu et al., 2018). (Chutipat et al., 2023; Edyvean et al., 2023) explained that Thailand's Bio-Circular-Green Economy (BCG) model is a sustainable future model that incorporates circular economy principles. Malaysia is enhancing its infrastructure with projects like the MRT system in Kuala Lumpur, while also developing its technology and innovation sectors to fuel economic growth. On the whole, circular economy practices are gaining traction in the Asian construction industry with the objective of reducing global impacts and conserving natural resources.

**Circular Economy in Malaysian Infrastructure Projects**

The growing urbanization process in Malaysia requires proper infrastructure provision. Local governments have traditionally been responsible for building local infrastructure, but this approach has increased the financial load on the local government. To support the new growth centers and rapid population growth, further infrastructure development is necessary. The local government must find measures to motivate the private sector, particularly the private developers involved in significant development projects, to do so (Bina et al,.2008).

Malaysia has successfully carried out a number of sustainable infrastructure projects aimed at promoting sustainable development and reducing environmental impact. One of these projects is the Green Energy and Sustainable Water Infrastructure project, which is focused on developing sustainable water infrastructure and renewable energy sources. In addition to this, Malaysia has also implemented sustainable transport infrastructure projects such as the Mass Rapid Transit and Light Rail Transit, which have been instrumental in reducing traffic congestion and promoting sustainable urban mobility. Another notable initiative is the Green Building Index (GBI) certification system which has been effective in promoting sustainable building practices and renewable energy sources. Moreover, Malaysia has also implemented waste management infrastructure projects such as waste-to-energy facilities and sanitary landfills, which have contributed to reducing waste and promoting sustainable practices. Overall, these


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projects are a testament to Malaysia's unwavering dedication to sustainable development and reducing its environmental impact.

A rising number of market participants recognize that limited resources are mostly a result of resource scarcity, which has generated major environmental concerns such as pollution, floods, smog, and so on. (Górecki et al., 2019). The Circular Economy (CE) is a concept in industrial and social evolution that seeks holistic sustainability goals through a zero-waste culture. It is based on concepts like "Waste Products," "Industrial Ecology," "Cradle to Cradle," "Performance Economy," and "Biomimicry." It entails restoring products and materials at the end-of-life stage, changing to renewable energy, eliminating harmful chemicals and waste, and maximizing competitive advantage through the superior design of materials, products, systems, and business models (De los Rios & Charnley, 2017).

Circular economy (CE) addresses climate change, biodiversity loss, waste, and pollution, benefiting businesses, the environment, and mankind. It is based on three principles: eliminating waste, circulating products and materials, and regenerating nature. CE has two main cycles: technical cycle, where products are reused, repair, remanufacture, and recycling, and biological cycle, where nutrients from biodegradable materials are returned to Earth through composting or anaerobic digestion (Salleh et. al., 2022). Figure 1 shows the difference between linear economy and circular economy.


**Figure 1:** Linear Economy versus Circular Economy
*Source: Garcés-Ayerbe et al., (2019); Adams et al., (2017)*

The Twelfth Malaysia Plan, announced by Prime Minister on 27 September 2021, outlines a five-year plan for waste management and transitioning to the CE. It includes developing policies, legislation, and economic instruments, reviewing eco-design requirements, introducing a new regulation on household e-waste, creating a comprehensive waste database, constructing integrated waste management facilities, reviewing existing legislation, promoting single-use products, and constructing integrated scheduled waste treatment and disposal facilities.

### Knowledge Gap and Study Positioning

The majority (75%) of those involved in Malaysia's construction business are not familiar with the concept of Circular Economy (CE), according to survey results, and 90% of respondents said they are not prepared to implement such practices in the next five years (Siew, 2019). The CE can help create jobs and economic growth by investing in eco-innovations, secondary raw materials, recycling processes, and industrial symbiosis. Design for a circular economy aims to maintain product integrity and close loops while building economically viable product-service systems. Despite all the literature gathered related to circular economy in ASIA and especially Malaysia infrastructure, there are a few research questions arise: (1) what are the barriers of integrating circular economy into design and construction of infrastructure projects in Malaysia, and (2) what are the countermeasures of integrating circular economy into design and construction of infrastructure projects in Malaysia.

Therefore, the objective of this study will fill the gaps by (1) identifying the barriers of integrating circular economy into design and construction of infrastructure projects in Malaysia and, (2) identifying the countermeasures of integrating circular economy into design and construction of infrastructure projects in Malaysia.

## RESEARCH METHODOLOGY

The data collection process entails gathering qualitative information from interviews with stakeholders ranging from the client or project owner, consultants and contractors. Thematic analysis is used to analyse the qualitative data collected.

### Data Collection: Semi-Structure Interview

This study collects data on identifying the barriers and countermeasures for the integration of CE into design and construction of infrastructure projects in Malaysia from open-ended interviews via various methods including online survey (Google Docs), face to face and phone interview. Opara et al. (2021) found that Google Docs provides unique online, written interviews for qualitative


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research, addressing time, budgetary, and geographical limitations in case studies. Online surveys provide control, flexibility, and accessibility for research participation (Braun et al,. 2021). As a result, stakeholders are purposely interviewed utilizing these methods in order to gain their unique viewpoints, practical knowledge, and experiences on the subject. The data was utilized for analysis and treated as anonymous.

A purposive sample technique was used, allowing researchers to select individuals who may give useful comments and information for data gathering. (Campbell et al., 2020) agreed that purposive sampling able to aims to match samples to research objectives, improving rigor, study rigor, and data trustworthiness.

This study's target respondents are mostly consisted of the stakeholders who are directly involved in the design and construction phases of the industry, particularly in infrastructure projects. These respondents are the industry stakeholders varying from the client/project owner, consultants and contractors. Figure 2 shows that most of the respondents have experience in infrastructure projects ranging from transportation, water, energy, waste, amenities and landscape.

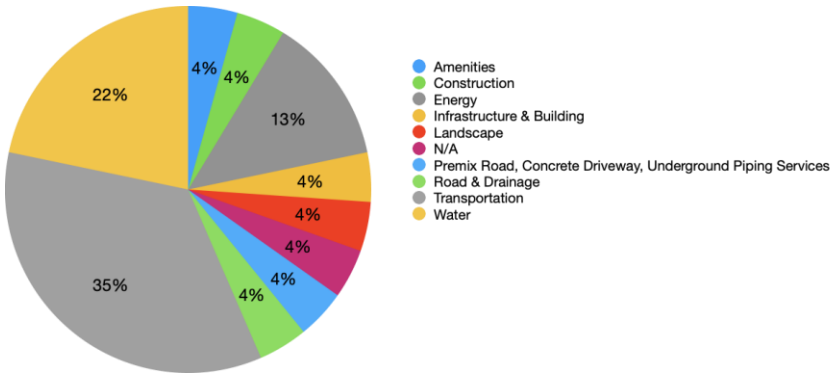


**Figure 2:** Type of Infrastructure Projects Involved by Respondents

The interview method collects statistically useful information about groups, requiring proper construction, ordering, scaling (Satya & Roopa, 2017). Through a systematic literature review, the design of the questionnaire must be carefully considered in order to collect usable and relevant information. The individual survey with interviews questions begins with an introduction to the topic, respondent demographic and an open-ended question questionnaire. In addition to that, question, the participants are given few introduction surveys such as their awareness on Circular Economy, current role or designation in the industry, working experience, education level and type of infrastructure that has

been involved. Then, additional open-ended questions depending on their responses. Satya & Roopa, (2017) suggested that questionnaires should always have a specific purpose that is relevant to the study objectives, and it should be clear from the beginning how the data will be used. This study's data collection involves interviewing twenty-three (23) respondents as portrayed in table 1.

**Table 1:** Respondents' Demographic

| No of Respondent | Stakeholder | Current Position | Years of Industrial Experience |
|---|---|---|---|
| R1 | Client/Project Owner | Executive | 11-15 |
| R2 | Client/Project Owner | Project Manager | >16 |
| R3 | Client/Project Owner | Innovation Lead | 11-15 |
| R4 | Client/Project Owner | Project Manager | 6-10 |
| R5 | Contractor | Project Manager | 11-15 |
| R6 | Consultant | Engineer | 11-15 |
| R7 | Consultant | Architect | 11-15 |
| R8 | Consultant | Engineer | 6-10 |
| R9 | Client/Project Owner | Lead, Liaison | >16 |
| R10 | Consultant | Engineer | 6-10 |
| R11 | Consultant | Town planner | 6-10 |
| R12 | Client/Project Owner | Project Manager | >16 |
| R13 | Consultant | Engineer | 6-10 |
| R14 | Contractor | Project Manager | 6-10 |
| R15 | Client/Project Owner | Engineer | 11-15 |
| R16 | Client/Project Owner | Project Manager | >16 |
| R17 | Contractor | Project Manager | >16 |
| R18 | Contractor | Project Manager | 11-15 |
| R19 | Consultant | Project Manager | 6-10 |
| R20 | Client/Project Owner | Project Manager | >16 |
| R21 | Client/Project Owner | Project Manager | >16 |
| R22 | Consultant | Quantity Surveyor | 11-15 |
| R23 | Consultant | Engineer | >16 |

## Data Analysis: Thematic Analysis

Thematic analysis is used to find patterns in interview data during data analysis. (Lester et al., 2020) agreed that thematic analysis is a flexible and user-friendly tool for qualitative analysis that helps researchers analyse data, uncover trends, and improve analytical abilities and confidence when performing qualitative research.

Figure 3 shows all the research techniques using thematic analysis to analyse the data collected from interview in this study. Thematic analysis detects patterns in qualitative data by going over it numerous times, categorizing it into themes, and interpreting it in the context of the research topic. (Nowell, Norris, White, & Moules, 2017) outlined the six-phased approach for undertaking theme analysis, which is an iterative and reflective process that evolves over time and


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requires a continual back and forth between stages. First phase is to get familiarize with the data. This required reading and re-reading data to identify early trends and insights. The second phase is generating initial code. This stage will use codes to identify and label data in order to communicate meaning. The third phase is searching for themes which to collect and evaluate codes for themes in order to correctly represent data. In the fourth phase it will involves comparing the themes to the facts to verify they are consistent and relevant which is themes reviewing. While in fifth phase, the process requires the defining and naming the themes and the final phase is producing the report. This entails writing up the analysis, incorporating data quotations and examples to support the themes and findings.

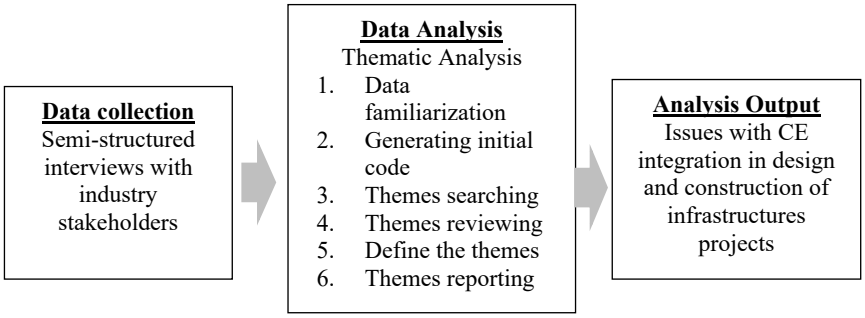


**Figure 3:** Thematic Analysis Process

## RESULT AND DISCUSSION

This study presents the findings of twenty-three (23) questionnaire interviews with clients/project owners, consultants, and contractors. The respondents are required to respond by identifying barriers and countermeasures for integrating CE into the design and construction of infrastructure projects in Malaysia. Based on the results, the findings suggested that the main barriers of CE integration are consisted of internal and external factors; technical, organisational, economic, political, social and environmental aspects. Then, the countermeasures of CE integration are categorized into the hard and soft strategies; raising the awareness of CE, encouraging stakeholder's collaboration and creating financial incentives, and investment opportunities. The details of themes and subthemes are discussed in the subsequent subsections.

### Barriers for Integration of Circular Economy into Infrastructure Projects

Adoption of sustainable practices in infrastructure projects might be hampered by social, technical, environmental, economical and political reasons. Lack of

information, technical fragmentation, and reluctance to change are also social problems. Technical problems include the fragmentation of the Malaysian building business, a lack of experience, and a paucity of resources. Higher upfront expenses and expenditures are examples of economic issues, whereas regulatory and legislative hurdles are examples of political factors. Financial incentives, high initial costs, and market demand are all economic and political barriers that impede sustainable design (Charef et al., 2021). Collaboration and coordination among stakeholders are critical for implementation success. Figure 4 summarizes the themes and subthemes of problems the barriers.

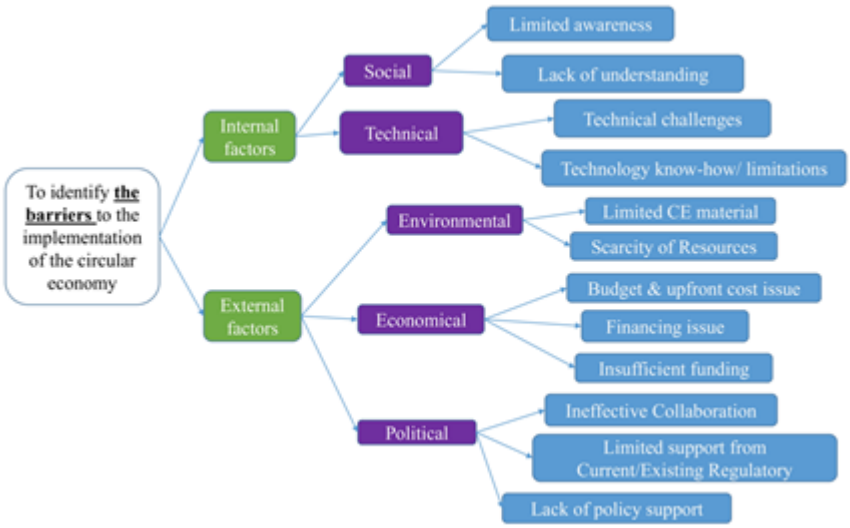


**Figure 4:** Internal and External Factors of Barriers for Integration of CE into Infrastructure Projects

## Internal Factors

*Social factors*. The adoption of sustainable practices in infrastructure projects might be hampered by a lack of knowledge and comprehension of circular economy concepts among stakeholders such as designers, contractors, and government agencies. Construction professionals may be unfamiliar with these notions or are unaware of their potential advantages, which can lead to resistance to change and a reluctance to invest in new technology and procedures.

*Technical factors.* The Malaysian construction sector is fragmented, with many small businesses lacking the experience to embrace sustainable practices. This may impede the implementation of sustainable practices due to a lack of collaboration and knowledge-sharing among stakeholders. Resistance to change may also impede the adoption of sustainable practices in infrastructure


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projects, since certain stakeholders may be resistant to new ideas or approaches, making it difficult to incorporate circular economy concepts into project design and construction.

**External Factors**

*Environmental factors.* The scarcity of resources such as recycled materials and renewable energy technology might make it difficult to integrate circular economy ideas in infrastructure projects. The scarcity of sustainable materials in Malaysia makes it difficult for developers and contractors to implement these principles into their projects. This is especially true in rural or distant places, where supply chains may be constrained, making circular economy ideas difficult to incorporate into infrastructure design and development.

*Economical factors.* Sustainable elements in infrastructure projects have the potential to raise building costs, affecting developers and contractors. Sustainable practices, on the other hand, can provide long-term advantages and savings. Implementing circular economy concepts may need greater investment or higher upfront expenditures, which may be prohibitively expensive for smaller construction enterprises or those with restricted budgets. Furthermore, the use of sustainable materials and technologies may be more expensive than traditional materials and technologies, making it challenging for designers and contractors working on limited budgets to embrace these practices.

*Political factors.* Adoption of sustainable practices in infrastructure projects might be hampered by regulatory and legislative obstacles. These hurdles might include favoring virgin resources over recycled materials, causing uncertainty, and restricting the use of specific sustainable materials or technologies. Governments play an important role in encouraging sustainable practices, but a lack of supportive legislation, rules, and guidelines may hinder their adoption. Furthermore, a lack of collaboration and coordination among parties such as designers, contractors, and government agencies might stymie the implementation of circular economy concepts in infrastructure projects.

**Countermeasures for Integration of Circular Economy into Infrastructure Projects**

The link between barriers and countermeasures entails ideas or actions to overcome possible barriers to incorporating circular economy concepts into civil infrastructure systems. These countermeasures are intended to assist effective integration and address the unique barriers that exist. Their efficiency is determined by their capacity to successfully handle the unique barriers that exist. The circular economy promotes sustainable infrastructure projects through policies, regulations, and lifecycle assessment. Figure 5 summarizes the themes and subthemes of problems the countermeasures.

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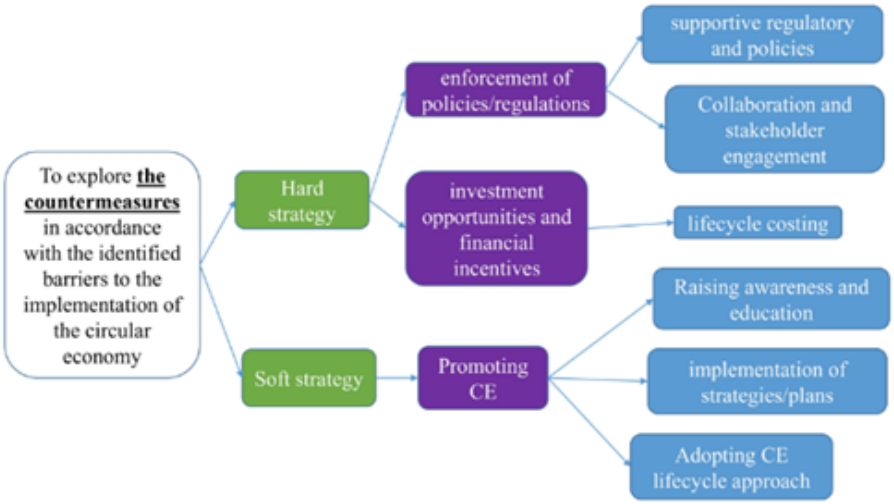


**Figure 5:** Hard and Soft Strategies of Countermeasures for Integration of CE into Infrastructure Projects

## Hard Strategies

*Enforcement of policies/regulations.* Policies and regulations are critical for supporting the ideas of the circular economy in infrastructure projects. Setting resource efficiency objectives, developing sustainable material selection criteria, and offering financial incentives are examples of these. Green infrastructure, such as green roofs, rain gardens, and bioswales, may imitate natural systems while encouraging resource reuse. Collaboration and stakeholder involvement with suppliers, contractors, and local communities may raise knowledge of sustainable design and construction practices, helping to develop a more circular economy approach.

*Investment opportunities and financial incentives.* A lifetime approach to infrastructure projects takes into account the whole lifespan of the project, from design to building, operation, and decommissioning. This method encourages circularity and reduces waste. Prioritizing environmentally friendly and sustainable items in procurement procedures is critical for encouraging sustainable materials and practices in infrastructure projects. Circular procurement practices priorities the use of sustainable and circular materials and goods, such as purchasing resources from suppliers who practice circular economy or reusing or recycling materials.


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### Soft Strategies

*Promoting CE.* Considering disassembly and recyclability when designing infrastructure projects means that materials and components may be easily separated and reused at the end of their lives. This method encourages the reuse and recycling of materials, components, and systems. A lifecycle approach to infrastructure projects takes into account the full lifecycle, from design to building, operation, and decommissioning. This method aids in the identification of waste reduction opportunities and promotes circularity. A lifecycle evaluation of infrastructure projects can help discover opportunities for resource efficiency and circularity, as well as evaluate the environmental impact of materials and design choices and the potential for reuse and recycling at the end of the project's lifespan.

## STUDY IMPLICATION

This study's contribution will aid policymakers, other researchers, and industry practitioners in making decisions and improving existing standards.

### Theoretical Implication

This study outlines challenges to incorporating CE in Malaysian infrastructure projects, as well as solutions and methodological issues. Few studies have used qualitative methodologies, and the majority have focused on building and building-related projects. Stakeholder preferences for incorporating CE into design and construction remain pessimistic. From an academic perspective, the thematic analysis presented in this study demonstrates barriers and countermeasures from the views of industry stakeholders, as well as information transfer or awareness challenges.

This study also examines the circular economy from stakeholders' perspectives, obtaining feedback and ideas. Results can be used to develop potential solutions for incorporating CE in Malaysian infrastructure projects design and construction. Furthermore, this study contributes to the investigation of areas that can broaden and enhance stakeholders' knowledge and awareness in order to conduct new strategies and paradigms for future discussion and decision-making on infrastructure design and construction utilizing the CE concept.

### Practical Implication

From a practical perspective, this study's findings will benefit the construction industry. Stakeholders or industry practitioners might utilize the results to make early decisions on infrastructure development throughout the initiation and planning stages. Understanding CE ideas may help enhance infrastructure design while reducing environmental effect, maximising economic viability, and promoting social equality. This raises knowledge among senior management in

built-environment organisations, including developers, resulting in proactive decision-making and enhanced understanding of health, well-being, and productivity challenges.

**Limitation and Future Directions**

This study has identified barrier and countermeasures on the integration of CE in design and construction of infrastructure projects in Malaysia. The current study investigated and focuses more on identifying barriers and countermeasures only. Secondly, the inability of respondents from private companies to share elaborated internal data and the limited number of available stakeholders to conduct a questionnaire survey. Thirdly, majority of respondents were in middle management positions, which do not have full authority in decision-making stage. However, some of them do have the knowledge and awareness on CE and sustainability.

This study's limitations did not impact the quality of its findings, as the objectives were met. The findings can be applied in project initiation and planning stages for implementation. Despite a limited sample size of twenty-three respondents, the information was analysed with existing literature and saturation determined. More information from developers, consultants, contractors, and government representatives is required for future research and analysis, allowing for the actual application of findings in managerial contexts. Quantitative methods can also be used to evaluate the collected variables.

## CONCLUSION

As a result, all the aims of study are achieved. Based on the findings from the interview, the results show that barriers to integrating the CE into design and construction of infrastructure in Malaysia are due to social, technical, environmental, economic, and political issues. Lack of awareness and comprehension of circular economy (CE) concepts, as well as technical problems and resource scarcity, can all hinder the application of these practices. Economic considerations such as greater upfront costs and limited budgets may also impede the adoption of CE concepts. While for the countermeasures to integrate the CE concept are including of enforcement of policies or regulations, more investment opportunities and financial incentives and promoting of CE in infrastructure projects. A lifecycle approach to infrastructure projects can discover waste reduction opportunities and encourage circularity. As a result, this study will serve as a guideline for stakeholders to include the CE idea in the design and construction of infrastructure projects in order to fulfil the SDGs. The findings of this study will provide stakeholders with a new strategy and paradigm for future discussion and decision-making on infrastructure design and construction using the CE idea. To integrate circular economy principles into Malaysia's


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construction industry particularly for infrastructure works, stakeholders must work together to promote awareness, provide training, develop policies, and invest in waste management infrastructure.

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# MANAGERIAL COMPETENCIES AS A BAROMETER FROM CONSTRUCTION PROJECT MANAGERS'S PERSPECTIVE

**Nurhayatul Khursniah Hasim[1], Hafez Salleh[2]**

[1,2,] *Faculty of Built Environment, University of Malaya, Centre for Building, Construction, and Tropical Architecture (BuCTA),*
UNIVERSITI MALAYA

## Abstract

The Construction Industry faces a significant gap in the managerial competencies of Construction Project Managers (CPM) towards project performance. The identification of a competent project manager is essential as it contributes towards economic growth and the achievement of the current Sustainable Development Goals (SDGs). This research aims to determine the core managerial competencies from the CPM's perspective. Specifically, to achieve the aim of this research it comes with two (2) objectives, which are to identify the managerial competencies and to determine the core competencies required by CPM. The research method adopted was a quantitative approach via structured questionnaire survey. Based on research findings, it establishes the core managerial competencies which are knowledge, skills, and attitude as a crucial barometer for CPM led to a positive impact on the help of Machine Learning (ML) toward project performance. The contribution of this research is imperative and can serve as reference benchmarking for CPM.

***Keywords***: Managerial Competencies, Construction Project Managers (CPM), Machine Learning (ML), Competencies Benchmarking, Project Success.

[2] Associate Professor at Universiti Malaya. Email: hafez@um.edu.my

# INTRODUCTION

In the Construction Industry nowadays, managerial competencies are indeed synonymous with project performance (S, 2023) which becoming the focus is to lead to higher efficiency and more effective performance towards SDGs 9 adopted by The United Nations (UN) in 2015 agenda. The effective culture of the current CPM's managerial competencies scenario is significantly reflected in the UN, SDGs. Sustainable development is all the rage and Malaysian Construction too has been quick to jump on the bandwagon, especially with regards to their effective culture (Ineza, 2022) and efficient technology initiatives. To evaluate the project success which of business in any organization depends on its organizational culture (Osodlo, 2021). In this research, a pilot study has been conducted to determine whether managerial competencies as a critical barometer for Project Managers in the Construction Industry are indeed feasible. Absolutely, integrating managerial competencies with an understanding of the specifics of culture can greatly enhance communication effectiveness, foster technology innovation, and ensure compliance with the Construction Industry Competency Standard (CICS). The key factor is to identify the critical core competency governed by the CIDB, particularly in the CICS, which is best suited for the needs of the industry. In addition, managerial competencies concerned in the construction industry will need more robust competency (Osodlo, 2021) as opposed to the competency needed for other industries. Any misfits would be detrimental to the whole process and would result in project delays (Tariq, 2022).

# LITERATURE REVIEW

## Managerial Competencies for Construction Project Managers

In this study, the following definition of competency is best suited to fulfil the scope of the whole study within the context of managerial competencies. Taking the cue from this definition of competency, which is, "the state of having sufficient quality knowledge, skills and experience, positive mental attitudes and physical soundness to perform a particular task as expected'. (Ineza, 2022) This research will explore in detail the core competencies required from the perspective of Project managers. Competency is a set of related knowledge, attitudes, skills, and other personal characteristics that influence a significant part of the work that they performed. It correlates with job performance (Nik Sarina et.al, 2023), can be measured against well-accepted standards, and improved through training and development. A person's competencies include personality traits, knowledge, skills, experience, and are supported by motivation, and self-esteem related to functioning in a group. Competencies can be divided into two basic groups, i.e., hard and soft competencies. Hard ones relate to a specific job position. They are defined as technical and functional competencies. On the other hand, soft competencies are personality traits contributing to given professional roles (behavioural, social, interpersonal). Hence, competency is the ability of a


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person, team, or company to mobilize and combine resources (i.e., knowledge, skills, and attitudes) to act in each situation (Jesperson, et. al.., 2021). Challenges such as problem-solving, conflict-handling, negotiating, and communicating effectively are some of the competencies managers must be able to deal with confidence. Not only they must be competent in one aspect of the job, but they must be competent in many other aspects as well. The only way to ensure this is for managers to be equipped with multiple competencies with promising advance (Hafez et.al.,2023) by their position. The findings of researchers discovered that managerial competencies, including attitudes that project managers possess, do have a significant impact on project performances (Xiang et al., 2018).

*Core Competencies for Construction Project Managers*

Numerous studies have demonstrated that project teams must implement universally accepted standards and practices in order to achieve CPM success. (Stanleigh, 2010; Ahadzie et al., 2009; Crawford, 2005; 1998). However, there is an empirical indication that project team members tend to struggle in coping with the needed level of job and task performance in their project roles and management capabilities (Stanleigh, 2010; Ahadzie et al., 2009). This development tends to affect the ability of project team members to perform and deal effectively with their broader functions of creating a CPM culture within the necessary to produce the desired performance outcome (Stanleigh, 2010; Enshassi, Mohamed, and Abushaban, 2009). A project team PM-based environment (Skipper and Bell, 2008). This often leads to managerial inefficiencies, team ineffectiveness, and project failures (Enshassi, Mohamed, and Abushaban, 2009). It is therefore imperative that project managers possess the critical benchmark standard that requires them to perform efficiently and effectively. Discharging their responsibilities by trial and error rather than by competencies should be a thing of the past. Most researchers such as Ahadzie et al., (2009) agree that leadership traits supported by the needed core competencies in their job responsibilities are deemed critical to the success of project completion. The emphasis on core competencies as one of the key drivers to be possessed by project managers such as leadership and management skills, effective communications, and being result-oriented were identified as significant competencies required (Lee et al, 2003) observed that the inner confidence and self-belief from personal knowledge and experience are likely to play an important role in a manager's ability to deliver a project successfully. They emphasized the importance of the competencies of project managers concerning project success. A larger study conducted, by Kendra T, (2004) reached a similar conclusion. They found that certain competencies such as leadership skills, Effective Communication, Team Spirit, and Emotional Intelligence are some of the success factors that contribute toward project success. Core competency has three components, and they are as follows. The first component is knowledge.

The state of having sufficient quality knowledge refers to the body of knowledge the project manager must have acquired during his tertiary level of education. Such knowledge is technical and deals with the subject matter that pertains exclusively to the discipline of study he is involved in. A project manager, having acquired a degree in his chosen discipline for instance and having passed the respective exams would be acknowledged as having sufficient quality knowledge. This type of knowledge is in the form of theoretical knowledge short of having the skills needed to perform a task well. The higher the level of his degree, the more knowledge he is deemed to have acquired (A, 2021). The second component is skill and experience are the necessary subsequent aspects of the competency a project manager must have. Without the relevant skills to support the knowledge a person possesses the transference of knowledge into something tangible may not be realized. So, the project manager must use his knowledge to good use by applying whatever knowledge he has to something beneficial to the people and environment he interacts with. When he applies what he knows consistently, he will be very skilful in what he does. Applying those skills to different situations would result in him acquiring the necessary experience to make use of the knowledge and skills productively. The experiences he is exposed to would ascent him to the level of an expert.

The third component is having a positive attitude. A project manager who is devoid of a positive attitude would amount to nothing even if he has the knowledge and skills required for the job. A person lacking a positive attitude (S, 2023) would also lack the passion to do a given job. More often than not, he will complain and make unnecessary demands before he gets the job done. Possessing a positive attitude is the motivational factor that drives knowledge and skills to be manifested in tangible form. Attitude is defined as 'a disposition a person takes about an object or subject'. The disposition may take the form of cognition, emotion, and action or part thereof. A project manager with a positive attitude will think, feel, and act according to the requirements of his duties and responsibilities to the best of his abilities (Crawford, 2005). A person with a positive attitude is believed to be more likely to demonstrate a tendency for good behaviour than a person who is not. It is imperative, therefore, to take note that possessing sufficient knowledge, having the required skill set, and adopting a positive attitude is key to being competent.

**The correlation between Competencies and the positive impact of the help of Machine Learning (ML) towards the sustainability of project performance**

The correlation between competencies, project performance, and even organizational performance has been underlined by various authors, among them Schmitt and Kozar (1978), Mullay (2003), Crawford (2000 and 2005), Kendra and Taplin (2004), Koong and Liu (2006). Following this scenario, it is well supported by Project Management literature that project managers need to


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possess core competencies in the industry that they are in. The idea or notion of making a big difference between tough and gentle knowledge (Gardiner, 2005). This author explains that the terms tough and gentle refer to the nature of the skills. Soft skills are those related to human capabilities and behaviour, while hard skills are technical. Hard skills are those concerned with the technical aspect of the job which the job holder must possess to perform well. Hard skills come under the term technical competency in the core competency, of which the other two are Functional and Generic skills. The soft skills consist of things such as interpersonal communication, problem-solving and decision making, negotiation, conflict-handling, and motivation. It is also found in the literature that these skills are cited as "human" competencies (El-Sabaa; 2001), "personal transferable skills" (Bennet 2002), "interpersonal" skills (PMBOK Guide 2004), "micro-social" competencies (Kendra and Taplin, 2004), or even "social" skills (Brandel, 2006). El-Sabaa (2001) refers to human skills like the capability to work in a group and to create cooperation among the group members; this is exceptionally associated with the person's perceptions about themselves and others. How managers view themselves, their colleagues, and supervisors will have an impact on how they interact in their capacity to encourage cooperation. Soft skills are more difficult to master and use successfully due to the fact they are associated with a person's EQ (Emotional Quotient) (Gardiner, 2005). The need to ensure that project managers possess a specific set of skills is highlighted by Schmitt and Kozar (1978), as these authors related inefficient and ineffective project managers with assignment failures. Koong and Liu (2006), identified in their research the significance of project managers' competencies as critical to achieving project success. According to this survey, the competencies possessed by project managers will determine if the project being managed will contribute to organizational profitability or otherwise. Mullaly's (2003) study observed that 64.5% of project managers have little or no formal competency-based training. The researcher discovered that the lack of managerial competencies due to the absence of formal training and development is a key reason why project managers fail to manage projects efficiently and effectively. As such, the project managers' failure to comprehend the anticipated effects resulted in projects being poorly executed. Mullaly (2003) explains that there are still a lot of what he termed `accidental´ project managers, who are no longer even conscious that what they are doing requires specific competencies acquired through formal training and development. Following this argument, project managers are not able to accumulate the critical competencies needed to accomplish their job. What normally takes place is that, although project managers are employed for their technical competencies (hard skills), they do not possess the required functional and generic competencies (soft skills) to function well. With the arguments put forth by Schmitt and Kozar (1978), Mullaly (2003), and Koong and Liu (2006) it

becomes clear that project managers need to possess a set of managerial competencies to be efficient and effective.

In project management, although the requirements emphasized the importance of technical competency, this study discovered that project managers must acquire the functional and generic competencies as well to perform their jobs efficiently and effectively. Other researchers such as Stretton (1995), ElSabaa (2001), Crawford (1999, 2000, 2005, 2006), have found that possessing technical competencies (hard skills), has been the main focus of attention and the Functional and Generic skills (soft skills) are somewhat being neglected. Pollack (2007) goes on to assert that the human resource management practices listed in Project Management literature are "elementary". The author asserted that his research in the field has observed that 'soft skills' play a central role in managing projects when people are involved. Flannels and Levin (2005 p.1), give a boost to that point by stating that "people problems can preclude challenging success, specifically in terms of managing projects." However, as Blackburn (2000) mentions, expert bodies keep away from mentioning interpersonal skills in their content material due to the fact they are seen as less easily defined.

Recently greater attention has been given to soft skills necessary to control human initiatives (Edum-Fotwe and McCaffer, 2000; Cowie, 2003; Muzio, et al. 2007; Pollack, 2007). The need for such knowledge in Project Management is further reinforced by Boardman (2006), who states clearly that the challenging part of the job refers to soft skills concerning people. Flannes and Levin's (2005) book entitled "Essential People Skills for Project Managers" supported this trend.

The enhancement of managerial competencies critical to carrying duties and responsibilities and has been agreed by many researchers such as Todd et.al., (1995), Redman and Matthews, (1997), Chan and Swatman, (2000), Bennet, (2002), Gallavin, et.al., (2004), Lai (2005), and Koong and Liu, (2006). The many bodies of knowledge that have emerged in certain countries are examples of previous efforts to determine the potential interest in the area of project management. A greater dynamic and holistic model, which also relates competencies to performance, was introduced by Kendra and Taplin (2004). Their open machine cultural model for assignment success takes into consideration cultural factors and is primarily based on four key aspects: Project Manager Competencies, Performance Measurement Systems, Business Processes, and Organization Designs. Kendra and Taplin's (2004) framework are totally based on four dimensions, the micro, and macro-organizational plan elements; having technical and generic considerations. Kendra and Taplin's (2004) this framework is more complete and shows that different elements also contribute to good performance. Particularly it demonstrates the significance of organizational tradition and values. However, it also acknowledges that the Project manager's knowledge is one of the essential factors that lead to project


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success. The competencies start to play an extra strategic position (Shenhar and Levy, 1997; Kloppenborg and Opfer, 2002; Gardiner, 2005; Jugdev and Müller, 2005 Söderlund 2005) their consequences will impact organizational performance. In the end, the employer will be affected by way of choice and the combined result of the projects they undertake. The learning with the aid of Soderlund (2005), which was elaborated based on a couple of cases of giant Swedish companies, additionally contributes to demonstrating the significance of soft skills competencies. Another applicable finding was that the companies studied paid a lot of attention and spent magnificent effort to boost teamwork competence (Ruth D, 2005). An article by Boardman (2006) illustrates, that using a storytelling approach, demonstrates how simply important the soft skills. Most of the difficulties faced by the manager had been associated with the softer part of Project Management dealing with and influencing people. Gardiner (2005) also stressed that both types of skills, hard and soft are critical to managing projects successfully.

## RESEARCH METHODOLOGY

The research methodology is developed to collect the required data. A quantitative method is adopted in this research. The distribution of questionnaires is carried out. Feedback from many respondents can be collected within a limited time through questionnaire distribution. Besides, data collected from a large sample may result in higher accuracy. Three techniques, namely Cronbach's Alpha Reliability Method, Frequency Distribution Analysis and Kruskal-Wallis H Test, are applied in quantitative data analysis. To determine the managerial competencies, that lead to higher efficiency and more effective performance, a quantitative model is used in this research to gather comprehensive valuable feedback. Online Survey questionnaires were conducted. Feedback was analysed using the 5-point Likert Scale. The questionnaires are distributed via media channels such as WhatsApp, Facebook, LinkedIn, and email. The data is collected within one month. Time allocation for receiving feedback is sufficient to ensure the quality and quantity of the results. Considering an approximate response rate of 50%, questionnaires are sent to 1000 potential respondents. Accuracy can be further improved if the response rate exceeds 50%. In this research, data collection is conducted through an online survey created using Google Forms as well as physical distribution. In addition, physical and virtual interviews are also conducted. In this research which is the most suitable to suit the aimed to determine the core competencies that depending on the results using the Johari window, individuals may need to make adjustments to their communication styles and behavior choices to more effectively convey the (C, 2018) they want others to know about themselves or the things they want to change outright. In this assessment, all the individuals have an open Arena which means open and two-way communication exists in the workplace environment.

Some showed distinctive Arena, especially those who are Sanguine and Choleric in personality. Although there are open communications between leaders and team members, the open Arena is not open wide enough due to the local cultural behaviors as opposed to the West. The Johari Window is therefore an effective communication tool to discover one's strengths and weaknesses that can be further explored. The McKinsey 7S Model (Ruth D, 2006) is a change management tool for analyzing organizational design, alignment, and performance. It offers a simplified method of identifying organizational gaps, inconsistencies, and conflicts. Other than that, in this research, data collection is conducted through an online survey created using Google Forms as well as physical distribution.

## ANALYSIS AND DISCUSSION

Data analysis is conducted to interpret the data for discussion on the findings. The process to analyse all the collected data from the research into statistics. In this research the data analysis is used to interpret data and make conclusions from the accumulated data by using Statistical Package for Social Sciences (SPSS). SPSS was chosen and adopted in this research due to it being able to generate the main benefit of utilising the data, making it simple to learn and operate (Landau and Everit, 2004) It possesses extensive statistical capability. Its ability to create variables from pre-existing data makes it special (Maclnnes, 2016). Furthermore, a few techniques such as Cronbach's Alpha Reliability Test, mean ranking and Kruskal-Wallis test have been used to analyse the managerial competencies data required.

Reliability is defined as the quality of the measurements being error-free, hence consistent results are collected (Vehkalahti, 2020) Cronbach's Alpha is used to calculate the reliability of the independent variables and the dependent variable (Koçak, 2014). Cronbach's Alpha Test is a vital tool for those researchers who want to examine the reliability and accuracy of data. The formula shows the range of Cronbach's alpha reliability coefficient (Vehkalahti, 2020). For score of more than 0.7 is usually considered appropriate. Some researchers however, advocate for higher values of 0.90 to 0.95. A low alpha value indicates that the number of items is insufficient, or the items' characteristics are not closely related. The alpha value required for this research should not be less than 0.7. Table 1 shows the reliability level for Cronbach's Alpha values.


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**Table 1**:Reliability Level for Cronbach's Alpha Values.

| Cronbach's Alpha Value | Reliability Level |
|---|---|
| $\alpha \geq 0.9$ | Excellent |
| $0.9 > \alpha \geq 0.8$ | Good |
| $0.8 > \alpha \geq 0.7$ | Acceptable |
| $0.7 > \alpha \geq 0.6$ | Questionable |
| $0.6 > \alpha \geq 0.5$ | Poor |
| $0.5 \geq \alpha$ | Unacceptable |

Descriptive statistics method is used to provide a general overview of the data. It measures the frequency distribution, central tendency, dispersion, and relationships between variables (Vehkalahti, 2020). Data can be visualised in the form of diagrams, such as tables, graphs, and charts. The diagrams illustrate the mode, mean, median, variance and standard deviation of the data collected. These values assist in summarizing and presenting the results, as well as identifying outliers. Kruskal-Wallis H test is a non-parametric test to examine whether there are significant statistical differences between groups of an independent variable (Mbuli, 2022). It is determined by the ranking of each variable. The data for each group is ranked, and the rank values are summed up to determine the H value. Figure 2 shows the Kruskal-Wallis H Test Formula.

$$H = \left[ \frac{12}{n(n+1)} \sum_{j=1}^{c} \frac{T_j^2}{n_j} \right] - 3(n+1)$$

**Figure 1**: The Kruskal-Wallis H Test Formula.

Where,
n = sum of all sample sizes
c = number of samples
$T_j$ = sum of ranks in the $j^{th}$ sample
$n_j$ = size of the $j^{th}$ sample

The H value is then compared with a p-value, say 0.05. If it is less than the p-value, it shows that there is a significant difference between groups and vice versa which the discussion is in the findings.

## FINDINGS

In the pilot study conducted, the results show that there is a strong correlation between enhanced managerial competencies and high work performance which leads to a significant reduction in project delays. Highly competent project managers are found to be more efficient and effective in performing their job well consistently. Undoubtedly, managerial competencies are one of the critical

factors that can help reduce project delays. The competency model of Jabatan Kerja Raya (JKR) was used as the basis for measuring the competency level of the participating managers consisting of 28 high-ranking CPM selected from each state in Malaysia. They are Heads of the Department of each respective state. The core competency model of JKR was used as a standard benchmark practice to be followed. The core competency model comprises the following core competency clusters which pertain to Technical Competency (competency which is mandatory to be possessed by the Job Holder), Functional Competency (competency which is needed to ensure that works are performed well, and Generic Competency (competency which must be acquired by the jobholder to interact well with other stake-holders. In this context, it is imperative that enhancing managerial competencies be made a standard benchmark for project managers to possess especially in the construction industry. It is proposed that the CIDB Construction Industry Competency Standard (CICS) be used as a benchmark to produce project managers who are certified to handle construction projects efficiently and effectively. The institution of formal Competency-based Training and Development program should model the ISO9001 Quality Management System under Clause 7.2 (Competence) with the view to ensuring that Project Managers do indeed possess the required competency required to handle projects in the construction industry efficiently and effectively. The followings are the discussions and recommendations from the pilot study based on the various management instruments used to gather feedback on a face-to-face basis. The alpha value for each section of the questionnaire is summarised in Table 2. SPSS was used to pilot-test all 140 surveys that were gathered. According to Table 2, each section of the questionnaire generated an alpha value more than 0.70, indicating that the data had strong internal consistency (Gliem & Gliem, 2003). This shows that the pilot study and the result of the responses were reliable. All the 140 responses would be included in the main study since no changes were made to the pilot research questionnaires.

**Table 2**: Reliability Level for Cronbach's Alpha Values.

| Category | Number of items | Cronbach's alpha |
|---|---|---|
| Core Competency toward project performance | 90 | 0.879 |
| Good Standard Benchmark | 50 | 0.801 |

In this research, SPSS used the Kruskal-Wallis test to see if there were significant differences between respondent groups. (Koçak, 2014) states that if the asymptotic significance value is less than 0.05, the null hypothesis is rejected with a 95% confidence level. The core competencies which are ranked by mean and standard deviation based on the opinions of three groups of respondents:


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consultants, contractors and developers and client. These core competencies are prioritised according to advantage categories, as shown in Table 3 to Table 6.

The five most strongly agreed were from the views of the consultant, developer (including the contractor), and client.

**Table 3**: Top 5 of Core Competencies from Consultant's CPM Perspective

| Rank | Core Competencies | Mean | SD |
|---|---|---|---|
| 1 | Knowledge | 4.46 | 0.886 |
| 2 | Technology innovation | 4.34 | 0.639 |
| 3 | Skills | 4.26 | 0.980 |
| 4 | Attitude | 3.51 | 1.067 |
| 5 | Culture | 3.46 | 1.291 |

**Table 4**:Top 5 of Core Competencies from Developers' CPM Perspective

| Rank | Core Competencies | Mean | SD |
|---|---|---|---|
| 1 | Technology innovation | 4.34 | 0.902 |
| 2 | Knowledge | 4.09 | 0.995 |
| 3 | Skills | 4.00 | 0.984 |
| 4 | Culture | 3.87 | 1.129 |
| 5 | Attitude | 3.72 | 1.301 |

**Table 5**: Top 5 of Core Competencies from Client's CPM Perspective

| Rank | Core Competencies | Mean | SD |
|---|---|---|---|
| 1 | knowledge | 4.56 | 0.669 |
| 2 | Skills | 4.03 | 0.897 |
| 3 | Attitude | 3.84 | 1.051 |
| 4 | Technology innovation | 3.53 | 1.047 |
| 5 | Culture | 3.38 | 1.212 |

**Table** 6: Overall Ranking on Managerial Competencies

| Rank | Managerial Competencies | Mean | SD |
|---|---|---|---|
| A1 | Knowledge | 4.28 | 1 |
| A4 | Skills | 4.04 | 2 |
| A3 | Attitude | 4.02 | 3 |
| A2 | Technology innovation | 3.69 | 4 |
| A8 | Culture | 3.59 | 5 |
| A6 | Experience | 3.37 | 6 |
| A5 | Personality | 3.25 | 7 |
| A7 | Sustainable benchmarking | 3.21 | 8 |

This ranking was done based on the mean and standard deviation values. According to the ranking, knowledge is ranked as the highest ranked competency for managers particularly in the context of CPM. Three of the eight of the managerial competencies, are significantly related to the sustainable industrialization towards SDGs fostered. The key issues contributing to the Malaysian government's programmes' low effectiveness are a lack of enforcement and implementation (Tsiga, 2016). From the Malaysian government's perspective, the core competencies of CPM is an alarming issue that needs to be significantly improved. Hence, the client and government focus on SDGs establishes of managerial competencies as a crucial barometer for CPM to build the resilient infrastructure, promote effective sustainable industrialization and foster efficient technology innovation. (Ahmad. I, 1997) Next, perception of knowledge is identified as the core competencies most agreed by the CPM. A Negative perception on the culture is ranked on the lower argument because it is based on the attitude and personality of CPM itself. This result shows significantly, most CPM still have a strong concept that build resilient infrastructure, promotes effective sustainable industrialization, and fosters efficient technology innovation. It is mentioned by Gardiner, (2005) that notably imperative to appraise as managerial competencies as a crucial barometer for CPM as established in Construction Industry Competency Standard (CICS) the Construction Industry Development Board (CIDB) Malaysia which the result enhancing the establishment of managerial competencies that be made a standard benchmark for CPM to possess effective culture and the machine learning as an efficient technology innovation.

Table 7 shows that the Kruskal-Wallis test was applied in this research to compare consultants', contractors' and developers' opinions towards the managerial competencies as a crucial barometer to CPM. The significance level for this study is set at 0.05. The Kruskal-Wallis test generated the following hypotheses:

1. Null hypotheses (H0); there is no statistically significant difference on managerial competencies between consultants, contractors and developers.
2. Alternative hypotheses (H1): A significant difference in managerial competencies exists between consultants, contractors and developers.

The finding shows CPMs equipped with the relevant core competencies are found to be more efficient and effective in performing their job consistently. Undoubtedly, managerial competencies are found to be the crucial barometer factors that can help to boost project performance.


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**Table 7**: Kruskal-Wallis Test for Managerial Competencies

| Managerial Competencies | Sig p-value | Decision (Reject/Failed to Reject) |
|---|---|---|
| Knowledge | <0.001 | Reject |
| Skills | 0.029 | Reject |
| Attitude | <0.001 | Reject |
| Technology innovation | 0.071 | Failed to Reject |
| Culture | 0.064 | Failed to Reject |
| Experience | 0.098 | Failed to Reject |
| Capital | 0.514 | Failed to Reject |
| Marketing | 0.153 | Failed to Reject |

## CONCLUSION

The results significantly determined the managerial competencies as a crucial barometer for CPM. It identifies the essential managerial competencies as a critical barometer for CPM to advance towards resilient infrastructure, encourage successful sustainable industrialization, and support effective technological innovation. It also establishes the core competencies in the imperative standards benchmarking. It thus looked at improving managerial skills that resulted in a favourable effect and the high success rate of sustainability project completion. It is recommended that to make the outcome of the CICS last its effectiveness. The follow-up action in formal training should be made at regular intervals on the acquired knowledge. ML consistently is the needed skills that formed to stay effective sustainable industrialization towards efficient technology innovation strives. These could be done by preparing a Monitoring and Control mechanism using ML as an efficient technology innovation to ensure that the succession planning process is implemented according to agreed schedules. This research would also provide valuable insights and opportunities for researchers to do further research which indirectly contribute to the accomplishment of various SDGs and overall UN goal accomplishment.

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# COMPARISON OF BIM-BASED QUANTITIES TAKE-OFF IN QUANTITY SURVEYING PROFESSION

**Lam Tatt Soon[1], Lik Syuen Wong[2], Myzatul Aishah Kamarazaly[3], Chai Chang Saar[4], Habizah Sheikh Ilmi[5]**

[1,2,3,4,5] *School of Architecture, Building and Design,*
TAYLOR'S UNIVERSITY

## Abstract

Quantity surveyor (QS) plays an important role in a construction project who is responsible for the construction cost. Quantity take-off (QTO) will be conducted by QS to measure the quantities of materials needed for the construction project followed by the preparation of bills of quantities (BQ). Building information modelling (BIM) was introduced to the construction industry and brings many benefits to the QTO process such as time saving and high accuracy. However, BIM-based QTO consists of numerous issues such as 3D modelling issues, quantities extraction issues and data loss issues. Hence, this research aims to compare and analyse the application of BIM-based QTO in the QS profession. The objectives of this research cover the comparison of BIM-based QTO in BIM software as well as the analysis of quantities extraction which complies with Malaysian Standard Method of Measurement of Building Works Second Edition (SMM2). This research was conducted by using two types of BIM software which are Autodesk Revit and Cubicost TAS. This research is expected to benefit the QS profession by delivering a better understanding of using BIM for QTO with the analysis and comparison of QTO data.

***Keywords***: Quantity Surveying profession, Building Information Modelling (BIM), Quantity take-off (QTO), Autodesk Revit, Cubicost TAS.

[1] Senior Lecturer at Taylor's University. Email: lamtatt.soon@taylors.edu.my

## INTRODUCTION

A construction project consists of many professionals to ensure the project is constructed successfully. Quantity surveyor (QS) is one of the professionals responsible for the construction cost and contractual relationships between various parties of a construction project (Hussin & Omran, 2009). A construction project without a QS might face problems such as tight budget, low quality project and run out of funds before the project is completed (Canadian Institute of Quantity Surveyors, 2021). QS manages and controls the construction project cost by applying expert knowledge to measure the quantities of materials and works required accurately to assist in obtaining the cost for labour, materials and plants required for the construction project (Hussin & Omran, 2009). Quantity take-off (QTO) will be conducted by QS to calculate and measure the quantities of materials needed for the construction project followed by the preparation of bills of quantities (BQ).

In recent years, technology development has brought BIM as a platform for the betterment of the industry's practice (Ali et al., 2018). The BIM model is able to improve the efficiency of a construction project as the information can be shared easily among all the involved parties with the assistance of cloud-based tools and BIM-based QTO software, allowing for automation of calculation which saves time and increases the accuracy of QTO. Furthermore, the current approach of BIM within the Malaysian construction industry is improving and the implementation of BIM is expected to provide accurate calculations since BIM models are more detailed (Omar & Fateh, 2023; Reyes, 2020). The automation of QTO has become increasingly favourable among QS and eventually led to the development of BIM-based QTO software such as Autodesk Revit and Cubicost TAS (Loh, 2018).

QTO is usually done by QS and refers to the calculation for quantities of materials needed for a construction project. Traditional method of QTO is done by manually taking-off the quantities with 2D drawings and QSs are required to review the specifications and scope of work from the drawings and obtain dimensions from the drawings (ProEst, 2021). The process of traditional QTO is very time consuming and error prone because it is based on human interpretation. Alternatively, BIM has been introduced to the construction industry and one of the most useful functions of BIM is it can perform automation QTO through BIM model where the calculations will be done using the element's geometric properties and the quantities in area, volume and length will be provided in text form (Monteiro & Martins, 2013). QTO by using the BIM method brings many benefits such as time saving, more accurate calculations and visualisation (Reyes, 2020). However, the BIM-based QTO faces a few limitations and problems and they differ for each software and building elements. The accuracy of the quantities obtained through automation calculation from the BIM-based QTO software are depending on the quality of the BIM model. The closer the BIM


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model is to the actual construction, the more accurate the quantities obtained. If the BIM model is incorrect or incomplete, the quantities extracted could be insufficient or excessive depending on the modelling process (Khosakitchalert et al, 2019).

Moreover, the modelling of a designed building does not often achieve 100% accuracy due to challenges and limitations in 3D modelling (Czmoch & Pękala, 2014). During BIM modelling, complex elements may be replaced by simple geometric forms to perform QTO due to absence of corresponding modelling tools, thus the adjustment made for the model will result in not achieving the exact visual representation of the designed building and the modelling tools of some building elements may be absent (Monteiro & Martins, 2012). Furthermore, BIM modelling can be affected by the compound elements which consist of multiple layers of material such as walls, ceilings, floors and roofs (Khosakitchalert et al, 2019). Additionally, software such as Revit which has the feature for QTO but is a BIM design authoring software designed for building modelling, could not handle the interception of some elements such as interceptions between beams and columns (Tanko et al., 2019). Besides that, it is not possible to extract all the essential quantities as there are still issues such as lack of details from the model where up to 50% of data for QTO are absent (Vassen, 2021; Olsen & Taylor, 2017).

The limitations and accuracy of QTO by BIM model differs for each software and BIM users are unaware about the workflow of BIM-based QTO (Ngo, 2018). Thus, this research is to conduct a case study to gain in-depth understanding of BIM-based QTO software in the QS profession. Due to lack of research between Autodesk Revit and Cubicost TAS, the case study will be conducted by developing BIM models in both software, followed up by analysing and comparing the quantities extracted from the models based on SMM2.

## LITERATURE REVIEW

Building information modelling (BIM) is a digital tool that can create a model of a building of a construction project digitally which consists of relevant data and precise geometry that can be used for the entire building life cycle for the planning of project, design, construction, operation and maintenance (Azhar, 2011). BIM is more than a 3D model, it has been progressively extending in the last few years and established seven dimensions of BIM from 3D to 7D (Simeone et al., 2013; Mesaros et al.,2019). BIM is able to reduce up to 7% of the construction project duration and the design and documentation of a construction project can be done concurrently which reduces up to 80% of the time taken when performing cost estimation (Latiffi et al., 2013; Memon et al., 2014; Hashim et al., 2021) Moreover, it can also increase the quality of the construction project in terms of design and documentation by providing better visualisation of the project. The information of the construction project can be obtained by involved

parties from a BIM model which reduces the information loss when sharing with other parties. BIM also reduces errors such as mistakes during the design or construction stage can be identified with functions like clash detection which are ab le to save up to 10% of the contract value. It also provides functions like generating accurate quantification which reduces human errors during QTO and produces cost estimation with 3% accuracy.

Quantity take-off (QTO) is an important task which is normally conducted by QS to measure the quantities of materials required for a construction project for preparation of BQ, cost estimation and cost planning (Pratoom & Tangwiboonpanich, 2016). In Malaysia, the QTO will be done following the standard method of measurement (SMM) in order to produce an appropriate and standardised BQ (Akbar et al., 2015). BIM QTO is a process where the quantities like area, volume, length and number can be extracted from the BIM model automatically from software that supports BIM QTO function (Liu et al., 2016). According to Vassen (2021) BIM QTO can automatically generate quantities and BQ which can eliminate the long and error prone traditional QTO method and reduce human errors (Hashim et al., 2021).

**Limitations in BIM Model Development**

A BIM model characterises the geometry, quantities and properties of building elements which enable the extraction of quantities and properties of materials (Azhar, 2011). However, there are several limitations and constraints when developing a BIM model.

***People Limitation***

A BIM model can be built by construction players involved in a construction project such as architect and QS and the modelling style of each modeller are different, thus the information contained in the BIM model may be difficult to extract or lack of information for other construction players (Xu et al., 2019). In the current industry, QS builds the BIM model based on the architects' CAD drawings along with construction information for QTO and cost estimating purposes and eventually convert it to a as-built 3D model at the later stage. Moreover, construction players such as QS are used to current measurement approaches and are unfamiliar with new tools like BIM. Thus, problems like a lack of support systems, lack of communication and mutual understanding among the construction players might result in incorrect interpretation and lead to incorrect or inefficient information extraction (Soon et al., 2019).

***Software Limitation***

Software limitations are the most important limitations in BIM implementation. Some BIM software could not handle large amounts of data and there is lack of AEC experts with knowledge and experience in creating software suitable for all


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construction professionals' task and responsibility. Vassen (2021) stated that BIM modelling is still unable to reach users' expectations and satisfaction as the BIM software's adaptability for varied design settings is still insufficient and unable to provide all expected information and data. Moreover, BIM-based QTO is dependent on the BIM model developed, thus items that are not included in the BIM models are unable to be quantified. Additionally, Tanko et al. (2019) stated that software such as Autodesk Revit is a BIM design authoring software with QTO feature that is mainly for designing with BIM modelling, thus it could not manage the interceptions of some building elements such as beams and columns.

One of the significant issues with BIM modelling is managing compound elements (Monteiro & Martins, 2012). Compound element is a building element with multiple layers such as walls, floors, roofs and ceilings and usually, the layers are core structure layer(s) and finishing layer(s) (Khosakitchalert et al., 2019). During BIM modelling, the compound elements like walls and floors will be modelled as a single element in most of the BIM software and it will lead to inaccurate or excessive quantities extraction as each layer of compound elements may not have the same dimension and quantities (Monteiro & Martins, 2012). Khosakitchalert et al. (2019) also stated that modelled walls may overlap with the structural columns and beams and the overlapped parts will lead to a surplus of wall quantities.

During BIM modelling for QTO, some building elements lack graphical expression due to their inexpressive physical scale or geometrical complexity (Vieira et al., 2022). Monteiro & Martins (2012) highlighted that building elements with complex geometry can be modelled in a simpler geometric form for QTO purposes as they lack corresponding modelling tools but the replacement of geometries will cause the BIM model to fail in achieving the exact visual representation of the proposed building. Godinho et al. (2020) also stated the application of automatic tools for extraction of parametric surface and data conversion of irregular geometry is not favourable. Moreover, in order to obtain the parameterisation while preventing heavy files which will affect the BIM model usability, some geometry of elements will be simplified.

### *Limitations in BIM Quantities Extractions*

The quantities extraction will be limited by the BIM model greatly such as the overlapping of compound elements which causes excessive quantities extracted and inadequate BIM model created by inexperienced modellers resulting in inaccurate quantities extractions. Monteiro & Martins (2012) mentioned that BIM model created with minimal budget will disregard many details of the building elements and result in irrelevant or affect the take-off parameterisation such as the majority of BIM software unable to differentiate between the window, doors or curtain walls' glass and frame and consequence in the capability to extract the quantities of opening only which compromise the quantities.

Furthermore, it is impossible to generate all the materials quantities from the BIM model as elements that are absent in the BIM model could not be quantified such as formwork, excavation and rebar, thus BIM-based QTO will still depends on manual quantities extraction to complete the QTO process for all essential quantities (Monteiro & Martins, 2013; Vieira et al., 2022). However, this limitation in BIM quantities extraction differs according to the BIM software. As stated by Monteiro & Martins (2012), the quantity extraction is limited by the parameters provided by the software to configure the measurement and quantities of each building element which means the measurement of elements through BIM-based QTO will be done according to predefined ways. Moreover, a model with high LOD is able to provide more precise quantities, there are still some activities that are required to be quantified and specified that are unable to be represented geometrically (Vieira et al., 2022).

## RESEARCH METHODOLOGY

This research will concentrate on a case study, incorporating the implementation of desk analysis. Case study is a type of qualitative research that explores a phenomenon by using different sources of data and ensures multiple details of the phenomenon can be revealed and understood (Baxter & Jack, 2008). In this case study, a double storey semi-detached house project with 334m2 of gross floor area (GFA) located in Selangor is selected. BIM models will be developed by using the project's contract document with two BIM software which are Autodesk Revit 2022 and Cubicost TAS C-III for analysis and comparison purposes. Desk analysis is carried out by utilising a laptop or desktop. Desk analysis relies on data collected from prior research or existing sources which is then filtered, analysed and summarised with the purpose of achieving a better understanding of the topic (Juneja, 2022, Villegas, 2023). The modelling process in Autodesk Revit 2022 and Cubicost TAS C-III will involve only architectural and structural elements, excluding reinforcement work. The BIM models in this study will be developed by using Autodesk Revit 2022 and Cubicost TAS C-III. The BIM model developed will be based on the drawings obtained for a double storey semi-detached house located at Selangor, Malaysia. In Autodesk Revit, architectural and structural elements will be developed in separate templates, and these templates will later be combined into a unified BIM model within the Autodesk Revit software. In contrast, Cubicost TAS has the capability to model both architectural and structural elements within a single BIM model. Subsequently, QTO will be carried out using Autodesk Revit's schedule function and Cubicost TAS's calculate and view quantities by category function to generate quantities for their respective BIM models. In Malaysia, quantities will be measured in accordance with the Malaysian Standard Method of Measurement of Building Works Second Edition (SMM2) to generate standardised BQ (Akbar et al., 2015). Therefore, all extracted quantities will adhere to the unit of


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measurement specified in SMM2. Comparison between the quantities extracted from the BIM models by using Autodesk Revit and Cubicost TAS will be calculated through the following formula Eq. (1).

$$\frac{\text{Revit QTY} - \text{TAS QTY}}{\text{TAS QTY}} \times 100\% \quad (1)$$

## DATA ANALYSIS

This chapter primarily focuses on comparing the quantities of architectural and structural elements in Autodesk Revit and Cubicost TAS. It explores into the comparison of various elements such as walls, finishes, footings, columns, beams, slabs, and more. The discussion will extend to addressing data loss in the BIM model after conducting a thorough comparison of Quantity Takeoff (QTO) between the both software applications.

### Architectural Elements

Table 1 shows the quantities comparison between Autodesk Revit and Cubicost TAS for external walls and internal walls. The quantity of walls in area for both software applications has a big difference up to 48.87%. This is because the QTO of walls in Autodesk Revit did not deduct the columns and beams and lead to excessive quantities. Khosakitchalert et al. (2019) also stated that the walls may overlap with the columns and beams and lead to surplus of wall quantities. The results of the quantities of walls after linking and binding the architectural and structural models in Autodesk Revit remain the same where the walls still overlapped with the columns and beams as shown in Figure 1. Moreover, the quantities of concrete in stiffeners and RC coping and fin obtained by each software have no difference but Autodesk Revit is unable to obtain the quantities of formwork.

**Table 1**: External and Internal Walls Quantities Comparison between Revit and TAS

| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| External Walls | | | | |
| Half brick wall (70mm thick) as box up wall | m2 | 3.17 | 3.29 | -3.65% |
| Half brick wall (100mm thick) | m2 | 278.81 | 187.28 | 48.87% |
| Half brick wall (100mm thick) as party wall | m2 | 15.23 | 15.14 | 0.59% |
| One brick wall (230mm thick) | m2 | 72.45 | 59.15 | 22.49% |
| One brick wall (230mm thick) as party wall | m2 | 11.72 | 9.92 | 18.15% |
| Internal Walls | | | | |
| Half brick wall (70mm thick) as box up wall | m2 | 18.06 | 17.89 | 0.95% |

| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| Half brick wall (100mm thick) | m2 | 281.91 | 224.98 | 25.30% |
| One brick wall (230mm thick) as party wall | m2 | 37.35 | 30.65 | 21.86% |

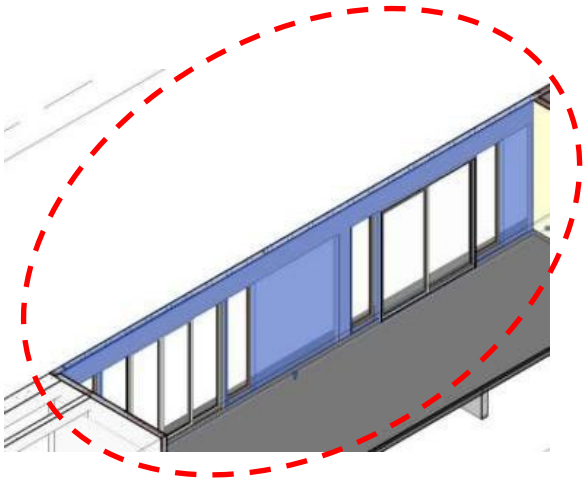

**Figure 1**: Wall Overlapped with Columns and Beam in Revit

**Table 2**: Floor Finishes Quantities Comparison between Revit and TAS

| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| External Floor Finishes | | | | |
| Cement and sand (1:6) paving | m2 | 21.57 | 21.40 | 0.79% |
| Stamped concrete with shanghai plaster border; to floors | m2 | 42.10 | 41.87 | 0.55% |
| Homogeneous tiles; to floors | m2 | 31.24 | 30.49 | 2.46% |
| Homogeneous tiles; to skirtings 100mm high | m | 17.02 | 17.26 | -1.96% |
| Shanghai Plaster; to floors | m2 | 40.39 | 39.33 | 2.70% |
| Ceramic tiles; to drops 100mm high | m | 1.00 | 1.00 | 0.00% |
| Porcelain tiles; to drops 100mm high | m | 7.30 | 7.30 | 0.00% |
| Internal Floor Finishes | | | | |
| Ceramic tiles; to floors | m2 | 39.83 | 39.03 | 2.05% |
| Porcelain tiles; to floors | m2 | 137.37 | 133.93 | 2.57% |
| Porcelain tiles; to drops 50mm high | m | 1.00 | 1.00 | 0.00% |
| Porcelain tiles; to skirtings 100mm high | m | 46.65 | 40.87 | 14.14% |


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| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| Timber strips; to floors | m2 | 120.33 | 117.31 | 2.57% |
| Timber strips; to skirtings 100mm high | m | 95.78 | 94.39 | 1.47% |

Table 2 shows the quantities comparison between Autodesk Revit and Cubicost TAS for external floor finishes and internal floor finishes. The floor finishes quantities to floors between both software are similar with a maximum of only 2.70% difference. Cubicost TAS has slightly lesser quantities compared to Autodesk Revit due to the modelling of wall thickness in Cubicost TAS included the thickness of cement plaster and paint and lead to the "Room" function applied the floor finishes to floors within the sides of cement plaster and paint instead of the side of the walls. The floor finishes to drops in both software are the same where the modelling of drops using "Wall: Architecture" in Autodesk Revit has the same result as "Vertical Floor Finish" in Cubicost TAS. However, the internal floor finishes to skirtings in Autodesk Revit have greater quantities compared to Cubicost TAS because the skirtings modelled with "Wall Sweep" overlapped with sliding doors as shown in Figure 2. Hence, QS should revise the model to in Autodesk Revit to it to ensure accurate skirting quantities.

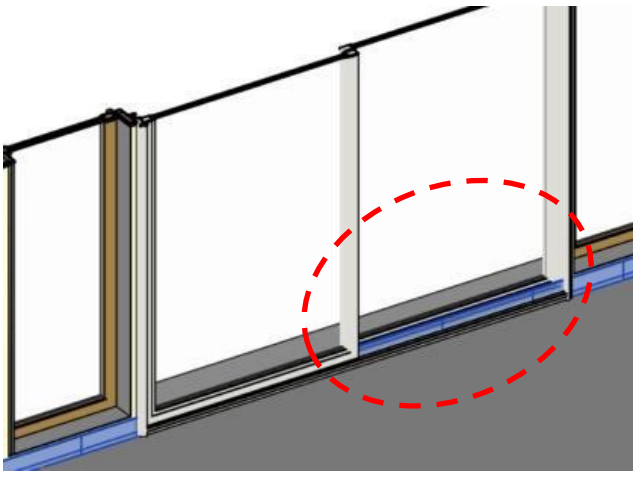

**Figure 2**: Wall Overlapped with Columns and Beam in Revit

**Table 3**: Ceiling Finishes Quantities Comparison between Revit and TAS

| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| External Ceiling Finishes | | | | |
| Skim coat to concrete soffits and sides and soffits of beams | m2 | 11.61 | 11.28 | 2.93% |
| Plaster board with weather shield paint | m2 | 12.37 | 12.37 | 0.00% |
| Moisture resistant plaster board with weather shield paint | m2 | 25.71 | 22.58 | 13.86% |
| Internal Ceiling Finishes | | | | |
| Plaster board with emulsion paint | m2 | 234.94 | 226.63 | 3.67% |
| Moisture resistant plaster board with emulsion paint | m2 | 54.72 | 55.25 | -0.96% |

Table 3 above shows the quantities comparison between Autodesk Revit and Cubicost TAS for ceiling finishes. The ceiling finishes obtained between Autodesk Revit and Cubicost TAS have slight differences as 2.93% and 3.67% which are acceptable. The "Automatic Ceiling" function in Autodesk Revit and "Room" function in Cubicost TAS results in similar quantities. However, the calculation of suspended ceiling in Autodesk Revit did not deduct the beams that overlapped with the suspended ceiling and ended up with excessive quantity with 13.86% of difference from Cubicost TAS. Lastly, the quantities of windows and doors obtained in number from Autodesk Revit and Cubicost TAS are the same. Autodesk Revit and Cubicost TAS are able to count the windows and doors modelled accurately. The QTO for roof covering and roof gutter for both types of software have no difference as the area of roof covering obtained from Autodesk Revit and Cubicost TAS is reliable if the modelling steps are appropriate. The modelling of roof gutter in Cubicost TAS with "Custom Line" able to obtain the same length as Autodesk Revit. Furthermore, majority of quantities for staircase structure and staircase finishes are unable to be obtained or are inaccurate in Autodesk Revit but is accurate in Cubicost TAS. However, the length of handrailing can be obtained in both software but Cubicost TAS obtained a shorter length due to the staircase modelled is not continuous and led to breaking of railing and resulted in a gap.

**Structural Elements**

Autodesk Revit is unable to model the excavation, thus it is also unable to generate quantities for excavation while Cubicost TAS has the tool to model the excavation and QTO. However, the QTO for filling of hardcore for both software is the same as the sketching of boundary lines of the ground slabs including


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hardcore layer in Autodesk Revit which has the same measurement and calculation method as Cubicost TAS.

**Table 4**: Pad Footing and Column Quantities Comparison between Revit and TAS

| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| Lean Concrete | m3 | 3.29 | 3.29 | 0.00% |
| Grade 25 reinforced in-situ concrete | m3 | 24.34 | 24.34 | 0.00% |
| Formwork; <0.25m high | m | - | 13.80 | - |
| Formwork; 0.25m – 0.50m high | m | - | 113.30 | - |
| Grade 25 reinforced in-situ concrete in column stumps | m3 | 1.53 | 1.55 | -1.29% |
| Grade 25 reinforced in-situ concrete in columns | m3 | 6.46 | 6.61 | -2.27% |
| Formwork to sides of column stumps | m2 | - | 19.94 | - |
| Formwork to sides of columns | m2 | - | 122.18 | - |

Table 4 above shows the quantities comparison of pad footings between Autodesk Revit and Cubicost TAS. The quantities of lean concrete blinding and RC concrete of Autodesk Revit and Cubicost TAS are the same with 0.00% difference. The modelling of pad footings in Autodesk Revit is only able to obtain the volume of RC concrete but not the length of formwork. However, modelling of pad footings with Cubicost TAS can generate quantities for both RC concrete's volume and formwork's length. Vassen (2021) also mentioned that the quantity of formwork is usually unable to be obtained from the BIM model. The volume of RC concrete obtained for column stumps and columns for both types of software are more or less similar but the volume obtained from Autodesk Revit are lesser than Cubciost TAS. The quantities of formwork for column stumps and columns are unable to be obtained from Autodesk Revit but is accurate in Cubicost TAS.

**Table 5**: Beams Quantities Comparison between Revit and TAS

| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| Lean concrete | m3 | 1.20 | 1.25 | -4.00% |
| Grade 25 reinforced in-situ concrete in ground beam | m3 | 14.34 | 14.35 | -0.07% |
| Grade 25 reinforced in-situ concrete in upper floor beam | m3 | 16.09 | 16.11 | -0.12% |
| Grade 25 reinforced in-situ concrete in roof beam | m3 | 10.46 | 10.50 | -0.38% |
| Formwork to ground beam 0.25m – 0.50m height | m | - | 42.60 | - |

| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| Formwork to ground beam 0.50m – 1.00m height | m | - | 247.35 | - |
| Formwork to upper floor beam | m2 | - | 211.67 | - |
| Formwork to roof beam | m2 | - | 178.12 | - |

Table 5 shows the quantities comparison of beams between Autodesk Revit and Cubicost TAS. The quantity of lean concrete for ground beam in Cubicost TAS is 4% or 0.05m3 more than Autodesk Revit because the lean concrete in Cubicost TAS did not deduct the volume where it intersected with the column stumps. However, the quantities of RC concrete for beams in both software are similar as the calculation method is the same by taking net length x width x height of the beams where net length is the length that has deducted the column stumps and columns, the height of ground beam is the height without deducting the thickness of ground slab, while the height of upper floor beam and roof beam is the height that has deducted the thickness suspended slab. The quantities of formwork for beams are unable to be obtained from Autodesk Revit but is accurate in Cubicost TAS.

**Table 6**: Slabs Quantities Comparison between Revit and TAS

| Elements | Unit | Revit Qty | TAS Qty | Difference |
|---|---|---|---|---|
| Mass Concrete | m3 | 1.00 | 1.03 | -2.91% |
| Grade 25 reinforced in-situ concrete in ground slab | m3 | 22.01 | 21.98 | 0.14% |
| Grade 25 reinforced in-situ concrete in upper floor slab | m3 | 23.64 | 23.53 | 0.47% |
| Grade 25 reinforced in-situ concrete in roof slab | m3 | 12.42 | 12.09 | 2.73% |
| Grade 25 reinforced in-situ concrete in roof kerb | m3 | 0.07 | 0.07 | 0.00% |
| Formwork to edge of ground slab | m | - | 38.43 | - |
| Formwork to soffit of upper floor slab <3.50m high | m2 | - | 114.19 | - |
| Formwork to soffit of upper floor slab 3.50m – 5.00m high | m2 | - | 34.01 | - |
| Formwork to edge of upper floor slab | m | - | 4.38 | - |
| Formwork to soffit of roof slab <3.50m high | m2 | - | 50.38 | - |
| Formwork to roof kerb | m2 | - | 1.30 | - |
| 0.25mm thick polythene sheet | m2 | 220.07 | 220.07 | 0.00% |


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Table 6 shows the quantities comparison of slabs between Autodesk Revit and Cubicost TAS. The quantities of concrete for slabs in both software are similar with a difference not more than 0.11m3 except for the quantity of RC concrete in roof slab. The volume of RC concrete for roof slab in Autodesk Revit is higher than Cubicost TAS due to the incapability to model the desired edge of slab and lead to greater quantity. The quantities of formwork for slabs are unable to be obtained from Autodesk Revit but is accurate in Cubicost TAS. The quantity of waterproofing in m2 for both software is the same as the sketching of boundary lines of the ground slabs including waterproofing layer in Autodesk Revit has the same measurement method as Cubicost TAS.

## CONCLUSION

Through this study, the BIM models are developed successfully and the comparison of QTO and limitations in modelling are analysed. It is found that the modelling process, methods and modelling experience for each BIM software are different. Some modellers' limitations in the BIM modelling can be addressed through manual checks. Hence, it is essential to manually verify the connection of elements to ensure they are correctly joined. The QTO results differ depending on the BIM software used. Certain quantities, such as formwork and excavation, are challenging to obtain in Autodesk Revit. The QTO of walls in Autodesk Revit did not deduct the columns and beams and lead to excessive quantities. However, Autodesk Revit, being a unified software covering Architectural, Structural, Civil, MEP, etc., is convenient and offers better visualisation of BIM models. In contrast, Cubicost TAS stands out in QTO as it offers more precise modelling tools for various elements.

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# TOWARDS DIGITAL FUTURE: UNLOCKING STRATEGIES TO INTEGRATE E-TENDERING IN THE CONSTRUCTION LANDSCAPE

**Nur Mardhiyah Aziz**[1]

[1]*Department of Quantity Surveying, Faculty of Built Environment,*
UNIVERSITI MALAYA, KUALA LUMPUR, MALAYSIA

## Abstract

The advancement of technology has introduced the electronic tendering process commonly known as e-tendering, as a promising approach in the construction industry. Despite its potential benefits, the adoption of e-tendering remains limited in Malaysia. This article intends to reveal the reasons behind the poor adoption of e-tendering in view of integrating improvement in the construction procurement process. Suitable strategies for successful e-tendering adoption will be proposed to transform the Malaysian construction industry into a digital future. Semi-structured interviews were conducted with 15 experienced construction industry players, each with at least five years of experience using the e-tendering system. The snowball sampling technique was employed to identify suitable respondents. Data collected were analysed using thematic analysis, revealing six main groups of strategies: people, process, work environment, service provider, cost and technology. These proposed strategies can serve as a practical guideline for the construction industry players seeking to adopt e-tendering systems. Additionally, they offer valuable insights for construction companies and policymakers in planning, revising, and prioritising appropriate strategies and practices for the future development or upgrading of e-tendering systems within the construction landscape. This study significantly contributes to the knowledge on e-tendering adoption, particularly in Malaysia, and provides valuable support for researchers, construction industry players, and policymakers in their efforts to embrace a digital future in the construction sector.

***Keywords***: e-tendering, construction industry, successful strategy

[1] Lecturer at University. Email: nurmardhiyah@um.edu.my

## INTRODUCTION

A wide range of technologies has dominated every sector, including the construction sector, to embark on the digital process. Tendering is one of the important processes in the construction life cycle. This process involves the submission of bids or proposals by contractors seeking to undertake a construction project after being selected by the client based on a qualifying offer (Chew, 2018). The introduction of e-tendering replaced the conventional paper-based tendering approach and offered substantial benefits such as improving the process and efficiency. Numerous researchers around the world have reported the benefits of the e-tendering (Mangitung *et. al.,* 2022; Mehdipoor, 2022; Sisofe *et. al.,* 2022). According to Tung *et al.,* (2021), digitisation has improved production in the construction industry.

By implementing the e-tendering system, the cost of preparing the tender documents has decreased as all the documents can be uploaded and downloaded through online platforms. It is estimated to save the tendering cost up to 42% of the original cost (M. Ashaari *et al.,* 2018). Tenderers can view the tender documents at anytime, anywhere, giving all users a sense of flexibility and convenience. In conventional tendering, every stage was carried out manually, increasing the chances of human error, like, inaccurate costing, incorrect formatting and late submission. Applying the e-tendering process can reduce the occurrence of unnecessary human error and increase the tendering process's efficiency (Tan & Suhana-Kamarudin, 2016). The concept of e-tendering has been introduced in the construction industry for years. According to Tan & Suhana-Kamarudin (2016), research shows that 57% of the respondents have experienced using the e-tendering system in Malaysia. Other researchers carried out a study to identify the reason for the lack of adoption of the e-tendering system from many different aspects such as the high initial cost (Lee, 2019; Wimalasena & Gunatilake, 2018), securities concern (Lee, 2019; Chew, 2018), reluctant to changes (Tan & Suhana-Kamarudin, 2016 and Lee, 2019) and lack of government standard and policies (Lee 2019; Wimalasena & Gunatilake, 2018). Researchers have proposed several improvement strategies in guiding the construction industry to migrate to the digital world; however, the implementation of e-tendering is still inadequate (Lee, 2019; Chew, 2018 and Yahya, et.*al.,* 2018).

Thus, this study was undertaken to understand the root cause of the low adoption of e-tendering, specifically in the Malaysian context, and to propose appropriate strategies to help the construction industry move towards the digital era.

## E-TENDERING

E-tendering is a digital system designed to facilitate the tendering process by utilizing an online platform for the exchange of necessary electronic

documentation. Is operational procedure closely mirrors the conventional tendering process, but with all processes conducted virtually through an internet. The key advantages of e-tendering adoption include shortened tender durations, enhance communication among stakeholders, high transparency through the tendering process, improved accuracy and quality of work, and reduced manual labour requirement (Chew, 2018). Figure 1 illustrates a comparative analysis of the timeframes involved using the e-tendering and conventional tendering system.

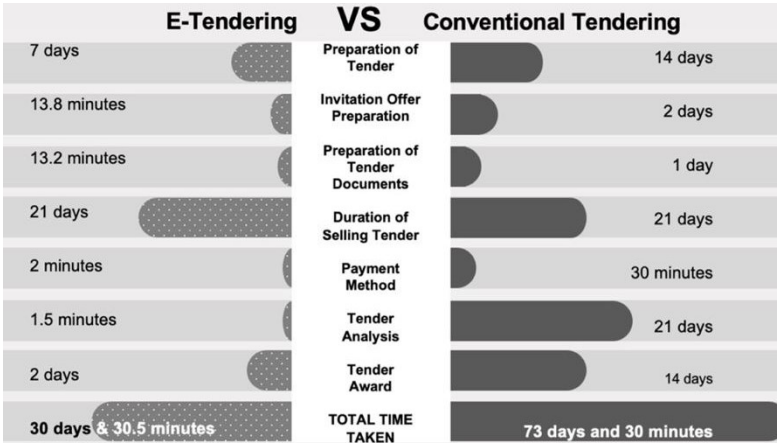


**Figure 1:** Average Tendering Process Duration for E-tendering System and Conventional Tendering

The use of e-tendering offers significant advantages in facilitating communication between clients and qualified tenderers. The digital platform enhances the sharing of essential project information, potentially reducing information leakage and minimising construction disputes (M. Ashaari et al., 2018). Chew (2018) added that e-tendering provides more accurate outcomes and ensure transparency compared to conventional tendering methods. This will potentially reduce computational errors, thereby enhancing the accuracy of work. Moreover, e-tendering reduced the usage of paperwork which lead to a decrease in labour-intensive tasks. Additionally, the automated system can improve the evaluation process, aiding in the selection of suitable tenderers for projects (M. Ashaari *et al.,* 2018). The advantages of e-tendering extend beyond improved communication and transparency. Research suggest that e-tendering can lead to cost savings and efficiency gains in the tendering process. By digitizing the procurement process, e-tendering can reduce the time and resources required for tender preparation, evaluation and award (Chan & Owusu, 2022). This an result


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in lower administrative costs, and faster project delivery, benefiting both clients and contractors.

Furthermore, e-tendering can improve the overall governance and accountability of the tendering process. The digital nature of e-tendering platforms allows for the easy tracking and auditing of tender activities, ensuring decisions are made transparently and in accordance with regulations (Sunmola & Shehu, 2020). This can help reduce the risk of corruption and improve the overall integrity of the procurement process.

## BARRIERS TO IMPLEMENT E-TENDERING

The slow adoption of e-tendering in developing countries, specifically Malaysia, has drawn the attention of researchers to find the factors behind this issue. A study by Mehdipoor *et. al.,* (2022), revealed that inadequate technology infrastructure like slow and limited internet connection, has limited the usage of e-tendering systems. The data security issue is another concern usually raised by the construction industry players. According to Omran (2020), the e-tendering process involves classified information, which makes it vulnerable to digital threats such as data breaches and unauthorised access.

Resistance to change is another typical response faced by most organisations when transitioning to the e-tendering system. This issue arises as people are comfortable with the current process and fear the unfamiliarity and uncertainty (Sunmola and Shehu, 2021). Besides, digital literacy is another prevalent barrier during the implementation of e-tendering. Everyone involved in the tendering process, like contractors, consultants, and suppliers, must have the right skills to use the e-tendering system successfully. Therefore, this requires comprehensive training and technical support to use it effectively. With technological advancement, Malaysia's construction industry and other developing countries are at the right time to push e-tendering implementation into practice. Thus, understanding the underlying issue is the first step to adopting an e-tendering system successfully. Table 1 summarises the barriers to implementing e-tendering in the construction industry.

**Table 1:** Barriers To Implement E-Tendering System

| Barriers | References |
|---|---|
| Lack of awareness | Mehdipoor *et al.,* (2022), Tran *et al.,* (2021), Sunmola and Shehu (2021) Kajendran (2022) Yevu *et al.,* (2021) |
| Lack of knowledge/ skills | Mehdipoor *et al.,* (2022), Tran *et al.,* (2021), Yevu *et al.,* (2021) |
| Resistance to change | Lee (2019), Mehdipoor *et al.,* (2022), Sunmola and Shehu (2021), Kajendran (2022) Yevu *et al.,* (2021) |
| Legal issue | Kajendran (2022), Mehdipoor et al (2022), Omran (2020), Sunmola and Shehu (2021) |

| Barriers | References |
|---|---|
| Lack of government policies and standards | Construction Industry Development Board (2022), Kementerian Kerja Raya (2022), Wimalasena & Gunatilake (2018), Tran *et al.,* (2021) Yevu *et al.,* (2021) |
| The disbelief in the reliability of e-tendering efficiency | Lee (2019), Wimalasena & Gunatilake (2018), Mehdipoor *et al.,* (2022), Sunmola and Shehu (2021) |
| High initial cost | Lee (2019), Chew (2018), Hassan (2021), Mehdipoor *et al.,* (2022), Kajendran (2022), Yevu *et al.,* (2021) |
| High maintenance costs | Lee (2019), Chew (2018), Tan & Suhana-Kamarudin (2016), Wimalasena & Gunatilake (2018), Mehdipoor et al (2022) |
| Securities issue | Chew (2018), Lee, (2019), Omran (2020), Kajendran (2022), Yevu *et al.,* (2021) |
| Incomplete technical coverage and infrastructure | Wimalasena & Gunatilake (2018), Mehdipoor et al (2022), Hassan (2021), Sunmola and Shehu (2021), Kajendran (2022) Yevu *et al.,* (2021) |

## STRATEGIES TO UNLOCK THE INTEGRATION OF E-TENDERING

Approaches from different aspects are required to enhance and successfully adopt the e-tendering system, spanning from people, financial, processes and procedures, and technological aspects. According to Chan & Owusu (2022), factors like project team planning, stakeholder involvement, change management, technical outsourcing, effective organisational policy and strategic plan, business process innovation and external collaboration, organisational learning, and relationship development need to be considered in formulating successful strategies for e-tendering implementation.

Among the benefits obtained when using e-tendering includes minimising the evaluation error (M. Ashaari et al., 2018; Chew, 2018), enhancing the efficiency of works (M. Ashaari et al., 2018), shorten the time for the tendering process (Chew, 2018; Lee, 2019) and improve communication (Chew, 2018). Form the literature, 12 strategies were identified and summarised in Table 2 below.

**Table 2:** Summary of the Strategies

| Strategies | References |
|---|---|
| Skill | ● Hiring experts (M. Ashaari *et al.,* 2018)<br>● Provide education and training (Lee, 2019; M. Ashaari *et al*., 2018; Wimalasena &Gunatilake, 2018; Chew, 2018)<br>● Awareness campaign (Ibem & Laryea, 2016)<br>● Provide comprehensive guidelines (M. Ashaari *et al.,* 2018) |


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| Strategies | References |
|---|---|
| Staff | ● Staff turnover (Yahya *et al.*, 2018)<br>● Attitude of staff when using e-tendering (Yahya *et al.*, 2018)<br>● Confidence to use new technology (Yahya *et al.*, 2018) |
| Leadership | ● Support from higher management (Yahya *et al.*, 2018; M. Ashaari *et al.,* 2018; Wimalasena & Gunatilake, 2018)<br>● Support from the government (Yahya *et al.*, 2018; M. Ashaari *et al.,* 2018; Wimalasena & Gunatilake, 2018)<br>● Organisation policy (Yahya *et al.*, 2018)<br>● Higher management commitment (Yahya *et al.*, 2018; M. Ashaari *et al.,* 2018; Wimalasena & Gunatilake, 2018) |
| Practice | ● Implementing Electronic Commerce Acts (Lee, 2019)<br>● Recognising e-signature (Wimalasena & Gunatilake, 2018) |
| Procedure | ● Prevention of tampering with documents (Yahya *et al.*, 2018)<br>● Improve data secrecy (Yahya *et al.*, 2018) |
| Structure | ● Cross-disciplinary communication (Yahya *et al.*, 2018)<br>● Standard tendering process (Yahya *et al.*, 2018)<br>● Create an incentive-based policy (Lee, 2019)<br>● Implement a compulsory staging policy depending on project size (Lee, 2019) |
| Awareness | ● Publicity about e-tendering (Yahya *et al.*, 2018)<br>● Awareness of best practice solutions (Yahya *et al.*, 2018) |
| Collaboration | ● Collaboration between the service provider and CIDB for system enhancement (Lee, 2019) |
| Technical | ● Simplify and organise the system (M. Ashaari *et al.,* 2018)<br>● Training among the tenderer (Yahya *et al.*, 2018) |
| Investment fee | ● Value management adoption (Lee, 2019)<br>● Gradual budget allocation for promotion (Lee, 2019)<br>● Reduction in purchase and installation price (Chew, 2018)<br>● Demand from tenderer (Yahya *et al.*, 2018) |
| System & Software | ● Incorporate security measures within the e-tendering system (Chew, 2018)<br>● Cooperation between CIDB and third-party tender service providers for system upgrades (Lee, 2019) |
| Networking | ● Improve the quality of internet service (Ibem & Laryea, 2016)<br>● Use software-as-a-service (SaaS) (Ibem & Laryea, 2016)<br>● Availability of high-speed internet (Wimalasena & Gunatilake, 2018; Ibem & Laryea, 2016) |

To successfully adopt e-tendering, organisations must focus on several key strategies like ensuring their staff are adequately trained to use the system (Lee, 2019; M. Ashaari *et al*., 2018). Having a strong leadership is also crucial, with leaders championing e-tendering and integrating it into the organisation. Establishing clear procedures, along with rising awareness among staff and stakeholders (Yahya *et al.*, 2018) about the benefits of e-tendering can help overcome resistance to change. Aligning the organisation's structure with e-

tendering goals, collaborating with others, and investing in the necessary resources are also vital. Additionally, considering the financial implications, cost associated with e-tendering platforms, and selecting the right system and software are key factors for successful adoption. By addressing these strategies, organisation can improve their chance of effectively adopting e-tendering.

## METHODOLOGY

This study is exploratory in nature and adopts an exploratory research perspective. A series of semi-structured interviews will serve as this study's primary data collection method. Initially, a literature review was performed to provide the researchers with a better understanding of the relevant topic (Lim, Aziz, & Mohd-Rahim, 2022). The review included articles published in databases, such as Scopus, Emerald and Science Direct, conference proceedings, dissertations, books, official reports, and the Government's official websites. Findings from the literature review were used in designing the interview questions. The semi-structured interview was chosen as it provides the researcher with a deeper understanding of the issues faced in the e-tendering system in Malaysia. Furthermore, a semi-structured interview session allows the interviewee to express their viewpoint based on their experience (Pollock, 2019), thus adding to a more comprehensive list of workable solutions for successfully integrating e-tendering. There are 3 sections involved in the interview process, starting with the interviewees' background, followed by the barriers to implementing e-tendering and the suitable strategies for integrating e-tendering into the construction industry landscape.

In this study, interviewees with more than 10 years of experience in the construction industry and who have experience in using e-tendering were chosen to get meaningful data. Initially, email and phone calls were used to approach the potential interviewees. On top of that, the snowball sampling technique is adopted to find suitable interviewees. A total of 15 interviewees were involved and the overview of the respondents' profiles are tabulated in Table 3 below. The semi-structured interviews were carried out physically and via Zoom meetings, depending on the interviewee's preference. The interview session took around 50 to 80 minutes. The interview sessions were recorded with the interviewees' permission for researcher reference.


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**Table 3:** Interviewees' Profile

| Interviewee | Position | Type of Organisation | Highest Level of Education | Working experience |
|---|---|---|---|---|
| 01 | Director | Private sector QS Consultant | Bachelor Degree | 30 |
| 02 | Project manager | Contractor | Bachelor Degree | 11 |
| 03 | Quantity surveyor | Government sector | Master | 24 |
| 04 | Quantity Surveyor | Private sector QS Consultant | PHD | 25 |
| 05 | Quantity Surveyor | Private sector QS Consultant | PHD | 20 |
| 06 | Associate Director | Private sector QS Consultant | Bachelor Degree | 29 |
| 07 | Contractor | Contractor | Bachelor Degree | 14 |
| 08 | Quantity Surveyor | Private sector QS Consultant | Bachelor Degree | 15 |
| 09 | Director | Private sector QS Consultant | Bachelor Degree | 40 |
| 10 | Quantity surveyor | Government sector | PHD | 18 |
| 11 | Project manager | Contractor | Bachelor Degree | 18 |
| 12 | Director | Private sector QS Consultant | Bachelor Degree | 29 |
| 13 | Contractor | Contractor | Bachelor Degree | 28 |
| 14 | Project manager | Contractor | Master | 11 |
| 15 | Contractor | Contractor | Bachelor Degree | 20 |

Collected data was analysed using the thematic analysis, which involved six steps: (i) familiarisation, (ii) coding, (iii) themes generations, (iv) reviewing the themes, (v) defining the themes and (vi) writing up. Before the thematic analysis was performed, data from the semi-structured interview were transcribed. After that, the information and keywords are highlighted and assigned with relevant codes. These codes will assist the researcher in forming a thorough understanding of the study. To produce pertinent themes, some codes are combined. The themes are then checked to make sure they are accurate.

## RESULTS AND DISCUSSION

### *Barriers to Implement e-Tendering*

From the thematic analysis, 8 codes emerged, which are further grouped into four main themes. The themes are people, process and procedure, financial and technology. Figure 2 summarises the process of the thematic analysis.

The first barrier identified is people. These include the lack of awareness about the benefits of e-tendering and the availability of the current technology, shortage of trained technical personnel, reluctance to shift to e-tendering, perception about the e-tendering method and disbelief in its efficiency. Interviewees 02, 03, 08, 11 and 13 experienced a lack of awareness of the benefits of e-tendering. Interviewee 11 mentioned "… there was lack of promotion and awareness among the construction industry players…". According to interviewees 02 and 08, this issue arises because they are unfamiliar with the IT system. On the other hand, interviewees 02, 05, 09, 14 and 15 experienced resistance to change. Lack of exposure was the main reason for not adopting e-tendering, according to interviewees 03 and 12. Accordingly, interviewees 05 and 15 resisted to adopt the system since they were already packed with the workload in the firm. Perception as a waste of time was the reason interviewees 09, 13 and 10 still opted for conventional tendering.

The second barrier is the process and procedure. Issues with digital contract enforcement, insufficient law for e-tendering, disputes, lack of standardisation on e-tendering procedures and lack of policies about electronic contracts and e-commerce. Interviewees 03, 06, 09, and 10 highlighted the barrier of legal issues. Although the acts had been enacted, interviewees were still unfamiliar with the latest legal act regarding online transactions, which made the tendering process more complex. The reason might be the acts were not widely introduced to all construction industry players. Furthermore, most interviewees (01, 02, 04, 05, 07, 08, 11, 13, 14) encountered a lack of government policies and standards. According to interviewees 01, 12, and 14, "…government should develop a standard procedure for all types of construction projects…". According to interviewees 02, 08, 11, 13 and 14, there is currently no standardisation on the e-tendering procedures to which the tenderer could refer. Interviewees 05 and 12 stated the lack of government policy on the enforcement to adopt the e-tendering system. Accordingly, interviewees 05, 08 and 14 did not believe in the efficiency of e-tendering. The interviewees were sceptical about reliability and efficiency since the system is not widely used in the Malaysian construction industry.

The third barrier is financial. This includes the high initial cost, high maintenance cost and the cost of purchasing compatible software and hardware. Interviewees 01, 03, 10, 12 and 13 encountered the barrier of high initial and maintenance costs. According to them, they experienced a lack of funding to purchase the software and hardware as well as to train their staff to ensure the companies are ready to adopt e-tendering.


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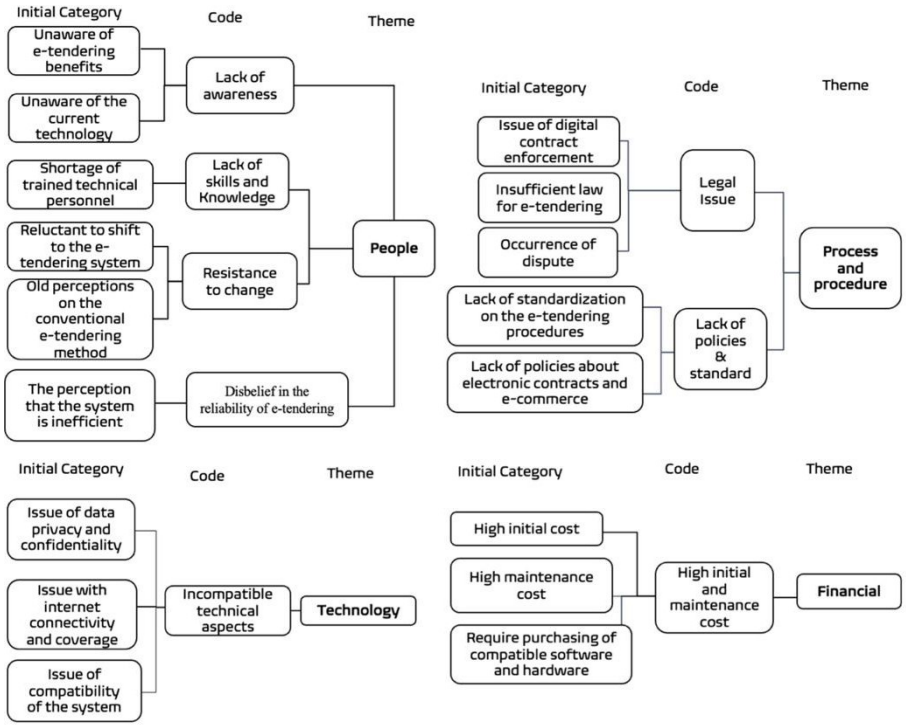


**Figure 2:** Summary of the Barriers

The final barrier is in terms of technology. These include data privacy and confidentiality issues, internet connectivity and coverage and the combability of the system. The issue of limited technical coverage of the e-tendering process is faced by interviewees 03, 04, 06, 07, 11 and 15. Interviewee 04 faced an issue with the low bandwidth coverage of the internet connection since the e-tendering transaction was online. The comprehensiveness of the e-tendering to be compatible with various electronic devices was the issue faced by interviewees 06, 07 and 15. This is because the software and hardware used might not be up to date for a small company.

### *Strategies to Unlock the Integration of e-Tendering*

Interviewees were asked about the possible strategies to improve the implementation of e-tendering in Malaysia. Based on the findings, the proposed strategies to unlock the integration of e-tendering were categorised into 4 themes: people, process and procedures, financial and technology. There are 5 proposed strategies for the people theme: hiring experts, education and training, an awareness campaign and providing comprehensive guidelines. M. Ashaari *et al.,* (2018), have emphasised the need to hire experts or skilled personnel in assisting the organisation during its transition to the new system. With this, issues relating

to the lack of technical knowledge can be avoided, thus increasing the organisations' likelihood of using e-tendering. Education, training and awareness campaigns are among other efforts the organisation should make to encourage the elderly staff who are reluctant to use e-tendering (M. Ashaari *et al.,* 2018; Hassan, M., 2021). As highlighted by interviewee 05 "…provide training to employees internally…". These efforts can potentially alter their negative perceptions towards e-tendering.

There are 5 strategies for the process and procedure theme that have been highlighted by the interviewees: the enforcement of the Electronic Commerce Acts, recognition of e-signature, having a standard e-tendering process, implementing compulsory staging policy depending on project size and cooperation to upgrade the system upgrade. Legislation has been established in Malaysia to support the e-tendering application. Nevertheless, several issues occur during its enforcement (Mehdipoor et al., 2022; Chan, & Owusu, 2022). The enactment of the 1997 Computer Crime Act has restricted unauthorised personnel access to the e-tendering system, thereby decreasing legal concerns. In 2012, the act was incorporated into the E-Commerce Law and Copyright Law to establish a comprehensive framework for cybercrime legislation in Malaysia (Mehdipoor et al., 2022; Lee, 2019). On top of that, the Electronic Commerce Act 2006 has acknowledged the importance of digital messages in online transactions. In 1998, the Digital Signature Act 1997 (DSA 1997) was enacted to validate digital signatures in Malaysia's electronic transactions (Wimalasena & Gunatilake, 2018). On top of that, all construction projects in every organisation should use e-tendering to increase the trust level in the system among the staff (Yahya *et al.*, 2018; M. Ashaari *et al.,* 2018; Wimalasena & Gunatilake, 2018). On the other hand, the local government may support e-tendering by establishing an incentive-based policy and staging compulsory policy. Staging compulsory policy will enhance the users' confidence in the system, especially for small-sized contractors. It is due to the involvement of the higher-grade contractor and then followed by the lower-grade contractor after a certain period. The staging policy is expected to help build confidence among small-sized contractors and give them ample time to prepare their staff's infrastructure, hardware, software and training before embarking on the e-tendering (Lee, 2019).

In terms of financial aspects, there are 3 proposed strategies: the adoption of value management, support from the government in terms of finances and reasonable purchase of software and hardware infrastructure. A value management method should be used to balance the financial resources available and the need to upgrade the e-tendering system to the tender review stage. Due to the potential financial challenges faced by small-size contractors, the government should offer incentives such as subsidies for facility acquisition and software installation costs (Lee, 2019). Interviewee 01 has mentioned that


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"currently, there is no financial support from government….". The government can do this by regulating the sale of e-tendering software and hardware infrastructure to maintain control over purchase prices. The availability of standardised and reasonable facilities and software prices will motivate more organisations to adopt the system (Chew, 2018).

The 5 proposed strategies for the technological aspect are hiring experts and professionals for system upgrades, cooperating between the service provider and CIDB for system enhancement, improving the quality of internet service, utilisation of SaaS and the availability of high-speed internet. A stable and fast connection to the internet is crucial for e-tendering, particularly for information sharing and submitting the online bid. The internet service provider should elevate their services to tackle the bandwidth issue and provide a robust internet connection with at least 100 megabytes per second (Wimalasena & Gunatilake, 2018). On top of that, in handling the issue with technological aspects, hiring a professional and an experienced e-tendering service provider is necessary to ensure the establishment of the system in the organisation. Accordingly, Ibem & Laryea (2016), encourage the use of tailored made internet-based software, as this allows clients to access the system by rental, eliminating the concerns on the infrastructure ownership and maintenance cost that require high initial expenses. Table 4 summarises the strategies to unlock the integration of e-tendering into the construction landscape.

**Table 4:** Summary of Strategies to Integrate e-Tendering

| Strategies | Code | Theme |
|---|---|---|
| Employ skilled and experienced staff | Hiring experts | **People** |
| Hired personnel with an e-tendering background | | |
| Provide education and training to tenderers to use the system | Education and training | |
| Understand the advantages and significance of using e-tendering | Awareness campaign | |
| Promotional talk on the benefits of e-tendering | | |
| Provide a comprehensive guideline | Comprehensive guideline | |
| Invest in a reliable e-tendering system to increase staff's confidence level in using e-tendering | Improve staff's confidence | |
| Implementing Electronic Commerce Act | Enforce Electronic Commerce Acts | **Process & Procedures** |
| Recognising the e-signature | Recognition of e-signature | |
| Standardise the e-tendering process | Standard e-tendering process | |

| Strategies | Code | Theme |
|---|---|---|
| Divide the e-tendering implementation into a few phases according to the project size | Implement compulsory staging policy depending on project size | |
| Collaboration between a service provider and CIDB for system upgrade | Cooperation for system upgrade | |
| Implement value management in reducing the cost required | Value management adoption | **Financial** |
| Government's financial assistance | Support from government | |
| Reduction of the installation cost | Reasonable price | |
| Reasonable installation cost | | |
| Hiring experts for system upgrades and maintenance | Hiring experts | **Technology** |
| Collaboration between the service provider and CIDB for system enhancement | Collaboration between the service provider and CIDB for system enhancement | |
| Using user-friendly system | | |
| Improve the quality of the internet service | Improve the quality of internet service | |
| Use SaaS to improve the procurement process | Use SaaS | |
| Install a high-speed internet connection in the company | Availability of high-speed internet | |

## PROPOSED STRATEGIES

To successfully integrating e-tendering into the construction landscape requires a comprehensive and holistic approach encompassing people, process and procedure, and financial and technological aspects. Neglecting any of the aspects may compromise the successful application of the e-tendering system. Investing in the people aspect is crucial in integrating e-tendering into the construction landscape. This involves providing comprehensive training and education to the personnel involved, which will empower individuals with the necessary skills to navigate the system effectively. This will further reduce the issue of resistance to change and, eventually, boost the confidence level. Streamlining the e-tendering process is another critical component in the enhancement effort. Standardising the tendering process, enforcing the Electronic Commerce Act and implementing the policies will ease the process of e-tendering integration.

Understanding the financial aspects to successfully integrating e-tendering into the construction is essential. Reduction in the purchasing and maintenance cost can become an initial step for the organisation to embark on a new system that is more efficient and undoubtedly enhances the overall performance of the tendering process. The technological aspect, which involves


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optimising the digital infrastructure and cooperation with CIDB and professionals, will reduce the learning curve associated with adopting the e-tendering system. Table 5 shows the strategies to integrate the e-tendering system into the construction landscape.

**Table 5:** Successful e-Tendering Strategies

| Theme | Barriers | Strategies |
|---|---|---|
| People | Lack of Awareness<br>Lack of Skills and Knowledge<br>Resistance to Change<br>Disbelief in the Reliability of e-tendering | ● Hiring experts<br>● Provide education and training<br>● Awareness campaign<br>● Provide comprehensive guidelines Development of confidence to use new technology |
| Process and Procedure | Legal Issue<br>Lack of Policies and Standards | ● Enforce Electronic Commerce Acts<br>● Recognition of e-signature<br>● Standard e-tendering process<br>● Implement compulsory staging policy depending on project size |
| Financial | High Initial and Maintenance Cost | ● Value management adoption<br>● Support from government<br>● Reasonable price |
| Technology | Incompatible Technical Aspects | ● Hire experts<br>● Collaboration between the service provider and CIDB for system enhancement<br>● Improve the quality of internet service<br>● Use SaaS<br>● Availability of high-speed internet |

## CONCLUSION

This study revealed the issue behind the lack of e-tendering adoption among the industry players, specifically in the Malaysian context. The study identified barriers, which is an essential first step in moving towards the digital future. The fundamental discoveries of this research proposed 4 strategic categories that the construction industry players and policymakers can focus on to implement e-tendering in the construction process. The proposed strategy is an initial step for the construction industry to prioritise their strategies in developing a robust strategic plan. The industry needs to adapt to the e-tendering strategies accordingly to avoid becoming stagnant and maintain competitiveness. Furthermore, this research has extended the knowledge regarding the existing barriers during the implementation of e-tendering in Malaysia. The list of the

barriers can be used as a foundation for other researchers to further understand the root cause of this issue.

Future research could focus on assessing the effectiveness of the proposed strategies in real world implementation. This could involve case studies to understand how these strategies are adopted and their impact which will provide valuable insight to policy makers and construction industry players.

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# ANALYZING THE ISSUES OF E-TENDERING IMPLEMENTATION IN PUBLIC-PRIVATE PARTNERSHIP PRACTICE: A PRELIMINARY STUDY IN MALAYSIA

**Nurul Wahida Mat Aron[1], Faizul Azli Mohd Rahim[2], Nur Mardhiyah Aziz[3]**

[1,2,3]*Center for Building, Construction & Tropical Architecture (BuCTA), Faculty of Built Environment,*
UNIVERSITI MALAYA

## Abstract

Public Private Partnership (PPP) has become a popular choice for policymakers in implementing important public projects, especially when it comes to the shortage of government funding resources and where it is necessary to counter public project inefficiency. However, the PPP tendering period, spanning from contract advertisement to contract award, tends to be lengthy due to reliance on paper-based tendering, with e-tendering not being fully utilized. Therefore, this study aims to enhance the understanding of issues related to e-tendering within the context of PPP practice in Malaysia. The research approach begins with a qualitative exploration through literature review and semi-structured interviews with five selected participants from various grades in the public sector, each possessing a minimum of three years of experience in PPP projects. The study identifies factors influencing e-tendering implementation, categorized into people, process, technology, and environment. It emphasizes the importance of IT literacy, consistent processes, suitable technology infrastructure, and organizational support. The readiness for e-tendering varies among participants, with some expressing optimism and others emphasizing the need for policy reinforcement. The outcomes of this study suggest the need for further exploration into the factors that PPP practitioners require before the implementation of an e-tendering system in PPP procurement processes.

***Keywords:*** Public Private Partnership, e-tendering, preliminary study, thematic analysis

[2] Corresponding Author Email: azli@um.edu.my

# INTRODUCTION

Public Private Partnership (PPP) is now an alternative procurement option for Governments worldwide, addressing infrastructure development and becoming a popular procurement approach (Das, Singh, & Jawed, 2022; Ruparathna & Hewage, 2015). A carefully designed and managed PPP contract is extremely effective in distributing the financial burden and operational risk of the project between the public and private sectors, enhancing the value for money, and reducing the development costs (Kalva, Brigis, Kruks, & Smits, 2022; Ramli, Adnan, Baharuddin, Bakhary, & Rashid, 2022; Tajul Ariffin, Mohd, Mustaffa, Bandi, & Mei Chee, 2019). The most critical stage in PPP procurement is the tendering stage as the PPP tendering procedure is more complicated and costlier compared to the traditional process in terms of the lengthy procurement period and lack of transparency during the tender process which is due to the manual process (Khaderi, Bakri, Abd Shukor, Mohamad Kamil, & Mahbub, 2019; Nordin, Ahnuar, Masrom, & Ali, 2023; Tolstolesova, Glukhikh, Yumanova, & Arzikulov, 2021).

With the widespread adoption of the internet, governments have seized the opportunity to modernize and offer traditional services directly online through digitalization. Hence, there's a compelling case for the digitalization of PPP tendering through the implementation of an electronic tendering (e-tendering) system. This transition is expected to enhance process efficiency, cost reduction, and overall accuracy while fostering heightened transparency (Issabayeva, Yesseniyazova, & Grega, 2019; Ratnawati, Setiawan, Taufik, & Mansoni, 2020). Notably, electronic tender awards are not yet common due to the relative novelty of e-tendering implementation in Malaysia (Ahmad, Abul Hassan, & Ismail, 2023; Soong, Ahmed, & Tan, 2020). Therefore, this study aims to comprehensively comprehend the issues linked to e-tendering within the context of PPP practices in Malaysia, specifically from the perspective of government personnel.

# LITERATURE REVIEW

## Public Private Partnership (PPP) Background

As PPPs have become an increasingly popular way to deliver public services and infrastructure projects, it is an increasingly popular choice for policymakers in implementing important public projects especially when it comes to the shortage of government funding resources and where it is necessary to counter public project inefficiency (Hashim, Sapri, & Ab Azis, 2019; Liu, Guo, Chen, & Martek, 2021; UKAS, 2023). PPPs have been practiced globally to achieve various objectives which include promoting infrastructure development, generating quality and funds, increasing construction and operational efficiencies, improving service delivery, reducing costs, and most importantly sharing risk

between the public and private sectors (Mohd Som, Omar, Ismail, & Alias, 2020). PPP involves the collaboration between public sector entities and private sector firms whereby a stand-alone business is created, funded, and managed by the private sector to develop an asset or provide services to the government and the public (UKAS, 2023a).

Officially, PPP in Malaysia was implemented in 2006 under the Ninth Malaysia Plan, and in the Tenth Malaysia Plan, 52 high-impact projects worth the sum of RM63 billion were to be executed via PPP (Musawa, Ismail, & Ahmad, 2017) and continue to be one of the construction procurement methods for public projects until now. A report by the World Bank (2022), stated that a total of 12 PPP projects in Malaysia reached financial closure with a total investment commitment of USD$4,739,000,000 (RM22.3billion). While a report from PPP Knowledge Lab (2021), stated that a total number of 126 PPP projects in Malaysia have reached financial closure since 1990 with a total investment of US$53,718 million (RM253.8billion). Currently, a total of 167 PPP projects are under construction/operation in Malaysia (UKAS, 2023b).

PPP offers several benefits that encourage collaboration with the private sector. Among these advantages, PPP is very effective for time-saving (O'shea, Palcic, & Reeves, 2019; Štěrbová, Halík, & Neumannová, 2020). If the projects are completed according to the contracted period, the consortium can start generating revenue by opening the facilities or services to the public. This will encourage the private sector to complete the project earlier. Financing the project through PPP also helps to accelerate project completion, and the private sector can profit after the project is completed (Tajul Ariffin et al., 2019). PPP is also a way how public sector can increase the effectiveness of infrastructure services and can be an engine of economic growth (Kalva et al., 2022).

**Public-Private Partnership (PPP) Problems**

PPP projects are delivered faster, and more cost-effectively compared to the traditional approaches generally focused on the construction period after the contract award. However, the tendering period between contract advertisement and contract award take longer time (Flannery et al., 2019). The most critical stage in PPP project procurement is the tendering stage with five problems identified during the tender stage which are complicated and costlier process; lengthy procurement period; lack of transparency; uncompleted projects; and open tender is not fully applied (Khaderi et al., 2019; Štěrbová et al., 2020). These problems in the tender process are due to the PPP procurement process that is usually carried out as paper-based tenders and manually (Bala & Dahiru, 2013; Cazalet & Zapatrina, 2021; UKAS, 2024).

Digitalization is a component of the wider modernization trend that has been occurring recently throughout the world. This trend toward digitalization


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with digital technology and artificial intelligence (AI) is particularly noticeable concerning the development of e-procurement for traditional public procurement (Alashwal, Mohd-Rahim, Karim, & Loo, 2020; Tolstolesova et al., 2021; Zainon, Lun, Zaid, Myeda, & Aziz, 2019). Therefore, problems in the PPP tendering process can be solved by implementing an electronic tendering (e-tendering) system. This e-tendering can be used to replace the manual form of PPP procurement procedure as e-tendering is one of the IT techniques that construction industry experts have emphasized to help change the industry's culture towards greater efficiency, transparency and modernization (Kazaz, Inusah, & Ulubeyli, 2022) in improve procurement procedures and process.

### E-tendering

Many studies have shown the benefit of e-tendering over manual traditional tendering processes (Aduwo et al., 2020; Fazekas & Blum, 2021; Ratnawati et al., 2020). During Tun Dr. Mahathir Mohamad's leadership as the Malaysian Prime Minister, the Multimedia Super Corridor (MSC) was established in 1996 under the Seventh Malaysia Plan as a project to enhance the ICT industry and introduce e-procurement as one of its flagship initiatives projects where transforming manual public procurement into electronic procurement (e-procurement) (Ahmad et al., 2023; Singh & Chan, 2022). The e-procurement system used in Malaysia by the Ministry of Finance Malaysia, known as ePerolehan was launched in September 1999 (MOF, 2016). However, e-tendering in the Malaysian construction industry has developed up to the second stage which involves two-way communication between clients and tenderers, excluding the award stage (Tan & Suhaida, 2016).

As there are also many challenges in implementing e-tendering (Al-Yahya, Skitmore, Cattell, & Bridge, 2018; N. Hashim et al., 2020; Kajendran, 2022; Maepa, Mpwanya, & Phume, 2023), Malaysian researchers also gaining interest in further research on e-tendering in Malaysian construction industry context (Ahmad et al., 2023; Deraman, Wang, Yap, Li, & Mohd-Rahim, 2019; Soong et al., 2020; Tan & Suhaida, 2016). Although the Malaysian Ministry of Finance has successfully implemented public e-procurement, but it is still unacceptable, and the system continues to be peculiar (Ahmad et al., 2023; Soong et al., 2020). Therefore, this study will focus on the implementation of e-tendering to improve the PPP procurement process.

## RESEARCH METHODOLOGY

The rationale behind employing a preliminary study design was to delve deeply into the perspectives and issues of individuals involved in PPP projects and electronic tendering processes. This approach was chosen due to its aptness to explore practitioners' attitudes and expert opinions (Creswell, 2021). A

comprehensive literature review was conducted to establish the study area and existing information available on the topic. The review included articles published in several databases, including Scopus, Web of Science, and Google Scholar. The search article started in 2013 till 2023 using specified keywords such as e-tendering, electronic tendering, e-procurement, PPP, and tender process, with Boolean search commands of "and" and "or". The Mendeley and Microsoft Excel software were used for data extraction and analysis. Findings from the literature review also served as the input for semi-structured interview questions.

Following this, a qualitative method approach was applied involved conducting interviews with expert practitioners to explore the research area further and obtain a better understanding of current practices and phenomena in Malaysia. According to Piaw, (2022) a semi-structured interview is when the interviewer not only several formal questions that have been prepared before the session but is also given the freedom to question and explore the answers given by the participants in a more in-depth manner. The semi-structured interview was used as this approach allowed for flexibility in exploring participants' experiences, opinions, and suggestions regarding e-tendering in the context of PPP practice in Malaysia.

The semi-structured interviews were conducted using a purposive sampling technique to select participants from the public sector. Five participants who have at least three years of experience in PPP projects in Malaysia were chosen based on their expertise and experience in PPP projects in Malaysia, representing various grades within the public sector. The participants were selected to ensure a diverse range of perspectives and insights related to PPP procurement. Their backgrounds are presented in Table 1.

Potential participants were contacted to seek their interest and agreement to participate, and the objectives of the interview were explained by the researcher. The interviews were conducted face-to-face and took a duration of approximately 40-60 minutes per session. The interviews were audio-recorded to ensure accuracy in capturing participants' responses and facilitate subsequent data analysis. The interviews were conducted in English.

**Table 1:** Background of Participants

| Respondent | I | II | III | IV | V |
|---|---|---|---|---|---|
| Role in PPP project procurement | Involved in project procurement for health and social sector | Coordinate with end user of the project implemented via PPP | Project manager to manage the PPP project procurement | Government officer who negotiates for the PPP projects | Evaluate PPP proposal papers and negotiate with the |


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| Respondent | I | II | III | IV | V |
|---|---|---|---|---|---|
| | | | | | private sector |
| Able to define & describe PPP | Yes | Yes | Yes | Yes | Yes |
| Years Experience | 3 years | 8 years | 5 years | 4 years | 10 years |
| Able to define & describe e-tendering | Yes | Yes | Yes | Yes | Yes |
| Believe e-tendering can change manual tendering process? | Yes | Yes | Yes | Not sure | Yes |
| Experience in using e-tendering | No | No | No | No | No |
| Ready to implement e-tendering | Yes | Yes | Not sure | No | Yes |

The questions were designed to allow participants to provide their expert knowledge on the e-tendering process in PPP procurement practice including the practice of the PPP procurement process; the understanding of the e-tendering concept and issues of the implementation of e-tendering in the PPP process.

All the participants were assigned codes to protect their anonymity and the interviews were transcribed verbatim. A summary of the transcription was then emailed to the Participants to ensure its accuracy. This was done in such a way as to ensure the meaning was not compromised by being taken out of context. The data were manually analyzed to identify key themes and concepts that could be subsequently followed up.

All participants are knowledgeable in PPP and e-tendering, but only one is not sure that e-tendering can change manual tendering. None of them ever use e-tendering because of the unavailable system, however, three of them are ready to implement e-tendering in their work process.

## FINDINGS AND DISCUSSION

The results derived from the content analysis, revealed several findings regarding e-tendering in PPP practice in Malaysia.

### Public-Private Partnership as Best Procurement Practice

All of the Participants I, II, III, IV, and V are familiar with PPP because they are directly involved in PPP projects. They are involved in several PPP models such as build-operate-transfer, build-own-operate-transfer, build-own-operate, and built-lease-manage-transfer. All participants believe that PPP is the best project procurement method for public infrastructure projects compared to other project

procurement methods. Participants I stated that PPP offers a 'solution' to reduce burdens on governments by sharing significant project risks. Meanwhile, Participant II mentions that PPP complements the traditional procurement methods; however, depending on the model, the projects cover the whole life cycle of the project, which traditional procurement lacks.

According to Participant III, when comparing both methods, the traditional tender method is much easier because the process is straightforward. However, PPP is much easier to implement as it does not involve government money at the initial stage of implementation, and the project is completed according to the timeframe since the contractor will get paid after the project is completely built and handed over to the government. Even though the PPP tender process is more complex and takes longer, the project experiences fewer delays and is completed faster compared to traditional procurement, making PPP tenders more cost and time-saving. This opinion is similar to the discovery from (Štěrbová et al., 2020) in their study of comparing traditional procurement with PPP.

Meanwhile, Participant IV mentions that PPP helps reduce the fiscal burden of the government. Participant V also believes that PPP is the best method because the duration of a project is long and includes all necessary costs, especially maintenance costs. In PPP, the maintenance costs are already incorporated, while in other methods, the costs are separated and only the building cost is calculated. This finding suggests that PPP is widely recognized and valued for its potential to deliver successful infrastructure projects in Malaysia.

**Public Private Partnership Tender Process**

Based on their experiences, Participants I, II, and III agreed that the PPP project procurement tender takes longer to award compared to other project procurement practices, while Participants IV and V are unsure. Participant II experienced this prolonged duration due to the meticulous negotiations required in PPP projects, encompassing technical, financial, and legal aspects, while Respondent III highlighted the need for careful planning and detailed agreement formulation, which contributes to the extended timeline.

All participants agree that the current tender process for PPP project procurement is manual, requiring submission of hardcopy documents and evaluation. Participant I agree that the time and effort used for manual and online processes will differ and suggests optimization. Despite the manual process, Participant II's experience indicates that only the sale of tender documents is done electronically.

According to Participant III, the current practice necessitates comprehensive documentation of details and instructions to avoid future


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complications which is in line with recommendation from Khaderi et al., (2019) that suggest standard guideline is necessary to guide path in ensuring all method are mange clearly. Nevertheless, there is a need to transition to digital methods, especially considering the challenges posed by remote work during the COVID-19 pandemic, which has made managing manual documents difficult and has consequently slowed down the workflow. Participant V believes that the current manual paper-based application process can be replaced with a digital process for a more effective workflow. However, based on Participant IV's experience, changing the manual process is difficult due to the involvement of negotiation processes by various PPP types.

**E-Tendering Usage**

On a personal level, the majority of participants believe that e-tendering can benefit PPP tenders through transparency, time savings, value for money, an automated system, and sped-up tender processes. Only one participant was personally unfamiliar with the concept of e-tendering. Both parties concur that e-tendering will change the PPP tendering work process because it can reduce human error and digitalize government services. Additionally, due to the lack of availability of such systems, all participants acknowledged their lack of experience with e-tendering for PPP projects and that they had not been exposed to handling such systems.

In addition, two participants claimed that there are no suitable e-tendering guidelines available, and two others expressed uncertainty about the existence of any such guidelines. However, one respondent pointed out the existence of e-procurement guidelines that might be used. Four participants also thought that by reducing human error and enabling the digitalization of government services, which can hasten the tender process, e-tendering has the potential to alter the PPP tendering work process. However, one respondent stated that before making comparisons, e-tendering must be implemented.

**Factors to consider when implementing E-Tendering**

The thematic analysis conducted on the views and comments from the Participants has resulted in 12 codes, which are further grouped into four main themes. These four themes are people, process, technology, and environment. Table 2 summarizes the process of thematic analysis.

The people-related factor is defined as the ability of employees to accept and adapt to the system (Goulding & Lou, 2013; Wang, Liu, & Parker, 2020). These include IT literacy, user understanding, slow response, cater to the user needs, staff competencies, competent people, and resistance to opt. Therefore, there is a need for staff to undergo hands-on training on the usage and function of the system. Besides that, to successfully implement e-tendering, the

staff should have the skill of IT literacy (Mehdipoor, Iordanova, Mehdipoorkalooraz, & Ghadim, 2023) and ICT competencies in handling systems (Kazaz et al., 2022) to ensure system functionality, as well as good comprehension and knowledge of PPP.

The process-related factors cover how an organization needs to implement IT successfully which is related to the ability of the organization to absorb and integrate the proposed systems into the current practice (Alyahya, Skitmore, Cattell, Nepal, & Bridge, 2018). These include consistent process, confidentiality of the process, consistent process, sensitive information misuse, transparency in the process, availability of guideline, right process, risks, process timeline compliance, and legal and policy issue. This shows that the policies and procedures should be strengthened before being integrated into the digital system as well as proper guidelines for the whole digitalization process. These policies and guidelines are important to ensure everyone consistently applies the conducted procurement process in the same direction.

The technology-related factor deals with the use of necessary infrastructure to allow an organization to use and monitor the e-tendering service (Maepa et al., 2023) which determines whether the organizations are prepared to adopt and implementation of e-tendering. These include IT infrastructure, big data needed, budget, costs occurred, security requirements, functional of system, troubleshooting system malfunction, security of the system, higher security needed, and confidentiality of data. Before implementing e-tendering, the financial support should provide suitable system infrastructure as well as physical equipment and software tools. Both physical equipment and tools will determine the functionality of the implemented system. On top of that, high system security is also required to protect the confidentiality of process and data to avoid the misuse of sensitive information besides promoting transparency of the tender process.

The environment is surrounding an employee where all of the work activities are carried out may bring positive or negative outcomes (Khan, Mahmood, & Shoaib, 2022). This factor has become the basis of decisional and financial support as organization behaviours and structures are often influenced by the demands of players on whom the organizations depend for resources and rules (Doherty et al., 2013). These include top management support, the ICT department needs to strengthen, plan, and guide people to the same direction, awareness, and current culture process. Both top management and the ICT department play an important role in implementing e-tendering. The top management determines the direction and future implementation of the system in the organization while the ICT department should ensure that the system will run smoothly, especially in terms of compliance with the timeline of a process.


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**Table 2:** Thematic analysis of factors to implement e-tendering.

| Factors | Code | Theme |
|---|---|---|
| IT literacy<br>User understanding | Skill | People |
| Cater to user needs | Needs | |
| Staff competencies<br>Competent people<br>Resistance to opted | Staff | |
| Consistent process<br>Confidentiality of process<br>Sensitive information misuse | Practice | Process |
| Transparency in process<br>Guideline not ready<br>Risks factors<br>Process timeline compliance | Procedure | |
| Legal issue<br>Policies issue | Issue | |
| IT infrastructure<br>Big data needed | Infrastructure | Technology |
| Budget<br>Costs occur | Finance | |
| Security requirements<br>Functional of system<br>Troubleshooting system malfunction<br>Higher security needed<br>Confidentiality of data | Systems | |
| Top management support<br>ICT department needs to strengthen | Leadership | Environment |
| Future plan<br>Guide people in same direction<br>Not aware | Management | |
| Current culture process | Culture | |

**E-tendering Readiness**

When asked about their readiness for the practical utilization of e-tendering, Participants I, II, and V demonstrated readiness, given their belief in its potential to enhance efficiency. They highlight that a substantial number of government employees are enhancing their IT literacy and competencies, in line with the ongoing digitization of processes. However, Participant V holds a differing perspective and expresses unreadiness due to the belief that PPP policies and procedures need strengthening before implementing any e-tendering system. Similarly, Participant III expressed uncertainty, mentioning the need to

personally test the system and acquire the necessary equipment, knowledge, and a supportive community for effective e-tendering.

From Participant I's point of view, succession planning is a crucial tool to assess organizational readiness for e-tendering. The current situation is that when a project team member transitions to another department, monitoring the project becomes slightly more challenging, as the replacement officer must manually review the entire project tendering timeline and related events. Systematizing project information within an electronic system could simplify understanding the project's current status, indicators, and situation. This is due to the reliability of the data, allowing for immediate action to ensure project progress. In addition, surveys, interviews with those involved, testing of an e-tendering system prototype, having clear PPP tender policies, guidelines, and workflows for each model and type of project, as well as watching users interact with the system, can all be used to determine whether they are ready for e-tendering.

Participants I, II, and III feel that e-tendering has a chance to be successfully implemented phase by phase within Malaysian PPP contexts with the right support from everyone. The Internet of Things (IoT), 4IR, and digitization are the reasons for this. Respondents IV and V are unsure, though, as the Malaysian PPP market is predominately based on direct negotiation. Only recently, starting in 2018, have the majority of new PPP projects switched to RPF open/close tenders, the majority of which are still going through the tendering process. The current strategy should then be successful as it moves towards the tender.

These findings are in line with existing literature on PPP and project procurement. The recognition of PPP as the preferred method for public infrastructure projects align with previous studies (Das et al., 2022; Kalva et al., 2022; Musawa et al., 2017). Challenges associated with the lengthy tendering process and meticulous negotiations in PPP projects have been acknowledged in the literature (Flannery et al., 2019; Tajul Ariffin et al., 2019; Tolstolesova et al., 2021). This finding indicates that e-tendering is not currently fully implemented in the context of PPP projects in Malaysia, supporting the observations made by Bala & Dahiru, (2013) that PPP procurement processes are typically manually and paper-based (Cazalet & Zapatrina, 2021). However, the lack of e-tendering implementation and guidelines specifically for PPP projects in Malaysia requires further investigation and may offer fresh new insights for future research.

## CONCLUSION

E-tendering has the potential to significantly improve the PPP procurement process by enhancing transparency, reducing costs, and increasing competition. However, to maximize the benefits of e-tendering, it is important to address the


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challenges of accessibility, security, and integration. By doing so, organizations need to ensure and be ready to implement e-tendering to deliver high-quality public services and infrastructure projects. The outcome of this study proposes further study regarding the factors needed by PPP individuals before implementing the e-tendering system in the PPP procurement process.

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# SEISMIC RESILIENCE OF CFRP CONFINED RC COLUMNS: EXPERIMENTAL ANALYSIS

**Nur Hajarul Falahi Abdul Halim[1], Fara Diva Mustapa[2], Mohamad Zahierrudien Ismail[3]**

[1,2,3]*Faculty of Built Environment and Survey,*
UNIVERSITI TEKNOLOGI MALAYSIA

## Abstract

Resilience and sustainability are the key goals of any building and infrastructure, especially in countries with moderate to high seismicity. However, in countries with low seismicity like Malaysia most existing buildings are designed to carry only the gravity load, which is vulnerable when subjected to additional loads such as earthquakes. Lateral ground motion can severely damage vital components like columns in the form of concrete crushing associated with the buckling of longitudinal reinforcement. This paper presented the application of fibre-reinforced polymer (FRP) as reinforcement in RC columns based on experiments for resilience and sustainability of RC structure. The application of FRP for retrofitting and strengthening structural elements not only increased the axial, shear and bending capacity, but also high durability towards harsh environment. CFRP in sheets/strips were flexible as compared to FRP bars; therefore, they can easily be shaped into spirals to confine the core concrete of column. This study showed that by using FRP sheets as internal confinement improved the seismic response of RC columns better than the conventional carbon steel material. A discussion on the performance of FRP sheets as internal confinement and their potential in improving the resilience and robustness of RC structures was presented for future directions.

***Keywords***: Seismic, strengthening, FRP

[1] Senior Lecturer at Universiti Teknologi Malaysia Email: nurhajarulfalahi.ah@utm.my

## INTRODUCTION

Despite advances in technological development, extreme natural or human-made events occasionally lead to catastrophic collapses of buildings and infrastructure systems. This is the result of climate change and general changes in our society with increasing pressure to optimise the design and management of infrastructure, including the use of more sustainable materials, structures and land (Chen et al., 2023; Deng et al., 2021; Pan et al., 2022). Recent worldwide devastating hazards indicated that buildings were not sufficiently resistant to disasters and lack the ability to recover rapidly after disasters, which not only brought tremendous economic losses and casualties, but also long-term environmental impacts. (Ahmed, 2017; Johar' et al., 2013). Generally, in low to moderate seismicity countries like Malaysia, contractors or engineers do not pay much attention to ground motion in the design of structures, which may lead to large injuries and significant impacts on economy, society and the environment (Chandra Dutta et al., 2021; Jia & Zhan, 2023; Nugroho & Chiu, 2023). Therefore, enhancing the resilience and sustainability of buildings under hazards by using robust construction materials is the objective demand of sustainable development.

For many years, reinforced concrete (RC) has become the main structure and infrastructure worldwide, and carbon steel has been used for making reinforcement bars, hoops and ties. However, in addition to corrosion of steel reinforcements, RC faces other problems which relate to confinement in RC elements. Lateral reinforcements which are used to confine the longitudinal bars play a vital role in the ultimate load capacity and ductility of RC members like columns (Jing et al., 2016; Saatcioglu & Razvi, 1992; Yang et al., 2022). While corrosion of steel degrades tensile capacity and service life of the structure, improper design and inadequate transverse reinforcement may lead to buckling of main rebars and shear failure (Liang et al., 2022; Mei et al., 2023; Yang et al., 2020). Figure 1 shows the damaged columns during the 2015 Sabah earthquake which struck Ranau, Sabah, Malaysia with a moment magnitude of 6.0 (Alih & Vafaei, 2019). In many existing columns, lateral reinforcement is provided by using 6 mm to 8 mm diameter bars with 90˚ -hooks at about 200 mm –250 mm spacing, which are vulnerable to ground motion and lead to significant damage of RC buildings. This condition was also found in building structures during the 2015 Gorkha earthquake.

Based on the above facts, the implementation of seismic design for buildings in Malaysia is essential to mitigate the effects of potential large earthquakes that may occur in the future. In late 2017, the Malaysian National Annex (NA) to Eurocode 8 (EC8) was released and design engineers were requested to employ it for the seismic design of buildings in Malaysia (Iliani Rosli et al., 2022; Looi et al., 2021). However, there were major challenges in implementing the 20-year-old EC8 framework for a country so far away from Europe like Malaysia (Looi et al., 2021; Ting et al., 2019). Challenges include


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the lack of seismic data that presented great uncertainties, difficulties and poor workmanship on site due to stringent detailing of Medium Class Ductility (DCM) as well as lack of skills and knowledge of dynamic analysis in structural design by practicing professionals (Looi et al., 2021; Ting et al., 2019).


**Figure 1:** Damaged columns due to inadequate/poor detailing of confinements
*Source:* (Alih & Vafaei, 2019)

Resilience refers to the capability of structures and infrastructure systems to withstand the effects of extreme events (Capacci et al., 2022; Jia & Zhan, 2023). Researchers have proposed several ways to maintain the integrity of structure under extreme loading. For example, Tang el at. (Tang et al., 2020) studied stainless-steel tube for stub columns under axial load. Results showed that the bearing capacities of columns increased with thickness of the stainless-steel tube. This was similar with Guo et al. (Guo et al., 2019) who used 10 mm with smooth and flat surface stainless-steel tube confined concrete (SSTCC) stub column. Chen et al. and Xu et al. (Y. Chen et al., 2023; Xu et al., 2023) found that the ultimate strengths and deformation capacities of stainless-steel reinforced concrete columns was considerably influenced under seismic loading. However, the columns showed relatively higher ductility and energy dissipation capacity due to high ductility of stainless steel (Xu et al., 2023). Alih et al. (Alih & Khelil, 2012) conducted a study on inoxydable steel as reinforcement bars in concrete beam to investigate their performance under bending moment. The study reported that the austenitic bars exhibited higher ultimate strength and ductility than carbon steel. However, despite the advantages of using non-corrosive stainless-steel, stainless-steel bars are expensive and their response to lateral dynamic loads needs further investigations (Rabi et al., 2019; Vahed, 2017).

In recent decades, FRP bars and sheets were widely used in the reinforced concrete elements as reinforcements and confinements technique. An addition to FRP sheets, FRP bars are also used as reinforcements in RC elements. For instance, Gamal et al. (El Gamal & Alshareedah, 2020) investigated the

behaviour of concrete columns reinforced with GFRP bars and spirals under axial force. The investigation reported that although the GFRP-reinforced columns had a lower first peak load than the steel-reinforced columns, they behaved similarly. Zeng et al. (Zeng et al., 2023) run a similar test and found that the FRP bars with diameter of 16 mm were more sensitive to the pitch-to-diameter ratio and carried higher load capacity than the FRP bars with diameter of 10 mm. Prajapati et al. (Prajapati et al., 2022) tested four full-scale RC columns under cyclic loading. The test reported that columns reinforced entirely with GFRP achieved higher lateral load, lateral drift and failed more gradually as compared to the hybrid columns.

Based on the previous studies, FRPs suffer from some drawbacks as external reinforcement including low resistance towards fire and severe effect on the bond between concrete and FRPs under harsh environment (Jarrah et al., 2018; Zhang et al., 2018). Surface treatment and coating with different materials were used to deal with the drawbacks mentioned; however, to maintain the quality of bond surface for the whole structure is challenging and costly (C. Chen et al., 2019; Wang et al., 2014). Therefore, one way to reduce the adverse effects on FRPs is to use FRPs for internal confinement so that the concrete cover can protect the FRPs against elevated temperatures and harsh environments.

Motivated by this idea, this study investigates the cyclic behaviour of RC columns internally confined by CFRP strips. This study highlighted an approach to observe the seismic resilience of this method under reversed cyclic lateral loading as per reported in many references (Shin & Kim, 2020; Tafsirojjaman et al., 2020). Details of the tested columns are presented in the next section. The obtained results from the tests are showed and discussed soon after that. The seismic performance by using this method could benefit future research in FRPs and seismic design of RC structures.

## EXPERIMENTAL PROGRAM

### Test Specimens

Figure 2 and Table 1 summarise the details of specimens and Table 2 shows results from the material strength tests. In this study, four full-scale RC columns were constructed. The design and detailing of the constructed columns followed the recommendations of Eurocode 2 (EN 1992-1-1, 2005). Two columns were used as reference (i.e., CSC and CSS) and results obtained from the other two columns were compared with each of these columns. All columns had similar size and longitudinal reinforcements, but their transverse reinforcements were different. The columns had a square cross-section with size of 200 mm, and they were reinforced longitudinally by six 12 mm diameter ribbed bars. In Figure 3, the longitudinal bars for CSC and FRP had a rectangular arrangement within the cross-section of columns, while CSS and SFRP columns had a circular arrangement within the cross-section of columns. The height of all columns was


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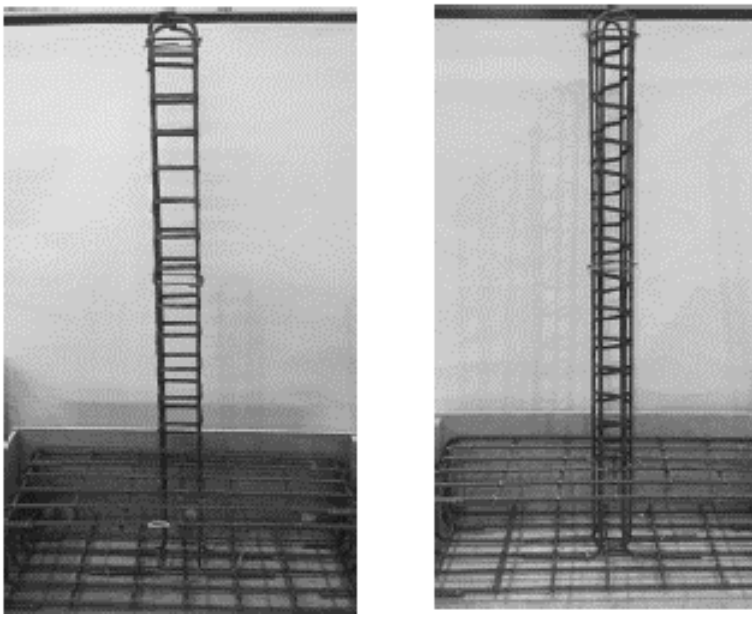
1500 mm. The reference columns were transversely reinforced by 6 mm diameter carbon steel stirrups and spirals with spacing of 100 mm. The transverse reinforcements of the CFRP-columns were made by CFRP strips. The width and thickness of the CFRP strips were 15 mm and 0.164 mm, respectively, with spacing of 100 mm. To avoid a biased comparison, tensile strength of the transverse reinforcements in all four columns was designed to be equal. A high-performance epoxy adhesive was used to attach CFRP strips to the longitudinal bars. The primary role of epoxy adhesive was to prevent movement of CFRP strips during concreting. All columns had a strip foundation of 1,250 mm length, 550 mm width and 400 mm thickness. The foundation was reinforced longitudinally and transversely by six and seven 12 mm diameter bars, respectively. It should be mentioned that the compressive strength of concrete (f'c) measured on the standard cylinder was 24.8 MPa.



(a) FRP (b) SFRP

**Figure 2:** Arrangements of longitudinal rebar and transverse reinforcements of columns with CFRP strips

**Table 1:** Details of the tested specimens

| Specimen ID | Size (mm) | Length (mm) | Longitudinal reinforcement (mm) | Transverse reinforcement (mm) | S/ Spiral (mm) |
|---|---|---|---|---|---|
| CSC | 200 | 1500 | 6ϕ12 | $\phi$6 (steel bar) | 100 |
| CSS | 200 | 1500 | 6ϕ12 | $\phi$6 (steel bar) | 100 |
| FRP | 200 | 1500 | 6ϕ12 | 15×0.164 (CFRP stirrups) | 100 |
| SFRP | 200 | 1500 | 6ϕ12 | 15×0.164 (CFRP spirals) | 100 |

**Table 2:** Results obtained from the material strength tests

| Material | Size (mm) | Yield strength *fy (MPa)* | Yield strain *εy (%)* | Modulus of elasticity (GPa) | Ultimate strength *fu (MPa)* | Ultimate strain *u (%)* |
|---|---|---|---|---|---|---|
| Steel | 12 | 563 | 0.76 | 210 | 648 | 10.6 |
| | 6 | 391 | 0.86 | 200 | 449 | 5.9 |
| CFRP | 15× 0.164 | - | - | 252 | 4369 | 2.2 |

**Test Setup**

Figure 3 shows the employed test setup in this study. As seen from this figure, the constructed columns were fixed within a strong steel frame by using two steel channels connected to their foundation. The lateral loads were applied to the columns by two hydraulic jacks. The columns were also subjected to a constant axial force as conducted by (Aydemir et al., 2023; Hung et al., 2024). However, the intensity of the constant axial load is restricted to 70 kN due to the limitation in the laboratory. In order to record the intensity of applied lateral loads, two load cells were installed in front of the hydraulic jacks. Value of the applied axial force was monitored by another load cell. . Lateral displacements of columns were recorded by two linear variable differential transformers (LVDTs) that were installed on the top of columns. Vertical and horizontal movements of the foundation were also monitored by installing to LVDTs at the foundation level. Two strain gauges were installed at the base of columns to monitor the strain values in the longitudinal bars.

Columns were subjected to a displacement-controlled loading protocol based on the specifications given in FEMA 461 (2007). This loading protocol requires at least 10 loading cycles before reaching the target displacement. Moreover, each loading cycle should be repeated twice. The applied displacement adopted at each loading cycle should be 1.4 times larger than the one applied to the previous cycle. After reaching the target displacement, increase in subsequent cycles should be 30%.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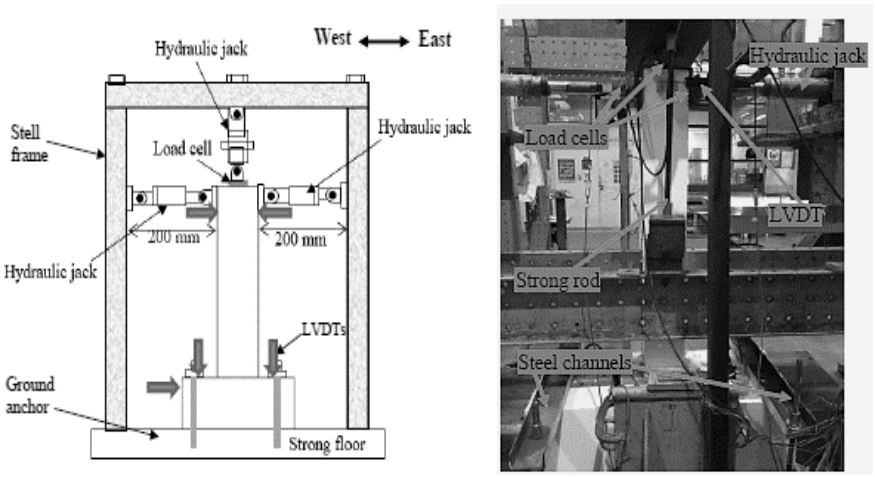



**(a) schematic diagram** **(b) lab test**

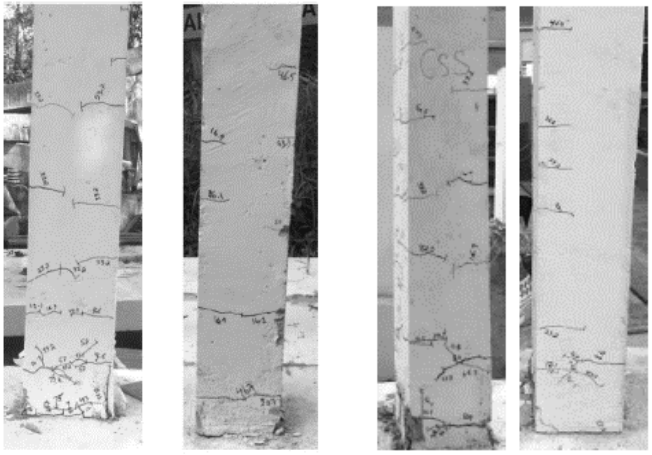
**Figure 3:** Employed test set up

## RESULTS AND DISCUSSIONS

### Failure Mode and Cracks Pattern

The observed crack patterns on the surface of columns are shown in Figure 4. The crack patterns corresponded to the end of tests when the loading was stopped. In this study, loading of test specimens was stopped when a 10% drop in the ultimate strength was observed. As can be seen from this figure, most observed cracks were perpendicular to the vertical axis of columns, indicating a flexural type of crack. The first crack in the CSC and CSS reference columns were observed when the lateral displacement reached 4.4mm and 4.41mm, respectively. On the other hand, the first cracks in FRP and SFRP columns were observed when the lateral displacement of columns reached 8.6mm and 4.44mm, respectively. The cracks in columns confined with stirrups were observed to be distributed between the foundation level and height of 1000 mm. Meanwhile the cracks in CSS and SFRP columns were mostly distributed between the foundation level and height of 1,128mm and 1,100mm, respectively. Concrete crushing and spalling were observed in all columns, when the drift ratio reached 3%. However, buckling of longitudinal reinforcing bars and rupture of CFRP strips were not observed. Large cracks and concrete sapling at the base of columns were the main reason for the failure of columns. Although columns exhibited almost a similar failure mode, Figure 5 shows that the number of cracks in the CFRP confined columns were less than that of reference columns. Besides, the observed cracks in CFRP confined columns were relatively shorter than that of reference column.

This was similar to the findings of (Ibrahim et al., 2017; Kharal & Sheikh, 2020), whereby damage to the columns reinforced with steel basalt-fibre composite bars were less than columns reinforced with steel bars.



(a) CSC (b) FRP (c) CSS (d) SFRP

**Figure 4:** Crack patterns along the tested columns

**Hysteresis Loops**

Figure 5 shows the hysteresis loops of tested columns and Table 3 summarises the obtained results from bilinear representation of backbone curves for the push direction of loading. It was evident from the figure that for the push direction of loading CFRP confined columns had larger ultimate loads (i.e., Fu) as compared to the reference columns. The ultimate loads of FRP and SFRP columns were 7.1% and 29% larger than the CSC and CSS reference columns, respectively.

The displacement ductility ratio (μ) was calculated as the ratio of displacement at the ultimate load (Δu) to the displacement at the effective yield (Δy). It was evident from Table 3 that the CFRP-confined columns showed a larger effective stiffness and displacement ductility ratio as compared to the reference columns for both confinement methods (i.e stirrups and spirals). However, the post-yield stiffness of reference columns was slightly larger than that of the CFRP-confined columns. Table 3 also shows that SFRP had a larger effective yield strength as compared to that all tested columns.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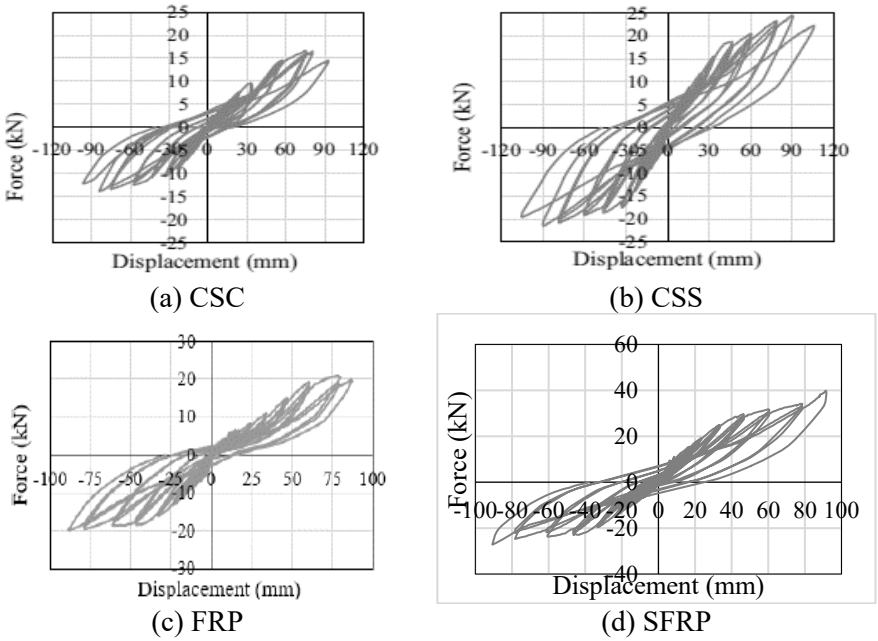


**Figure 5:** Hysteresis loops of tested specimen

**Table 3:** Summary of the obtained results for the push direction of loading

| Specimen(s) | Eff. stiffness | Post yield stiffness | Ductility | Displacement (mm) | | Strength (kN) | |
|---|---|---|---|---|---|---|---|
| | | | | **Δu** | **Δy** | **Fu** | **Fy** |
| CSC | 0.465 | 0.09 | 1.56 | 74.7 | 47.9 | 24.7 | 22.3 |
| CSS | 0.440 | 0.10 | 1.33 | 79.4 | 59.8 | 28.2 | 26.3 |
| FRP | 0.501 | 0.02 | 1.74 | 90.3 | 51.9 | 26.6 | 26.0 |
| SFRP | 0.772 | 0.05 | 1.87 | 91.6 | 48.9 | 39.7 | 37.8 |

## Energy Dissipation Capacity

The dissipated energy by each column was calculated through the area enclosed by their hysteresis loops. Figure 6 shows the cumulative energy dissipation of tested columns. It was evident from this figure that the CFRP-confined columns had dissipated more energy as compared to the reference columns. Besides, the difference between the dissipated energy by the CFRP-confined columns and reference column increased as the drift ratio increased. Also, the SFRP column had the largest energy dissipation as compared to the other CFRP-confined column. The figure also shows that the CSC and CSS reference columns, had

almost an identical energy dissipation for the entire range of drift ratios. The slight increase in the energy dissipation of FRP as compared to the reference columns could be related to the more cracks that appeared on the surface of its concrete during cyclic loading.

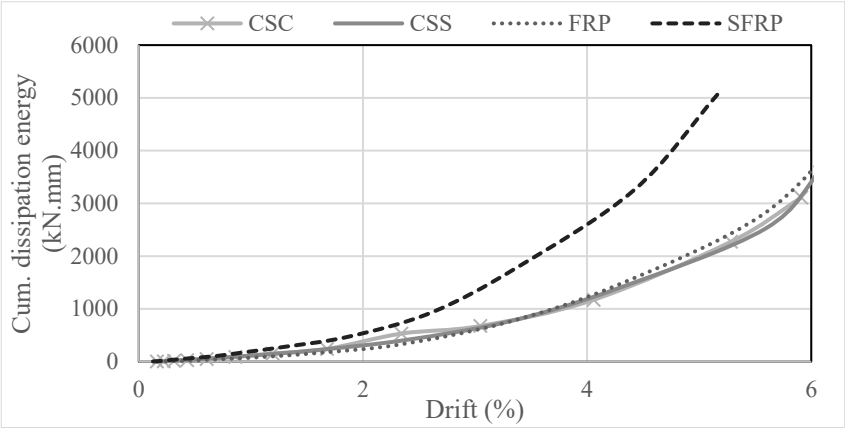


**Figure 6**: Cumulative energy dissipation of the tested columns

## CONCLUSION

This study investigated the seismic response of RC columns internally confined by CFRP strips. Four full-scale columns were constructed and subjected to a constant axial force along with a quasi-static cyclic loading. Two of the columns were transversally reinforced by steel stirrups and steel spirals used as the references. The other columns were transversally reinforced by CFRP strips in stirrups and spirals. All columns shared a similar size and longitudinal reinforcements. Besides, the tensile strength of the transverse reinforcements in all columns was similar.

Results indicated that the failure of all columns was because of the yielding of longitudinal reinforcing bars and concrete crushing at the base. The number of cracks in the CFRP-confined columns was less than the reference columns, and the crack lengths were relatively shorter. On average, the CFRP-confined columns showed a larger ultimate load and effective yield strength when compared with the reference columns. The effective stiffness of CFRP-confined columns was larger than the reference columns. The CFRP-confined columns showed a lower stiffness degradation rate and a larger energy dissipation than the reference column. It was also found that an increase in the CFRP strip width increased the ultimate load, effective yield strength, and displacement ductility ratio of columns.


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The outcome of this study demonstrated the feasibility and efficiency of using CFRP strips as the transverse reinforcement in columns. Under resilience characteristic, this method contributes to the robustness of the RC column to withstand the external load like earthquake. The potential of the proposed method using FRP strips as internal confinement materials in RC element can be further discovered can be further discovered by research on various parameters, life cycle assessment, and retrofitting.

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# GEOMETRICAL STUDY OF SUSTAINABLE POLYMER PILES WITH BUCKLING ANALYSIS

**Yee Yong Lee[1], Chee Khoon Ng[2], Yeong Huei Lee[3], Sim Nee Ting[4], Hoo Tien Nicholas Kuan[5]**

[1.2.4]*Department of Civil Engineering, Faculty of Engineering,*
UNIVERSITI MALAYSIA SARAWAK
[5]*Department of Mechanical and Manufacturing Engineering,*
*Faculty of Engineering,*
UNIVERSITI MALAYSIA SARAWAK
[3]*Department of Civil and Construction Engineering,*
*Faculty of Engineering and Science,*
CURTIN UNIVERSITY MALAYSIA

## Abstract

Bakau piling is commonly used to support lightweight structures, such as drains, manholes, road, raft foundations and box culverts in construction, aside from its ability to sustain the deterioration of high-water table areas. Consequently, from the high demands, it is leading to mangrove deforestation. On the other hand, the alarming consent of environmental problems is that plastic products generated and becoming waste is increasing every year in Malaysia. Plastic products, mostly from polymer, require a long degradation period of about 1,000 years. Mangrove deforestation and the non-biodegradable nature of polymer waste have become environmental and global issues that leading to the innovative motive in this research by introducing polymer as a new material to the pile manufacturing, an alternative substitute for the bakau pile. This study aimed to optimise the polymer piles in relation to their structural behaviour under compressive stresses. Based on the developed numerical models, the optimum cross-sectional area of the polymer pile by using the buckling analysis is very much depending on the shape and size, specifically second moment of area and slenderness ratio. In preventing of torsional buckling, doubly symmetrical sections are the predominant consideration in the pile design. It found out that, the optimum polymer piles with 1.90 cm2 of cross-sectional area could be suggested for H shape pile, and the proposed material is the high-density polyethylene (HDPE) with virgin to recycle ratio of 50% (VR 50). While serving the environmental issues of mangroves and waste management, polymer pile is a feasible alternative for sustainable construction.

***Keywords***: Bakau pile, polymer, polymer pile, cross sectional area, buckling

[1] Senior Lecturer at Universiti Malaysia Sarawak. Email: yylee@unimas.my

## INTRODUCTION

Bakau (Rhizophora) is a common types of mangrove tree from Rhizophorace family. Bakau wood is used extensively for piling in Borneo and South East Asia to support small and medium structures. It is commonly used to support drains, manholes, raft foundations and box culverts in construction, especially on peats and soft soils. In constructing activities in peats and weak soils, instability and large settlement are significant problems (Rahardjo, 2005). However, uncontrol usage of the bakau pile could cause mangrove destruction. Mangrove is very important to the ecosystem. It prevents coastal erosion. Mangrove forests play a primary role in keeping a hold of the sedimentation from the wave force. Mangroves avoid erosions of coastline along the coastline. Mangrove is also a source of livelihood. Mangroves provide people with various types of invertebrates, fishes, reptiles, amphibians, birds, and mammals. Mangrove forests have been recognised on its importance and prioritised the preservation of forests through many policies and practices (Abdul Latip et al., 2022). This is because the mangrove forest has plenty of microorganisms and algae as a food web for the invertebrates and fishes. It is also a breeding ground for all animals and fisheries that hold economic importance.

The impacts of mangrove destruction are at the expense of ecosystem sustainability and cause climate change impacts. Mangrove destruction causes habitat destruction and biodiversity loss, exacerbating ecosystem degradation. Destruction of mangroves contributes to coastal tidal erosion. Destroyed mangroves will cause more carbon to be retained in the atmosphere, leading to global warming. Many people depend heavily on mangrove forests for their livelihoods.

Therefore, a replacement for the bakau pile is a must to ensure the sustainability of the mangrove area. Bakau piles can be replaced with an alternative material, such as reinforced concrete or steel pipe piles, or with new age material, such as polymer piles. Thus, the usage of bakau pile on supporting embarkment, pile raft system on peats and soft soils, coastal revetment, short bridge approach, stability of excavation in soft clay (Rahardjo, 2005). Also, pile support for infrastructure structures, such as sewerage manhole, drains, walkways, septic tank, water tank plinth, pipeline and road raft foundation base will have other pile material options.

As a new age material, the polymer material is widely used daily. The polymer has become an essential item. Many products are made from polymer. The surge of polymer products in daily human life causes polymer waste management concerns. Polymer, or others known as plastic, is a petroleum-based synthetic organic material. There are a few types of polymers in the market, such as polyvinyl chloride (PVC), polyethene (PE), polycarbonate (PC), polyethene terephthalate (PET) and polypropylene (PP). Their qualities and characteristics make them appropriate for various industries, including home, construction,

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packaging, goods, vehicle, electronics equipment, and agriculture. A million tonnes of plastic waste are in landfills or the natural environment. In 2015, 79% of complete plastic waste was accumulated in landfills/open dumps or lost to the natural environment (Geyer et al., 2017). In addition, assessments indicate that an annual influx of plastic waste ranging from 1.15 to 2.41 million tonnes is entering the ocean through rivers (Syed Alwi et al., 2023). Synthetic polymers pose a significant challenge on land as they are often discarded in landfills. It persists for centuries and slowly releases toxins into the soil over time. Due to their biodegradability, new landfill sites are always needed as the use of synthetic polymers continues and expands. Moreover, polymer degradation is another polymer issue as it can take up to 1000 years to degrade in a landfill. Given the slow degradation of polymers, they could potentially find reuse in long-term applications like piling, where materials endure extended periods underground.

Both mangrove forest and polymer waste management hold enormous economic and ecological importance. Mangroves harbour unique biodiversity. Protecting mangroves can help save the planet from increasing pollution and polymer recycling. Therefore, a study is required to look into the possibilities of recycling polymers to replace mangrove products. One of the examples is creating a polymer pile. The polymer has the potential to be used as a pile due to its diversified polymer properties. Recycled polymer piles are a potential technological solution to environmental, construction and waste disposal challenges. This research will investigate the structural behaviour of various polymer piles strengths, shapes, and sizes through modelling software. The research outcome expects to determine the relationship between the structural behaviour of polymer piles. It aims to give the most optimum strength, shape, and size of polymer pile against cost. This research will provide an alternative deep foundation for small and low-loading structures in civil works.

## MODEL DEVELOPMENT

The polymer pile materials utilized for theoretical and numerical analysis include polyethylene (PE – HDPE), polypropylene (PP), and polyvinyl chloride (PVC). The polymer material is further categorized into 100% pure polymer, referred to as virgin, 50% pure with 50% recycled polymer, known as VR-50, and 100% recycled polymer, known as recycled. In comparison, polyvinyl chloride (PVC) was analyzed both as 100% pure polymer and 100% recycled polymer. The material properties are listed in Table 1.

A total of 144 samples of various shapes, sizes, and polymer materials were simulated using analytical and numerical models. The selected forms for this analysis were limited to circular hollow sections, square hollow sections, and H sections. The sizes varied from 100 mm to 400 mm in diameter or length, tailored to match the practical sizes of Bakau piles. The pile size analysis was based on a 1-tonne working load with a safety factor of 1.3, i.e., the pile capacity


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was 1,300 kN. The thickness of the hollow section was set as thin as 1 mm up to a maximum thickness of 72 mm. The length of the polymer pile was fixed at 3 meters for all the analyses. The 3-meter length was chosen as Bakau piles are typically available in lengths ranging from 1.5 meters to 3 meters. Other parameters, such as area, moment of inertia, and volume, were calculated based on the given dimensions and sizes.

**Table 1.** Properties of studied materials

| Material | | Young's modulus, MPa | Poisson ratio | Density, kg/m$^3$ |
|---|---|---|---|---|
| **HDPE** | HDPE | 240 | 0.46 | 970 |
| | VR-50-HDPE | 182 | | |
| | Recycled HDPE | 211 | | |
| **PP** | PP | 728 | 0.43 | 946 |
| | VR-50-PP | 544 | | |
| | Recycled PP | 303 | | |
| **PVC** | PVC | 728 | 0.40 | 1330 |
| | Recycled PVC | 638 | | |

## Analytical Model

The structural design of piles can be simplified to short columns by assuming that the columns are laterally retained unless bending moments are negligible (gravity loads only) and the soil is very soft. One of the column criteria is buckling. The buckling load is given as Euler's critical load:

$$P_{cr} = \frac{\pi^2 EI}{L_{eff}^2} \quad \text{Equation 1}$$

where,
Pcr = Critical or maximum axial load on the pile just before it begins to buckle
E = Modulus of elasticity for the polymer material
I = Least moment of inertia for the polymer pile cross-sectional area
$L^2_{eff}$ = Unsupported length of the polymer pile

## Finite Element Models

Finite element models were developed in this study. Figure 1 and Figure 2 describe the typical meshing and boundary conditions of the developed models. The verified modelling technique was applied in further model development.

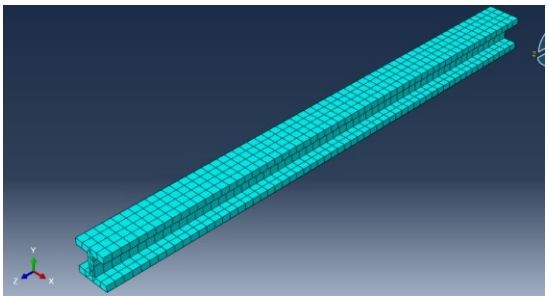

**Figure. 1.** Meshing of the model

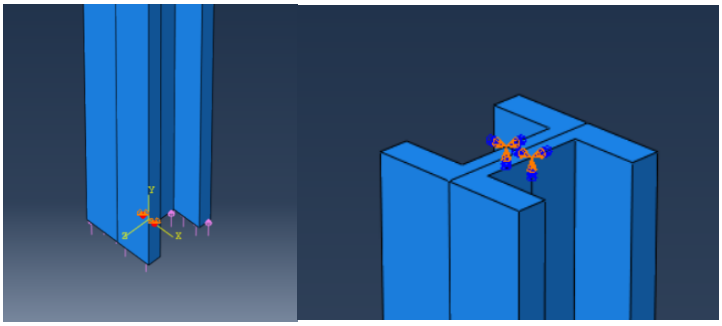

**Figure 2.** Assigned boundary conditions

## Finite Element Analysis

### *Circular Hollow Section (CHS) piles*

Forty-eight sample cases were analysed in circular hollow section shapes. The outer diameters (OD) were set at a minimum of 135 mm to 191 mm for solid circular and 200 mm, 250 mm, 300 mm, 350 mm and 400 mm for circular hollow sections. The inner diameters (ID) were in the range of 128 mm to 398 mm diameter. Typical failures are shown in Figure 3 and Figure 4. Results are tabulated in Table 2.

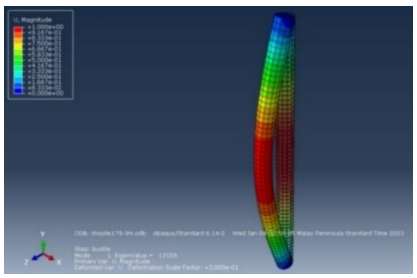

**Figure 3.** Typical deformation contour for solid circular section

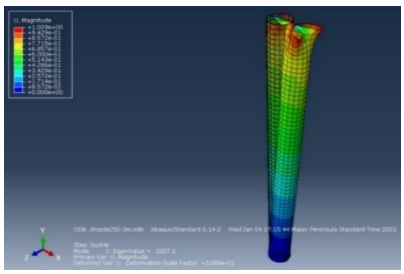

**Figure 4.** Typical deformation contour for CHS section


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### *Square Hollow Section (SHS) piles*

Forty-eight specimens were analysed in square hollow shape. The dimensions were studied in a range of 118 mm to 168 mm for solid square and 200 mm to 400 mm for square hollow sections. The wall thicknesses were ranged from 1 mm to 16 mm. Typical failure are shown in Figure 5 and 6. Results are tabulated in Table 3.

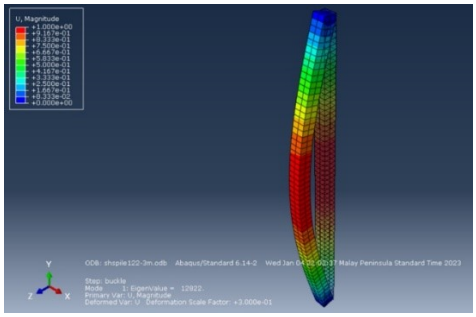

**Figure. 5.** Typical deformation contour for solid square section

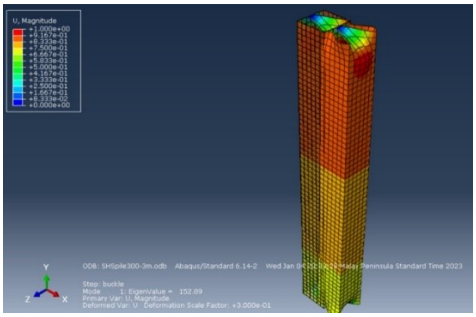

**Figure. 6.** Typical deformation contour for SHS section

### *H-section piles*

Another forty-eight samples were analysed in the H section shapes. The H dimensions were like those of square shape. The web and flange thicknesses were set at a range from 2 mm to 48 mm. Typical failures are shown in Figure 7. Results are tabulated in Table 4.

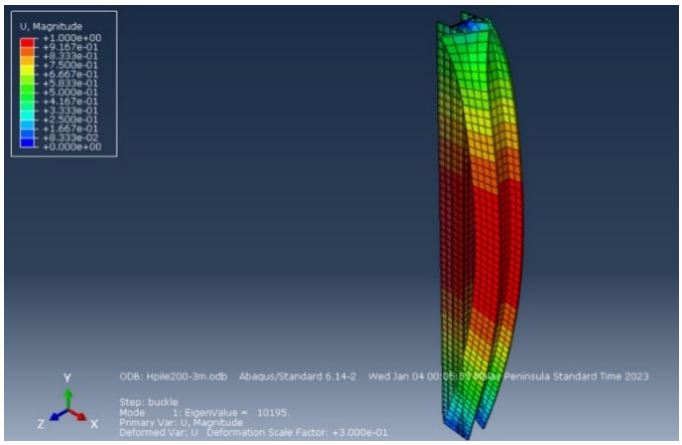


**Figure. 7.** Typical deformation contour for H- section

**Table 2.** Eigenvalues for CHS section with finite element analysis

| **HDPE** | | | | **VR50-HDPE** | | | |
|---|---|---|---|---|---|---|---|
| OD, mm | ID, mm | Thickness, mm | Eigenvalue, N | OD, mm | ID, mm | Thickness, mm | Eigenvalue, N |
| 179 | - | Solid | 13150 | 191 | - | Solid | 12918 |
| 200 | 159 | 41 | 21763 | 200 | 128 | 72 | 12834 |
| 250 | 232 | 18 | 7530.7 | 250 | 225 | 25 | 12049 |
| 300 | 290 | 10 | 1780.1 | 300 | 287 | 13 | 2425.8 |
| 350 | 344 | 6 | 516.53 | 350 | 342 | 8 | 738.45 |
| 400 | 396 | 4 | 203.86 | 400 | 395 | 5 | 250.97 |
| **100% recycled HDPE** | | | | | | | |
| OD, mm | ID, mm | Thickness, mm | Eigenvalue, N | | | | |
| 184 | 162 | 22 | 12910 | | | | |
| 200 | 146 | 54 | 12774 | | | | |
| 250 | 225 | 25 | 13969 | | | | |
| 300 | 289 | 11 | 1934.6 | | | | |
| 350 | 343 | 7 | 637.25 | | | | |
| 400 | 395 | 5 | 250.97 | | | | |

**Table 3.** Eigenvalues for SHS section with finite element analysis

| **HDPE** | | | | **VR50-HDPE** | | | |
|---|---|---|---|---|---|---|---|
| **OD, mm** | ID, mm | Thickness, mm | Eigenvalue, N | OD, mm | ID, mm | Thickness, mm | Eigenvalue, N |
| 156 | - | Solid | 12890 | 168 | - | Solid | 13128 |
| 200 | - | 11 | 6998.1 | 200 | - | 16 | 12898 |
| 250 | - | 5 | 741.71 | 250 | - | 7 | 6998.1 |
| 300 | - | 3 | 123.98 | 300 | - | 4 | 209.70 |
| 350 | - | 2 | 33.869 | 350 | - | 3 | 81.303 |
| 400 | - | 2 | 27.261 | 400 | - | 2 | 20.673 |
| **PP** | | | | **VR50-PP** | | | |
| 118 | - | Solid | 12854 | 128 | - | Solid | 13289 |
| 200 | - | 4 | 1319.9 | 200 | - | 5 | 1800.5 |
| 250 | - | 2 | 189.91 | 250 | - | 3 | 419.69 |
| 300 | - | 1 | 16.299 | 300 | - | 2 | 87.313 |
| 350 | - | 1 | 13.759 | 350 | - | 1 | 10.282 |
| 400 | - | 1 | 11.236 | 400 | - | 1 | -20.55 |
| **PVC** | | | | **100% recycled PVC** | | | |
| 122 | - | Solid | 12822 | 132 | - | Solid | 13231 |
| 200 | - | 4 | 1133.8 | 200 | - | 5 | 1558.2 |
| 250 | - | 2 | 160.48 | 250 | - | 3 | 358.63 |
| 300 | - | 2 | 100.39 | 300 | - | 2 | 75.371 |
| 350 | - | 1 | 11.786 | 350 | - | 1 | 7.8441 |
| 400 | - | 1 | 9.3605 | 400 | - | 1 | 7.0277 |
| **100% recycled HDPE** | | | | **100% recycled PP** | | | |
| 162 | - | Solid | 13170 | 148 | - | Solid | 13207 |
| 200 | - | 13 | 9689.0 | 200 | - | 9 | 5002.8 |


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| **100% recycled HDPE** | | | | **100% recycled PP** | | | |
|---|---|---|---|---|---|---|---|
| 250 | - | 6 | 1057.0 | 250 | - | 4 | 502.14 |
| 300 | - | 4 | 243.11 | 300 | - | 2 | 152.89 |
| 350 | - | 2 | 29.776 | 350 | - | 2 | 41.682 |
| 400 | - | 2 | 23.967 | 400 | - | 1 | 4.5406 |

**Table 4.** Eigenvalues for H-section with finite element analysis

| **HDPE** | | | | **VR50-HDPE** | | | |
|---|---|---|---|---|---|---|---|
| OD, mm | ID, mm | Thickness, mm | Eigenvalue, N | OD, mm | ID, mm | Thickness, mm | Eigenvalue, N |
| 156 | - | Solid | 12745 | 168 | - | Solid | 13128 |
| 200 | - | 37 | 10195 | 200 | - | 37 | 12003 |
| 250 | - | 19 | 2128.8 | 250 | - | 25 | 12009 |
| 300 | - | 11 | 313.47 | 300 | - | 15 | 3562.7 |
| 350 | - | 7 | 116.39 | 350 | - | 9 | 870.49 |
| 400 | - | 5 | 30.837 | 400 | - | 6 | 184.03 |
| **PP** | | | | **VR50-PP** | | | |
| 118 | - | Solid | 12854 | 128 | - | Solid | 13289 |
| 200 | - | 12 | 10195 | 200 | - | 16 | 12003 |
| 250 | - | 7 | 2128.8 | 250 | - | 8 | 2327.7 |
| 300 | - | 4 | 313.47 | 300 | - | 5 | 446.01 |
| 350 | - | 3 | 116.39 | 350 | - | 3 | 85.733 |
| 400 | - | 2 | 30.837 | 400 | - | 2 | 22.554 |
| **PVC** | | | | **100% recycled PVC** | | | |
| 122 | - | Solid | 12869 | 132 | - | Solid | 13231 |
| 200 | - | 14 | 11722 | 200 | - | 19 | 12979 |
| 250 | - | 7 | 1851.9 | 250 | - | 10 | 3840.1 |
| 300 | - | 4 | 271.90 | 300 | - | 6 | 659.95 |
| 350 | - | 3 | 100.80 | 350 | - | 4 | 197.53 |
| 400 | - | 2 | 26.008 | 400 | - | 3 | 63.538 |
| **100% recycled HDPE** | | | | **100% recycled PP** | | | |
| 162 | - | Solid | 13170 | 148 | - | Solid | 13207 |
| 200 | - | 42 | 13661 | 200 | - | 29 | 13151 |
| 250 | - | 22 | 11590 | 250 | - | 15 | 8144.8 |
| 300 | - | 13 | 2744 | 300 | - | 9 | 1357.0 |
| 350 | - | 8 | 580.92 | 350 | - | 6 | 359.69 |
| 400 | - | 6 | 213.35 | 400 | - | 4 | 359.69 |

# ANALYSIS AND DISCUSSION

## Distribution of pile size and pile cross-sectional area's selection

The pile size and cross-sectional area selection in this study can be seen from Figure 8 to Figure 10, according to each type of material. The distribution of pile size and cross-sectional area is much broader and separated. The analysis will be a wider spectrum of understanding the structural behaviour and impact of shape and material in this study. The graph shows that the larger the pile dimension, the less the cross-sectional area.

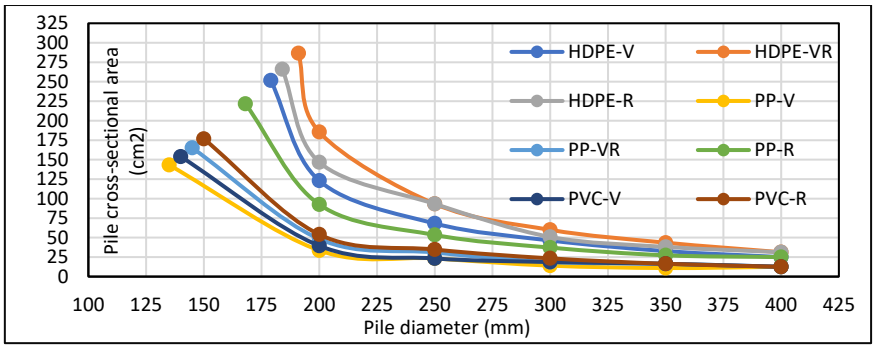


**Figure. 8.** Distribution of sample for circular hollow section (CHS) graph

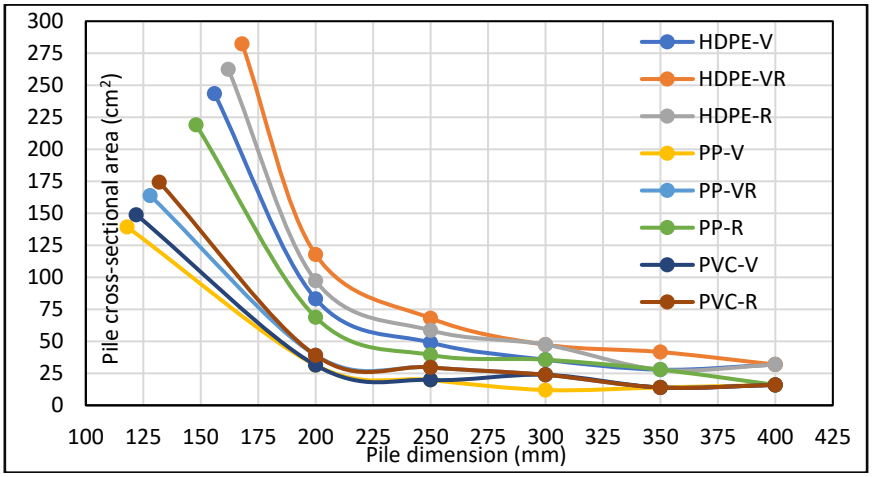


**Figure. 9.** Distribution of sample for square hollow section (SHS) graph

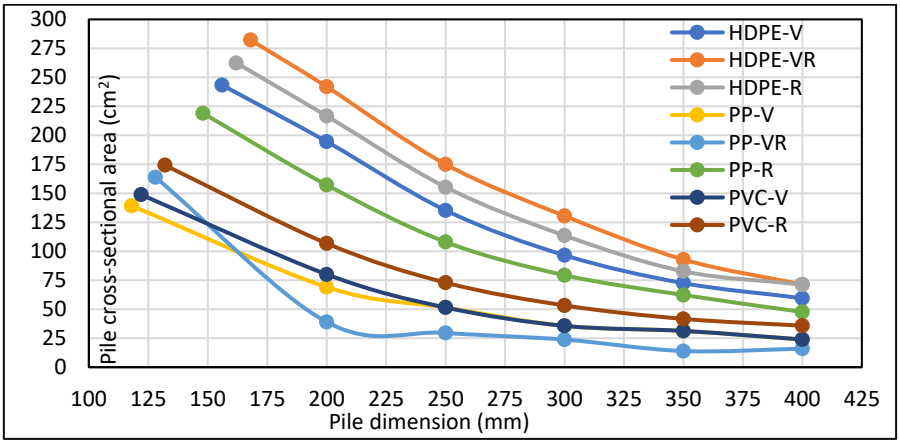


**Figure. 10.** Distribution of sample for H section (H Section) graph


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**Distribution of pile size selection**

Figure. 11 to Figure 13 show graphs of the distribution of pile cross-section against Eigenvalue. The highest Eigenvalue was 13,644 N from polypropylene (PP-VR-50) in 128 mm solid square size, and the lowest Eigenvalue was -20.55 N, which is also from polypropylene (PP-VR-50) in 128 mm square hollow section with 1 mm wall thickness. The negative value may be caused by a modelling error or is often associated with a loss of stiffness or solution uniqueness, either in the form of a material instability or the application of loading beyond a bifurcation point. Young's modulus also plays a role in affecting the buckling criteria. The greater the Young' modulus, the stiffer the material.

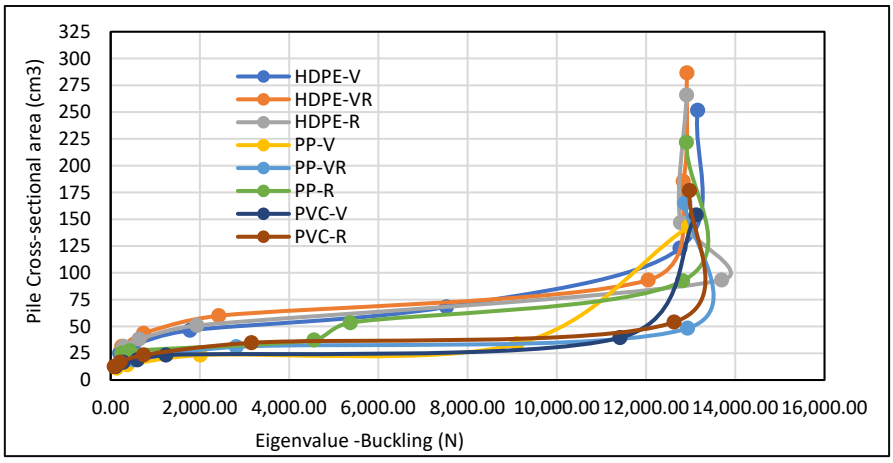


**Figure. 11.** Cross-sectional area vs eigenvalue of Circular Hollow Section

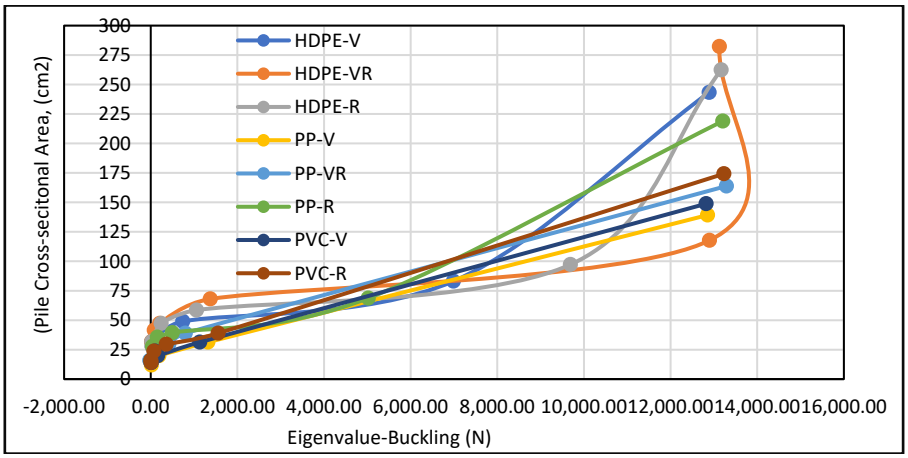


**Figure. 12.** Cross-sectional area vs eigenvalue of Square Hollow Section

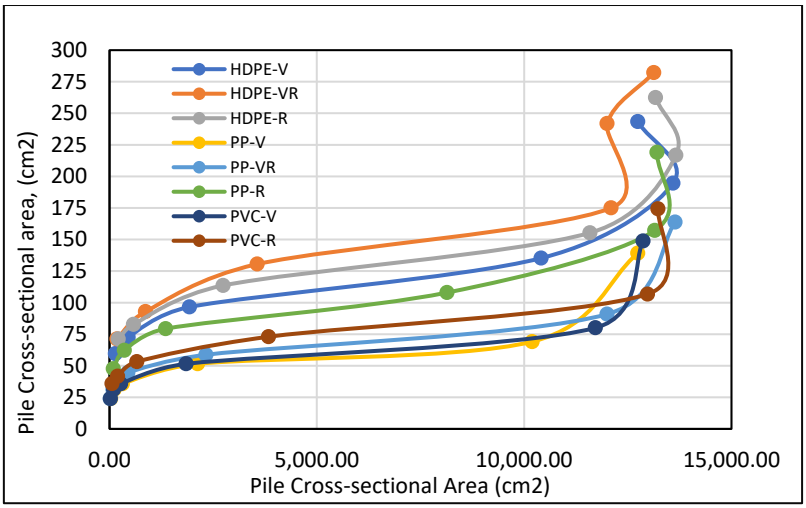


**Figure. 13.** Cross-sectional area vs eigenvalue of H Section

**Determination of optimum pile**

A three-dimensional graph plotted on which Eigenvalue is plotted together with cross-sectional and pile dimensions. The intersection of the pile cross-sectional curve with the pile dimension curve is recorded as the optimum cross-section and dimension for the maximum Eigenvalue. For example, HDPE – Virgin as shown in Figure 14.

Where, point A for the H-section is read as;
Eigenvalue= 12,100 N
Pile cross-sectional = 1.60 $cm^2$
Pile dimension= 205 mm

The finding of the optimum cross-sectional area of the polymer pile by using the numerical modelling method utilising buckling analysis much depends on the shape and size. The Young's modulus and Poisson ratio used in the modelling is almost similar for all polymer materials. Therefore, it does not affect the modelling.

Many models have encountered early failure. The main factor of premature failure is the selection of model thickness. A model of at least 25 mm thick could give a more reliable buckling analysis than below 25 mm thickness. The model with thickness below 25 mm had failed before the element could reach its maximum load, as predicted in the calculated buckling load. The expected buckling failure deformation changed from flexural buckling to another buckling failure (local, distortional, lateral-torsional buckling). Thus, the shape selection and thickness will ultimately enable the modelling to be tested in the best


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condition. From the analysis, the solid shapes were better represented by the Eigenvalue against calculated critical load.

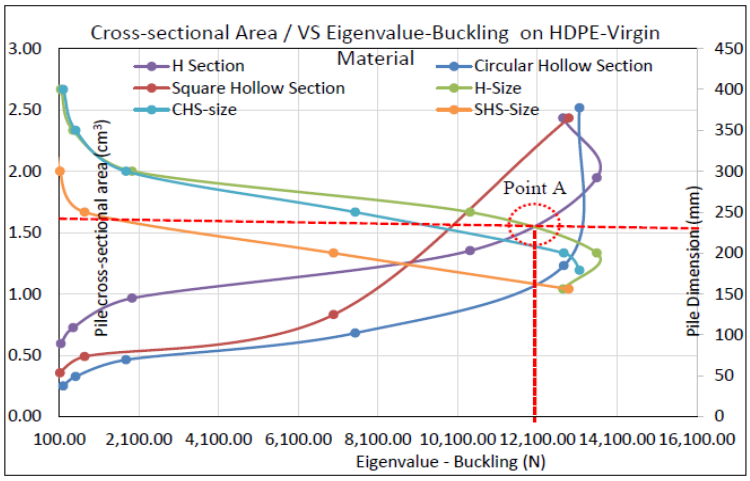


**Figure. 14.** Three-dimensional graph for HDPE-Virgin

Other than that, many factors can affect the analysis, such as the selection of boundary conditions, meshing, material properties and type of steps or load to apply on the element. This parameter could have a significant impact on the numerical analysis. The validation process is vital to ensure data collected from the numerical method is accurate. Trial and error in a numerical way are essential, leading to the exact desirable condition and result.

From Table 6, the row highlighted with yellow is the highest Eigenvalue expected to be carried before the element fails. H section showed the highest numbers of Eigenvalues, and the square hollow section showed the least Eigenvalue. The biggest dimension was 245mm, and the smallest was 145mm. While for cross-sectional, the biggest area was 1.90 $cm^2$, and the smallest area was 0.68 $cm^2$. In terms of material, HDPE had the highest passion ratio enabling it to give better results than other elements.

With the tabulation, it is summarised that;

1. The optimum size was 245 mm with cross-section area of 1.90 $cm^2$ (appx 190 $mm^2$) area of the H section. Then, followed by a circular hollow section with 200 mm and cross-section area of 1.40 $cm^2$.
2. The best shape of the pile was the H section because it had the ability to restrain in all directions. It also produced the least volume in conjunction with the buckling load resistance.

3. The best polymer to be used is HDPE-VR 50 because it achieved 182 MPA. The greater the modulus, the stiffer the material. However, this analysis is limited to buckling. In pile criteria, working load is the ultimate criterion.

**Table 6:** Summary of point intersected for circular hollow section, Square hollow section, and H section.

| Type of material | CHS | | | SHS | | |
|---|---|---|---|---|---|---|
| | **Eigenvalue, N** | **Dimension, mm** | **Area, $cm^2$** | **Eigenvalue, N** | **Dimension, mm** | **Area, $cm^2$** |
| HDPE -V | 13,100 | 200 | 1.4 | 9,100 | 180 | 1.35 |
| HDPE-VR-50 | 12,800 | 200 | 1.5 | - | - | - |
| HDPE-Recycled | 12,500 | 255 | 1.7 | 12,100 | 235 | 1.6 |
| PP-V | 11,800 | 155 | 1.25 | 9,250 | 145 | 0.9 |
| PP-VR-50 | - | - | - | 4,000 | 175 | 0.7 |
| PP-Recycled | 13,000 | 170 | 0.9 | 7,000 | 185 | 1.05 |
| PVC-V | 12,500 | 165 | 0.7 | 4,950 | 175 | 0.68 |
| PVC-Recycled | - | - | - | 5,000 | 180 | 0.79 |
| | H section | | | | | |
| | **Eigenvalue, N** | **Dimension, mm** | **Area, $cm^2$** | | | |
| HDPE -V | 12,100 | 205 | 1.6 | | | |
| HDPE-VR-50 | 12,500 | 245 | 1.9 | | | |
| HDPE-Recycled | 12,100 | 245 | 1.6 | | | |
| PP-V | 11,800 | 150 | 1.0 | | | |
| PP-VR-50 | 10,800 | 225 | 0.82 | | | |
| PP-Recycled | 10,400 | 225 | 1.3 | | | |
| PVC-V | 11,800 | 200 | 0.82 | | | |
| PVC-Recycled | 11,000 | 210 | 0.91 | | | |

## Costing Analysis

Value engineering focuses on maximizing the value of a product or project while minimizing costs. When considering a new material for a product, cost engineering plays a pivotal role in assessing its feasibility within the context of value engineering. Bakau and Belian Pepper Post (very young belian wood) have been traditionally used in civil engineering projects in light weight structures like drains, sewerage, and water reticulation as piles. As the supply diminishes and demand persists, the prices for Bakau and Belian wood have increased significantly, making them financially unviable for many projects. The Cost Engineering shows that for a typical 150mm X 150mm round solid bakau or belian piles, price range from RM 100 to RM 150.


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Another option is to use Reinforced Concrete (RC) piles as wood piles replacement. However, the challenges lie on that the fact the RC piles are typically manufactured as standard sizes of, like 150mm x 150mm x 6m, which actually provide more strength than necessary for lighter structures. Over-engineering increases material costs and might not be the most cost-effective solution. The cost per pile, ranging from RM 150 to RM 200, coupled with the need for specific piling machinery, significantly raises the overall expenses for these projects.

Given these challenges, polymer piles in this study composed of virgin HDPE, PVC, or PP, and designed with a Circular Hollow Section (CHS), offer adequate strength suitable for typical lightweight structures. The estimated material cost falls within the range of RM40 to RM100 excluding manufacturing cost. When compared with the cost per pile of RM180 for RC, RM150 for Bakau, and RM100 for Belian, the pricing of polymer piles emerges as a potentially viable option. Notably, the scarcity of wood piles, particularly Bakau and Belian, in the market further accentuates the feasibility of adopting polymer piles as a cost-effective alternative in civil engineering projects.

## CONCLUSIONS

There were 144 finite element models of various selected sizes and shapes have been developed. Data collected from the modelling exercise has enabled a comparison and validation with previous researchers' pile experimental data regarding polymer pile study. The collected Eigenvalues from numerical study were compared to analytical critical loads. In this study, the optimum polymer piles are 245 mm in dimension with cross-sectional area of 1.90 $cm^2$ from HDPE VR 50 material of H section shape. In comparison to RC, Bakau, and Belian, the pricing of polymer piles emerges as a potentially viable option. Considering the environmental impact linked to polymer production is recommended for future research.

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# THE AWARENESS OF CARBON EMISSION AND PLANNING AMONG MALAYSIAN CONSTRUCTION CONSULTANTS

**Myzatul Aishah Kamarazaly[1], Leong Wen Jing[2], Shirley Chin Ai Ling[3], Loo Siaw Chuing[4] and Naseem Ameer Ali[5]**

[1,2,3] *School of Architecture, Building and Design,*
*Faculty of Innovation and Technology,*
TAYLOR'S UNIVERSITY
[4] *Centre for Building, Construction & Tropical Architecture,*
*Faculty of Built Environment,*
UNIVERSITY MALAYA
[5] *School of Built Environment,*
MASSEY UNIVERSITY, NEW ZEALAND

## Abstract

This research paper investigates the level of awareness and understanding of carbon planning among consultants in the Malaysian Construction Industry. Findings revealed that the consultants in the industry have a relatively low awareness of carbon planning, with some having misconceptions or no knowledge of CO2 emissions. Importantly, there is a significant gap between awareness and actual implementation, as no firms in Malaysia have taken steps to enact carbon planning. Previous studies have emphasized the importance of carbon planning without explaining its implementation or the associated carbon data. To address these gaps, this study aims to identify barriers to implementation, motivate consultants to be more aware, and outline the procedures involved in carbon planning. The objectives include assessing awareness among Malaysian Construction Consultants, identifying the components of carbon planning, exploring implementation barriers, and suggesting practical ways to increase awareness. The study employed qualitative research methods focusing on green construction consultants in the Klang Valley region. Thus, this study seeks to fill the research gap by enhancing knowledge, familiarity, and awareness of carbon planning and promoting its implementation in the industry.

***Keywords***: Awareness, Carbon Planning, Construction, Consultants, Sustainability

[1] Corresponding Author. Email: yzatulaishah.kamarazaly@taylors.edu.my

## INTRODUCTION

The UNFCCC was established in 1992 to address global climate change. However, recognizing its limitations, the Kyoto Protocol was adopted in 1997 to strengthen international efforts. As a developing country, Malaysia ratified the UNFCCC and Kyoto Protocol. In 2015, the Paris Agreement replaced the Kyoto Protocol, urging all nations to set ambitious targets for reducing greenhouse gas (GHG) emissions (UNFCCC, 2015). Malaysia committed to reducing its emissions intensity to Gross Domestic Product (GDP) by 45% by 2030 as a signatory to the Paris Agreement. To fulfil this commitment, Malaysia is focused on developing enabling instruments for climate action, particularly in the construction sector, which contributes significantly to Carbon dioxide (CO2) emissions. Thus, understanding embodied and operational carbon is vital for emission reduction (RICS, 2012). Malaysia's construction sector accounts for 15% of national CO2 emissions and nearly 50% globally (IEA Greenhouse Gas Emissions, n.d.). Therefore, managing whole-life carbon emissions is crucial for net-zero emissions by 2050. Malaysia has enacted diverse green building initiatives to mitigate the environmental impact of the construction sector. The persistent challenge lies in the limited awareness hindering widespread acceptance and adoption of green construction practices. Through integrating comprehensive carbon planning and promoting sustainable growth, Malaysia aspires to transition into a carbon-neutral nation over the long term. These endeavours align with the objectives outlined in the Twelfth Malaysia Plan and are pivotal in advancing the agenda of achieving net-zero carbon emissions by 2050 (Twelfth Malaysia Plan 2021-2025, 2021). The research objectives are as follows:

i. To investigate the level of awareness of the elements of carbon planning among Malaysian Construction Consultants
ii. To identify the elements of carbon planning
iii. To determine the barriers to the implementation of carbon planning in the Malaysian Construction Industry
iv. To suggest practical ways to increase awareness of carbon planning initiatives.

## RESEARCH BACKGROUND

In Malaysia, there is a need to shift focus towards widespread adoption of carbon planning, following the example of developed countries like Australia. The lack of awareness among construction players is hindering sustainable development efforts. Disseminating information about carbon planning can change perceptions and drive positive actions. Despite setting a net-zero target for 2050, Malaysia lacks a comprehensive policy framework, carbon pricing instruments, and mandatory climate actions. Establishing transparent implementation mechanisms


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and incentives for the private sector to participate actively is crucial. Successful implementation relies heavily on public awareness and recognition. To effectively achieve climate goals, Malaysia must prioritize carbon planning and take proactive measures to increase nationwide awareness (CEO Action Network, 2021). By focusing on carbon planning, Malaysia can foster a culture of sustainability and encourage the construction industry to play its part in mitigating climate change.

## LITERATURE REVIEW

### A. Carbon Budgetary Framework

Carbon planning is essential for the government's commitment to sustainable growth, transparency, and addressing economic, environmental, and social concerns (HM Government, 2011). Achieving a low-carbon cities framework requires a sustainable approach to decarbonizing the economy while balancing environmental benefits, effects, and pricing. A comprehensive carbon plan will support Malaysia's transition towards achieving carbon neutrality by 2050 (Zakri, 2017), as outlined in the Twelfth Malaysia Plan. It will establish a legally binding framework with clear goals and commitments, ensuring the necessary institutions and mechanisms are in place to fulfil national and international climate commitments in the short and long term (World Bank, 2020).

#### *Legislation*

National climate change framework legislation is crucial for establishing institutions, setting goals, and ensuring oversight and accountability. The United Kingdom's Climate Change Act 2008 has inspired similar legislation in other countries (OCED, 2021). Malaysia lacks national climate change legislation, which hampers its commitment to the Paris Agreement. Implementing a legislative framework, like the UK's Climate Change Act, would provide a roadmap and institutional framework for effective climate change policies and implementation in Malaysia (CCC, 2020).

#### *Carbon Budgets*

The Climate Change Act established carbon budgets, which set limits on emissions in five-year increments (HM Government, 2011). These budgets ensure that GHG emissions are kept below levels contributing to global warming (ACTCCC, n.d.). Carbon budgets include long-term and sectoral targets, as shown in Figure 1, allowing governments to track emissions and adjust to achieve net-zero targets. Countries like France, Germany, and Mexico have implemented sector-specific targets to balance emissions across different industries (Annabel, 2022). By adopting a sectoral approach, it will expedite the long-term targets by striking the sectoral targets (Habert et al, 2022). Sectoral targets should clearly define the roles and responsibilities of regulatory authorities in monitoring and

enforcing these targets. Figure 1 depicts the breakdown of the carbon budget process into long-term and sectoral targets.

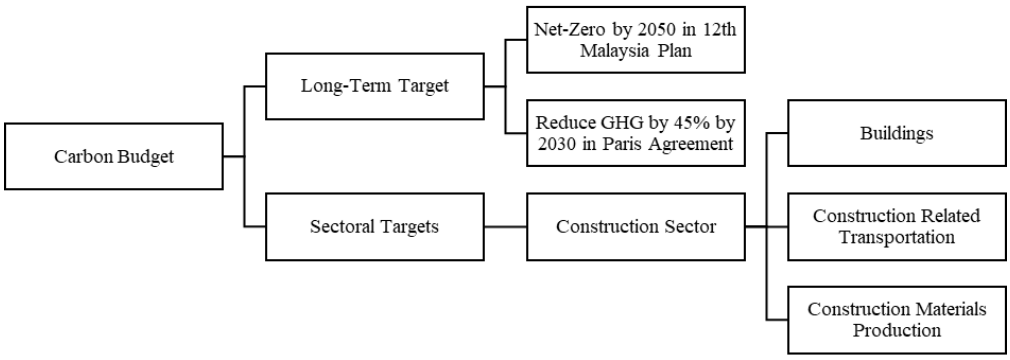


**Figure 1**: The Process of Carbon Budget in Construction Sector
*(Source: Martin & Adrian, 2004)*

## B. Carbon Benchmarking

Carbon benchmarking involves assessing an organization's carbon performance by comparing it to a predetermined standard or reference point. The process helps identify areas where improvements can be made by learning from the best practices of others. Benchmarking involves systematically comparing an organization's performance with others (Greenhouse Protocol, n.d.). By leveraging insights from top performers, targeted improvements can be made to enhance carbon performance.

### *Direct and Indirect Emissions*

GHG emissions are classified into three scopes, encompassing direct and indirect sources (Wei Huang et al, 2017). The built environment significantly contributes to CO2 emissions across all three scopes. Scope 1 emissions refer to direct emissions, while Scope 2 and 3 encompass indirect emissions. These emissions are further categorized to help companies define emission targets and develop effective reduction strategies. Studies have shown that construction materials manufacturing contributes over 45% of the industry's carbon footprint (Colin et al., 2017), while resource utilization and material delivery contribute significantly (Hammond & Jones, 2011). The interdependence of various aspects of development and the need for carbon monitoring tools in urban development has been highlighted by researchers. It is crucial for carbon assessment instruments to consider the interconnectedness of design choices and infrastructure.


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### *Whole Life Carbon Assessments*

Whole-life carbon assessments entail evaluating carbon emissions throughout the entire life cycle of a building, encompassing both operational and embodied carbon. Embodied carbon refers explicitly to the emissions generated during the construction and demolition phases of a building, excluding operational carbon impacts. There are no standardized regulations or peer-reviewed benchmarks for the preliminary phases of building monitoring established by the RIBA Work Stage. Each sector has its calculation approach, considering unique characteristics and processes. RICS has introduced the cradle-to-gate methodology, allowing for calculating embodied carbon factors and impacts (RICS, 2012). For the preliminary phases of buildings, RICS has chosen the Farringdon Station to undertake a cradle-to-gate embodied carbon assessment by retrieving embodied carbon factors from the Inventory of Carbon and Energy (ICE) Database (Behnam et al., 2013).

## C. CARBON PRICING INITIATIVES

Whether implemented through taxes or emissions trading, carbon pricing has effectively influenced behaviour and reduced greenhouse gas GHG emissions (World Bank, 2020). Despite this, Malaysia currently faces challenges as it lacks available carbon data and has not implemented a carbon pricing scheme. Behnam et al. demonstrated the effectiveness of carbon pricing schemes in other countries (Behnam et al., 2012). Thus, integrating carbon footprint and costing into financial and economic planning is essential (Zidan, 2017).

### Carbon Tax

A carbon tax is critical for reducing and eliminating fossil fuel use, preventing destabilization, and destroying the climate. Analysing GHG emissions is essential to determine the most effective way to implement Malaysia's carbon pricing regime. Policymakers can improve carbon pricing by studying other countries' systems. For example, France enacted the 2015 Energy Transition Law, which includes a carbon tax and CO2 performance standards (UNEFPI, 2016). A well-designed carbon tax in the United States could potentially cover 80% of emissions by taxing fewer than 3,000 taxpayers (Gilbert & David, 2009). The Australian Federal Parliament also passed carbon taxation legislation, establishing prices at 23 dollars per tonne in 2012 and 25.40 dollars in 2014 (Behnam et al, 2014).

### Emission Trading Scheme

The Emission Trading Scheme (ETS) has gained significant attention in addressing global climate change. It operates through a market-based mechanism where the carbon price is determined by supply and demand (Grantham Research Institute, 2018). Each company is allocated a specific amount of GHG emissions, and those with low emissions can sell their surplus credits to companies that

exceed their emission limits. These emission allowances can be obtained through auctions or allocation. The European Union (EU) is a prominent example, with the largest carbon trading scheme in operation (Sam, 2021). It covers various sectors and gases, regulating emissions from numerous large energy users across EU member countries. China has also launched its national ETS in 2021, further demonstrating the global adoption of such schemes (IISD, 2021).

## D. IMPORTANCE OF CARBON PLANNING

### Social Benefit

Energy efficiency positively impacts the environment in various ways, and enhancing homes' energy efficiency can substantially positively affect health. Increasing a home's energy efficiency has the potential to affect health in a much larger way positively. It has a significant impact on lowering GHG emissions, both the direct emissions caused by the combustion or use of fossil fuels and the indirect emissions reduction brought by the production of electricity (IEA, 2019). A home's energy efficiency is influenced by factors such as the thermal transmission characteristics of the building fabric, ventilation control, and the efficiency of heating and other energy-consuming devices used within the home, possibly coupled with on-site energy capture, determine a home's energy efficiency (James, Michael & Paul, 2012).

### Economic Benefit

Business engagement in climate change efforts is crucial for carbon emissions reduction and sustainability. The European Green Deal exemplifies the transformation toward a climate-friendly economy, presenting growth opportunities and cost savings (Jose et al., 2022). Carbon pricing mechanisms such as the ETS offer a cost-effective approach to abatement, incentivizing emission reductions and trading allowances (Alexander et al., 2018). Technological advancements like adopting renewable energy are vital for cutting CO2 emissions and costs. The implementation of carbon taxes, akin to Sweden's high carbon tax, not only improves economic efficiency but also diminishes dependence on foreign fossil fuels, ultimately curbing government spending Jamie (2020).

### Environmental Benefit

Outdoor air pollution caused by energy use in buildings harms respiratory health, cardiovascular health, and overall quality of life, like indoor air pollution. Indoor energy contributes to poor air quality in metropolitan areas worldwide, with 97% failing to meet annual air quality criteria (WHO, 2018). To address air pollution in China, the government has implemented low-carbon limitations and additional air pollutant control measures, improved air quality and reducing premature deaths Li et al., 2019). Addressing inequalities in access to clean energy is crucial


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for maximizing the health benefits of a low-carbon world. Regions with high population densities, such as South and East Asia, North America, and Europe, benefit most. Lowering GHG emissions in China and East Asia can significantly improve air quality and human health, with the associated costs being 10 to 70 times less compared to the benefits gained. Reductions in co-emitted air pollutants benefit air quality and human well-being (West, 2013).

## RESEARCH METHODOLOGY

For this study, a qualitative approach, specifically semi-structured interviews, was chosen as the research method to collect primary data from green practitioners and consultants in the construction industry. The aim was to examine the industry's understanding and awareness of carbon planning. Qualitative data collection was chosen due to the subjective nature of the information being sought. It allowed for a comprehensive exploration of social reality and the factors influencing carbon planning awareness in the Malaysian construction sector (Sutton & Austin, 2015).

## FINDINGS AND DISCUSSION

### Demographic Profile

The study involved semi-structured interviews with five green practitioners in Klang Valley, Malaysia, selected based on their expertise and experience in the construction sector. The respondents in this study represent a diverse group of professionals in the construction industry, which includes quantity surveyors, engineers, and energy consultants, as shown in Table 1. The respondents had varying work experience ranging from less than 5 years to over 25 years, providing insights into carbon reduction practices in the industry. Respondents 1, 2, 4 and 5 are from the managerial level and manage a wide range of green construction projects, whereas Respondent 3 is from the executive level with less than 5 years of experience. The nature of the projects overseen by the respondents serves as a foundational element for understanding the extent to which carbon reduction practices are incorporated into the broader framework of carbon planning within the construction industry.

**Table 1**: Respondents' Profile

| Respondent | Profession | Years of Experience | Designation | Types of Projects Managed |
|---|---|---|---|---|
| R1 | Energy Consultant | 20 | Managing Director | Office (Government/ Commercial), Hospital, University, shopping mall, Mixed Development, Airport, Factory, Petrol Stations, Data Centres, Highway |

| Respondent | Profession | Years of Experience | Designation | Types of Projects Managed |
|---|---|---|---|---|
| R2 | GreenRE Accredited Professional, Green Building Index (GBI) Facilitator | 8 | Associate Director | Residential (Strata Properties), Office (Commercial/Industrial), Township |
| R3 | Quantity Surveyor | <5 | Contract Executive | Data Centre, Residential (Strata Properties), Petrol Station, shopping mall, Nursing Home (International Project) |
| R4 | Quantity Surveyor | 20 | Managing Director | Residential (Landed), Office (Commercial), Mixed Development |
| R5 | Engineer, United Nation's Peer Review Program Consultant | 28 | Principal | Office (Government/Commercial), Mixed Development |

## Key Results to Objective 1: Level of Understanding of Carbon Planning in Construction Industry

The primary research objective of this study is to investigate the factors that impact the degree of comprehension of carbon planning within the Malaysian Construction Industry. Based on the findings of the literature review and in-depth interviews conducted, it can be ascertained that professionals within the construction industry demonstrate a relatively low level of awareness regarding the concept of carbon planning. The primary findings of the research illuminate the depth of understanding of carbon planning in the construction industry, particularly concerning Malaysia's carbon reduction commitments, as detailed in Table 2. The study also delves into implementing low-carbon construction practices and the perceived benefits of adopting carbon reduction measures. Concerning Malaysia's carbon reduction commitments, it became evident that professionals in the construction industry possess only an essential awareness and understanding of specific targets for reducing carbon emissions, as well as related policies and initiatives. This lack of awareness underscores the imperative for increased dissemination of information and educational efforts regarding Malaysia's carbon reduction goals within the industry.

The study extended its inquiry to assess the understanding of carbon reduction initiatives introduced by the government. Similarly, there was a lack of familiarity with effective strategies to integrate low-carbon practices into construction activities, as revealed through in-depth interviews with practitioners.


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Respondent R1 noted that Malaysia's emphasis is on economic growth rather than environmental concerns, aligning with the observation by Firdausi et al. that fulfilling the Paris Agreement becomes challenging if the country prioritizes economic growth over emissions reduction (Firdausi, Kamal & Hansa, 2022). Respondents R2 and R5 emphasized adopting low-carbon practices to achieve sustainable development and mitigate carbon emissions, aligning with the national goal of establishing multiple carbon-free cities in Malaysia. This perspective is consistent with Rahman's observation that a Low Carbon City's overarching objective is to significantly reduce carbon emissions while preserving the economic development potential of a city (Rahman, 2020).

In summary, using green initiatives was prevalent among the consultants interviewed. However, there appeared to be a lack of clarity and awareness regarding the concept and process of carbon planning. This again resonated with Bohari et al. findings that there is a lack of implementation guidelines about green approaches and sustainable concepts, and the developers frequently relied on experienced stakeholders in green ventures (Bohari et al., 2016). One intriguing discovery is that integrating advanced technologies and considering human factors can catalyse the successful execution of carbon planning within the construction sectors. To bridge these identified gaps, the government must provide comprehensive education and guidance to consultants and the public to promote the adoption of carbon reduction practices and planning.

**Table 2:** Green Construction Practice and Commitments in Malaysia

| Coding | Category | Elements | Respondents |
|---|---|---|---|
| A1a<br>A1b<br>A1c | Malaysia's Commitment | ● The Paris Agreement<br>● Low Carbon Cities Framework<br>● Twelfth Malaysian Plan | ● R1, R2, R3, R5<br>● R2, R5<br>● R1, R3, R5 |
| A2a-i<br>A2a-ii<br>A2a-iii<br>A2a-iv<br>A2b<br>A2c<br>A2d | Green Tools | ● Green Building Index (GBI)<br>● MyCREST<br>● GreenRE<br>● Leadership in Energy and Environmental Design (LEED)<br>● Energy-efficient technology<br>● Carbon Framework<br>● Low-Carbon Construction Materials | ● R1, R2, R3, R5<br>● R1, R2<br>● R2<br>● R1, R3, R5<br>● R1, R5<br>● R2, R5<br>● R1, R4 |
| A3a<br>A3b<br>A3c<br>A3d | Benefits of Carbon Reduction Practice | ● Reduction of Greenhouse Gas Emissions<br>● Improvement in Energy Efficiency | ● R1, R2, R3, R4, R5 |

| Coding | Category | Elements | Respondents |
|---|---|---|---|
| | | ● Cost Saving<br>● Environmentally Friendly Development | ● R1, R2, R3, R5<br>● R2, R3, R5<br>● R1, R2, R3, R4, R5 |

**Key Results to Objective 2: Insights into The Perception of Consultants on Carbon Planning Elements**

This study endeavours to elucidate the consultants' perspectives concerning the constituent components of carbon planning. A notable literature gap has been identified, where minimal existing research provides insights into the consultants' awareness of carbon planning elements, particularly within the construction sector context. Currently, prevailing research predominantly focuses on the benefits of carbon planning rather than comprehensively examining the entire process. As outlined in Table 3, the primary findings of the research provide substantial insights into consultants' viewpoints regarding carbon planning components. The study emphasizes the carbon budgetary framework, benchmarking, and pricing instruments.

**Table 3:** Elements of Carbon Planning

| Coding | Category | Elements | Respondents |
|---|---|---|---|
| B1a-i<br>B1a-ii | Carbon Budgetary Framework | ● Legislation<br>● Carbon Budget | ● R2, R3, R4, R5<br>● R2, R3, R5 |
| B1b-i<br>B1b-ii | Carbon Benchmarking | ● Direct and Indirect Emissions<br>● Whole Life Carbon Assessments | ● R1, R2, R5<br>● R1, R2, R5 |
| B1c-i<br>B1c-ii | Carbon Pricing Instruments | ● Carbon Taxation<br>● Voluntary Carbon Market (VCM) | ● R1, R2<br>● R1, R2, R5 |

Results indicated a restricted comprehension among consultants concerning the implementation and significance of the carbon budgetary framework. Numerous consultants have articulated the necessity for more explicit directives and assistance in integrating the carbon budgetary framework into their undertakings. According to Habert et al., a global carbon budget can set system boundaries and scalable targets with a flexible operational framework (Habert et al., 2020). Additionally, the respondents are generally aware of the purpose and potential benefits of carbon benchmarking. This has been proven by the


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deficiency in uniform methodologies and instruments for executing carbon benchmarking in the industry. Omar et al. (2021) opined that the construction industry's awareness and understanding of embodied carbon and material selection are still underestimated. This highlights the government's need to formulate clear directives and industry-wide standards to facilitate consistent and reliable carbon benchmarking practices. The research further uncovered respondents' contradictory views on carbon pricing mechanisms. A subset of partial consultants perceived carbon pricing as a plausible catalyst for promoting sustainable practices, whereas some voiced apprehensions regarding its influence on construction costs and competitiveness. This observation aligns with Dyarto and Setyawan (2021), suggested that adopting a complementary approach can mitigate the adverse effect of a carbon tax on commercial operations, thereby diminishing the resistance of business constituents. Overall, it was discovered that the construction industry's limited awareness of carbon planning is attributable to the absence of pertinent legislation and adequate guidance on SOP and guidelines. This underscores the importance of promoting the popularity and rigorous enforcement of these practices.

**Key Results to Objective 3: Barriers to Carbon Planning Implementation in the Construction Industry**

The third objective of this research is to identify the barriers impeding the adoption of carbon planning in the construction industry. The research findings found that numerous factors influenced the advancement of the transition within the construction sector. Key results in Table 4 indicated that all respondents perceived an insufficient understanding of carbon planning and inadequate education as the primary obstacles to the execution of the plan. This is consistent with Damse et al. 's literature findings that a framework has a significant amount of written material and the highest predicted decrease, allowing for analysis based on document research (Damse & Christensen, 2017). They also highlighted that the cost uncertainty impeded transitioning to an alternative construction approach from the conventional method. The respondents confirmed deficiencies in knowledge and awareness regarding carbon planning were attributable to inadequate educational and training opportunities, the absence of a comprehensive carbon footprint database, and a restricted comprehension of the concept. The primary focus of all participants centred around their awareness and understanding of the concept, with considerations of cost implications following closely. The identified lack of established guidelines and frameworks providing a singular directive for the carbon planning process was recognized as a primary factor contributing to the limited knowledge among consultants. This aligns with Azeez's recommendation that achieving effective management in pursuing a low-carbon future may prove challenging without a proficient measuring system and the mobilization of stakeholders through reinforced

partnerships (Azeez, 2021). In summary, the study revealed that addressing obstacles to awareness regarding carbon planning in the construction sector can pave the way for successfully integrating carbon planning measures.

**Table 4:** Barriers to Carbon Planning Implementation

| Coding | Category | Elements | Respondents |
|---|---|---|---|
| C1a<br>C1b | Cost Implications | ● High Upfront Cost<br>● Fear of Cost Uncertainties | ● R1, R2, R3, R4, R5<br>● R1, R3, R4, R5 |
| C2a<br>C2b<br>C2c | Industry Standards | ● Lack of SOP/ Standard Guidelines Specifically in the Construction Industry<br>● Lack of Policies and Regulations<br>● No Standardized Measurement Tools | ● R1, R2, R3, R4, R5<br>● R1, R2, R3, R4, R5<br>● R2 |
| C3a<br>C3b<br>C3c | Knowledge and Awareness | ● Limited Understanding of Carbon Footprint in Construction Activities<br>● Absence of Carbon Planning Education and Training<br>● Absence of Database on Carbon Footprint | ● R1, R2, R3, R4, R5<br>● R1, R2, R3, R4, R5<br>● R1, R2, R3, R4, R5 |

**Key Results to Objective 4: Acceleration of Carbon Planning Awareness in the Construction Industry**

The fourth research objective is to enhance the consultants' awareness of carbon planning in the construction industry. Based on the research findings, it was found that there is still room for improvement in the current framework and guidelines in the construction industry. A significant literature gap was identified in a dearth of existing research to determine how to enhance the comprehension of carbon planning concepts in the construction industry. Therefore, keywords related to enhancing overall carbon reduction practices in the construction industry context were identified from existing literature, such as the framework of carbon planning, the process of carbon planning, and a review of existing legislative perspectives on carbon planning practice. This research then contributed to refining and relating the strategies to boost the consultants' awareness of carbon reduction in the construction industry with information obtained from in-depth interviews. As per the findings tabulated in Table 5, the study highlights the pivotal role of the government in promoting awareness and implementing carbon planning in the construction industry. Respondents acknowledged the significance of government initiatives, policies, and regulations in creating a conducive environment for sustainable practices. This aligns with Habert et al.'s


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recommendations (2020) to establish a clear framework and procedure. However, some participants conveyed the need for more explicit directives, robust implementation, and additional incentives to stimulate widespread acceptance of carbon planning measures. Furthermore, respondents emphasized the importance of collaborative efforts and knowledge exchange among various actors within the industry. The study participants underscored the necessity for industry associations, professional bodies, and educational institutions to actively contribute to raising awareness, providing training, and facilitating knowledge exchange on carbon planning. The engagement of multiple stakeholders was deemed crucial in expediting the dissemination of knowledge on carbon planning and fostering a shared commitment towards carbon planning practices.

**Table 5:** Proposed Solutions for Acceleration of Carbon Planning Implementation

| Coding | Category | Elements | Respondents |
|---|---|---|---|
| D1a<br>D1b<br>D1c<br>D1d<br>D1e<br>D1f | Government Roles | ● Implementation of Carbon Taxation<br>● Establishment of SOP/ Standard Guidelines/ Framework<br>● Carbon Footprint Data Collection<br>● Legislation and Enforcement<br>● Incentives Encouragement<br>● Pilot Studies/ Showcase Projects | ● R1, R3, R5<br>● R1, R2, R3, R4, R5<br>● R1, R2, R3, R4, R5<br>● R1, R2, R3<br>● R2, R4<br>● R2, R3, R4, R5 |
| D2a<br>D2b<br>D2c<br>D2d | Other Opinions | ● Contractual Requirements<br>● Education<br>● Publications on Relevant Topics<br>● Market Demand | ● R1<br>● R1, R2, R3, R4, R5<br>● R1<br>● R2 |

## CONCLUSION AND RECOMMENDATIONS

The research underscores the key determinants impacting carbon planning awareness within the construction sector and the necessity for well-defined frameworks and adequate education to augment awareness. Sustained research and collaborative endeavours are imperative to raise awareness and facilitate the adoption of carbon planning practices, thereby accomplishing sustainable development objectives in the construction industry. The present research has yielded significant findings regarding the comprehension and recognition of carbon planning among consultants in Malaysia's construction sector. The results of this study can serve as a valuable resource for future researchers exploring

effective methods for increasing awareness of carbon planning among construction industry professionals and developers. For a more comprehensive understanding of carbon planning awareness in the industry, it is recommended to utilize alternative research methodologies such as case studies or Likert scale questionnaire surveys. It is recommended that future research should incorporate the viewpoints of construction consultants who hold executive positions. Further studies on this topic should address these considerations, as they are crucial for researchers to consider.

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# FUNDAMENTALS OF DEVELOPING CONCEPTUAL COST ESTIMATION MODELS USING MACHINE LEARNING TECHNIQUES: SELECTION AND MEASUREMENT OF BUILDING ATTRIBUTES

**Rui Wang[1], Hafez Salleh[2], Zulkiflee Abdul-Samad[3], Nabilah Filzah Mohd Radzuan[4] and Kok Ching Wen[5]**

[1,2,3]*Centre of Building Construction and Tropical Architecture (BuCTA), Faculty of Built Environment,*
UNIVERSITI MALAYA
[4] *Faculty of Computing,*
UNIVERSITI MALAYSIA PAHANG
[5] *Faculty of Engineering and Quantifying Surveying,*
UNIVERSITI ANTARABANGSA INTI

## Abstract

Ensuring the identification of building attributes is the primary task in developing a machine learning cost estimation model. However, the existing research on building attributes has the following shortcomings: it struggles to categorize building characteristics according to various cost types, and the suggested sets of attributes do not clearly establish measurement standards for these qualities. To address these issues, this study aims to select a set of building attributes suitable for conceptual cost estimation and establishment of measurement standards. Through a two-round process of focused group discussions, this research ultimately identified 13 building attributes that can be collected before the completion of building design. These attributes serve as a basis for assessing completed building projects during the model development phase and for evaluating new projects during the model application phase. This study provides a foundational framework for the development of conceptual cost estimation models, ultimately enhancing the accuracy of machine learning cost estimation models.

***Keywords**:* Conceptual cost estimation, machine learning, building attributes

[2] Associate Professor at Universiti Malaya, Email: hafez@um.edu.my

## INTRODUCTION

The success of construction projects is heavily dependent on cost prediction (Juszczyk, 2020; Park et al., 2022; B. Wang et al., 2021). A successful construction project should achieve on-time delivery within the budget while yielding a substantial return on investment (Ma et al., 2016; Peleskei et al., 2015). Inaccurate estimations can lead to cost overruns, construction delays, and many other, even worse, outcomes (Car-Puši & Mladen, 2020; Elmousalami, 2020; Mir et al., 2021).

Currently, qualitative and quantitative analyses are the primary methods for cost estimation (Hashemi et al., 2020). Qualitative methods based on expert judgment may introduce biases and result in inaccurate estimates (R. Wang et al., 2022). Quantitative techniques not only rely on historical data and expert knowledge but can also analyze project design, processes, and unique characteristics (Ugur, 2017). Quantity surveying is considered the most reliable quantitative method for obtaining construction costs (Ugur et al., 2018). However, it requires surveyors to possess substantial expertise, can be time-consuming, and is only feasible with a well-developed design (Ugur et al., 2018). Therefore, there is a need to enhance the efficiency of quantity surveying. Other traditional quantitative cost estimation methods mostly depend on statistical analysis and simple regression theory, which results in lower accuracy and longer time consumption and does not add value to cost estimation (Jiang, 2019). As a result, traditional budgeting methods no longer meet the needs of practical engineering budgets. It is essential to use computer technology for intelligent cost control in construction budgeting to improve accuracy (Abdel-Basset et al., 2020; Patil & Salunkhe, 2020; Xuan & Li, 2022).

Machine Learning (ML) is a branch of Artificial Intelligence (AI) and is a data-driven modelling technique (Brink et al., 2016). It can be used to automatically extract hidden patterns from high-dimensional data and convert them into explicit information or knowledge to address challenging issues in the construction industry (Zhou et al., 2018). As the name suggests, using ML methods to predict construction costs can eliminate the need for experts and quantity surveying calculations (Ugur et al., 2018) and can also overcome the issue of lacking accurate estimation data at the project's outset (Saeidlou & Ghadiminia, 2023).

Identifying building attributes is a primary task in developing machine learning cost estimation models. However, as summarized through the literature review, there is a lack of comprehensive research on the standardized selection of attributes for machine learning models in the field of construction cost estimation (Elmousalami, 2020; Pike & Grosse, 2018). To address this gap, Salleh et al. (2023) conducted a study to establish a standardized set of building attributes to guide the development of construction cost estimation models.


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Nevertheless, the attribute set still has the following shortcomings: 1) The study only identified the importance of different attributes but did not categorize attributes based on the needs of different cost types, such as conceptual cost estimation before design completion and project cost estimation after design completion; 2) The established attribute set did not provide clear measurement standards for attributes, including the classification and interpretation of numeric and textual attributes.

Therefore, to effectively address these issues, this study aims to select a set of building attributes suitable for conceptual cost estimation and establishment of measurement standards. This research, using a focused group discussion methodology, builds upon the standard building attribute set proposed by Salleh et al. (2023). It selects attributes that can be obtained before the building design is completed and provides clear measurement standards for these attributes. This study lays the foundation for developing construction conceptual cost estimation models, enhancing accuracy.

## LITERATURE REVIEW

### The main process of developing a machine learning cost estimation model

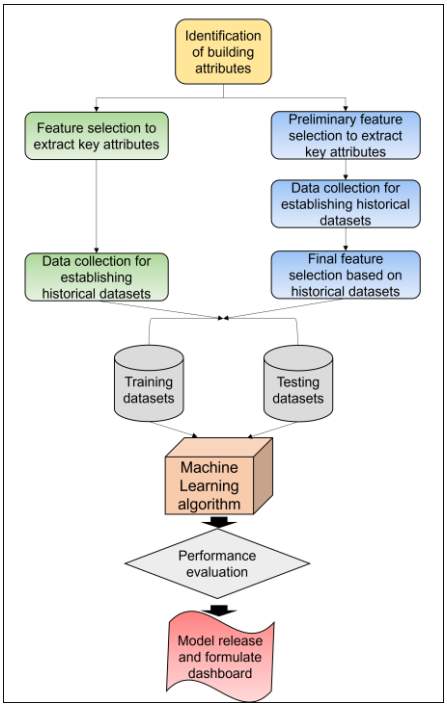


**Figure 1:** Flowchart for developing machine learning cost estimation model
*Source: compiled from (Abed et al., 2022; Hashemi et al., 2020)*

Figure 1 illustrates the main process of developing a machine learning cost estimation model. Initially, the identification of building attributes was the first task in the development of the model. Subsequently, key attributes were extracted from the identified building attributes. Then, data collection was conducted based on these key attributes to create a completed project dataset. This preparation is critical because the accuracy of the cost estimation model is affected by the input building attributes and the size of the dataset (Cho et al., 2013). In terms of feature selection, the dual feature selection method (blue area) is considered more scientific than the traditional method (green area). Prior to data collection, attribute importance is usually determined based on expert judgment and subjective ratings. However, dual feature selection ensures that the importance of attributes is assessed based on historical data after data collection is complete, and quantitative methods such as regression analysis are used (Matel et al., 2022). Once the data collection and identification of key attributes are complete, the historical dataset is divided into training and test sets and fed into the machine learning algorithm. To effectively validate the performance of the developed models, it is a prerequisite that various performance evaluation methods are used and multiple models are tested.

Therefore, identification of building attributes, feature selection, collection of completed project datasets, optimisation of machine learning algorithms, and evaluation metrics for model performance are key steps in the development of machine learning cost estimation models for construction projects (Abed et al., 2022; Hashemi et al., 2020). These steps contribute to improving the accuracy of cost estimation in construction projects, thereby enhancing project management efficiency and decision-making accuracy.

**Building attribute datasets**

In the context of construction cost estimation, attributes refer to specific features or factors considered in the estimation process to determine the construction cost of a building or structure (Elhag & Boussabaine, 1998; Elmousalami, 2020). Having a sufficient number of building attributes and a larger dataset of completed projects can effectively enhance the accuracy of cost estimation (Shin, 2015; Y.-R. Wang et al., 2012). The accuracy of cost estimation models can vary based on the input building attributes (Cho et al., 2013). However, it is not feasible to incorporate every possible attribute that a building might have into an estimation model (Juszczyk, 2017), and the selection of building attributes requires further research (B. Wang et al., 2021).

From the authors' previous study, Salleh et al. (2023) initially conducted a literature review to summarize a significant number of attributes. Then, through a questionnaire survey and focused group discussions during the Delphi research phase, they eventually identified 68 ranked attributes and


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formulated a building data attribute set, which includes 12 categories of variables such as Project Strategic and Parties-involved (as shown in Figure 2). This study provides the essence for the development of machine learning models for construction cost estimation, and future researchers in the field can refer to these listed attributes to determine the layout structure of new models. However, the attribute set still has the following shortcomings:

- The study only determined the importance of different attributes but did not categorize attributes based on the needs of different cost types, such as conceptual cost estimation before design completion and project cost estimation after design completion.
- The established attribute set did not provide clear measurement standards for attributes, including the classification and interpretation of numeric and textual attributes.

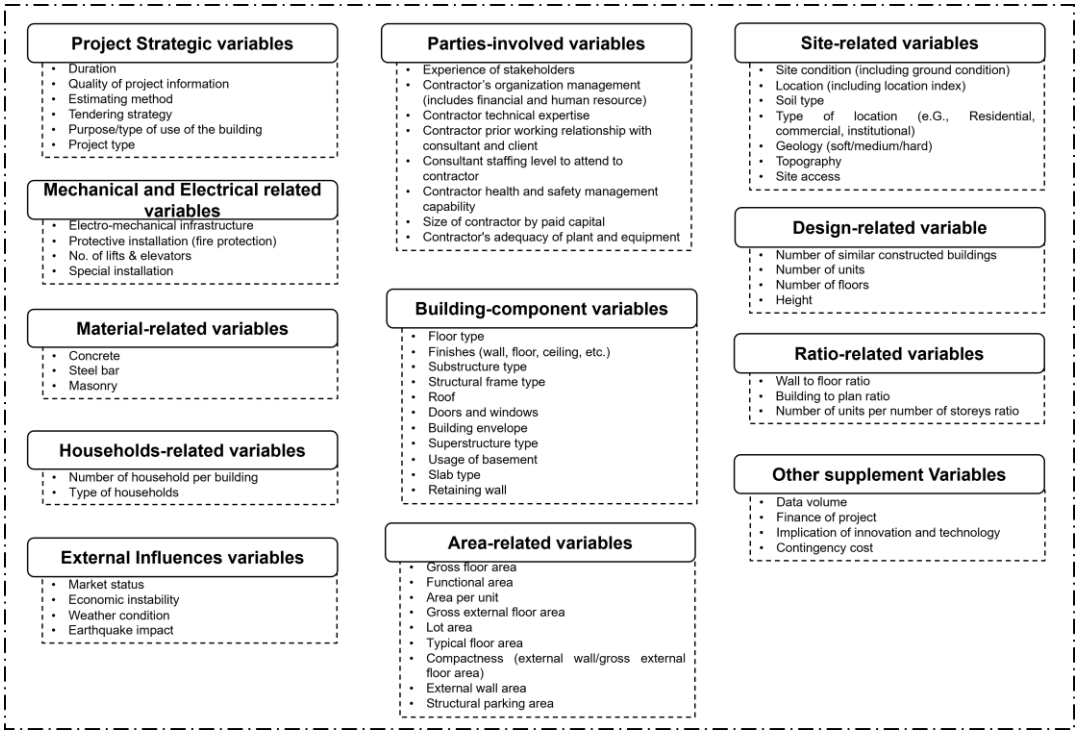


**Figure 2:** A standard attribute set of building for cost estimation
*Source: summarized from (Salleh et al., 2023)*

## RESEARCH METHODOLOGY

The application of the focus group discussion in this research is to poll a group of experts to reach a group consensus regarding the classification of attributes in building cost estimation. The focus group discussion was conducted in October 2023 in the Faculty of Built Environment, University of Malaya and mainly includes two rounds (refer to Figure 3): selecting building attributes for which data will be available before the building design is completed; clarifying the measurement of different attributes, both numeric and text. As the measurement of building attributes varies from country to country, three overseas experts were also invited for this study, the 14 experts of this study are shown in Table 1.

**Table 1:** Expert panel list of the focus group discussion

| Experts | Age | Gender | Position | Working Experience | Country |
|---|---|---|---|---|---|
| E1 | 33 | Male | Construction technical staff | 8 years (Enterprise) | Malaysia |
| E2 | 41 | Female | Construction technical staff | 14 years (Enterprise) | Malaysia |
| E3 | 32 | Male | Construction technical staff | 6 years (Enterprise) | China |
| E4 | 38 | Male | Researcher in quantity surveying | 9 years (Institute) | England |
| E5 | 31 | Female | Researcher in quantity surveying | 7 years (Institute) | Malaysia |
| E6 | 42 | Male | Researcher in quantity surveying | 7 years (Institute) | Malaysia |
| E7 | 36 | Female | Researcher in quantity surveying | 6 years (Institute) | Malaysia |
| E8 | 35 | Female | Researcher in quantity surveying | 4 years (Institute) | Malaysia |
| E9 | 44 | Male | Manager of building cost services | 10 years (Enterprise) | Malaysia |
| E10 | 51 | Male | Manager of building cost services | 14 years (Enterprise) | Malaysia |
| E11 | 38 | Female | Manager of building cost services | 8 years (Enterprise) | Malaysia |
| E12 | 36 | Female | Cost estimator | 6 years (Enterprise) | Malaysia |
| E13 | 47 | Male | Cost estimator | 14 years (Enterprise) | China |
| E14 | 44 | Male | Cost estimator | 9 years (Enterprise) | Malaysia |

*Source: from the actual focus group discussion*


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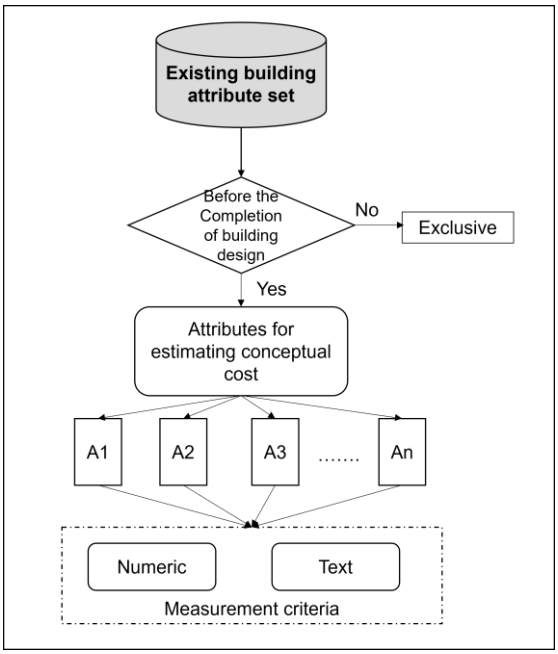


**Figure 3:** Research flowchart of focus group discussion
*Source: Authors' Deliberation*

**Round 1: Selecting building attributes for conceptual cost estimation**
Based on a literature review and the existing attribute sets, the attributes were categorized with respect to the completion of the building design as the boundary. In focused group discussions, experts were surveyed using a questionnaire to select attributes based on their past experiences. The goal was to determine which subset of attributes could be used to estimate conceptual costs by collecting data before the completion of building design. The final selection of attributes was made based on the results summarized from the questionnaires.

**Round 2: Clarifying the measurement of different attributes**
In the second round of discussions, experts provided their opinions on how to measure different attributes. In this study, expert viewpoints were aggregated and categorized. Based on the expert perspectives, specific measurement criteria for each attribute were summarized, and a distinction was made between numeric and textual attributes.

## RESULT AND DISCUSSION

### Selected building attributes for conceptual cost estimation

In the discussion, all experts unanimously agree that Duration, Number of Floors, Building Height, Floor Area, Tendering Strategy, Project Type, Type of Use of the Building, Soil Type, Topography, and Location can be considered as attributes for conceptual cost estimation. This is because these attributes can provide data at the preliminary design stage. However, there is controversy regarding the following 3 attributes:

- Market Status: Experts E5, E6 and E14 believe that measuring this attribute during the model application stage is challenging. Understanding future market conditions requires predicting trends based on past economic development, which demands a high level of economic knowledge. Considering the practical application of the model, if the relevant business has good market forecasting capabilities and can accurately predict future indicators such as inflation and lending rates, this attribute may be used as an input variable for the predictive model.

- Weather/Earthquake Impact: Expert E7 and E10 consider both of these attributes as uncertain factors. Although they can significantly impact project costs, they are challenging to measure. For example, different magnitudes of earthquakes can have varying impacts, but it is impossible to predict the magnitude of future earthquakes when applying the model. Weather impacts include seasons such as rainy or snowy periods, but these attributes cannot be quantified. Therefore, for these two attributes, if the project location for the model application is in an earthquake-prone or weather-affected area, these attributes may be considered; otherwise, they may not be relevant.

Through the first round of data collection from the questionnaire as well as data analysis, 13 building attributes that could be used to obtain data before the completion of the building design were screened and the results are shown in Table 2.


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**Table 2:** Attributes for estimating conceptual cost

| Classification | Attributes |
|---|---|
| Compulsory | |
| Project Strategic variables | Duration |
| | Tendering strategy |
| | Type of use of the building |
| | Project type |
| Area-related variables | Floor area |
| Site-related variables | Location |
| | Soil type |
| | Topography |
| | Number of floors |
| | Height |
| Alternative | |
| External influence variables | Market status |
| | Weather impact |
| | Earthquake impact |

*Source: from research result*

**Measurement of different attributes**

In the second round of discussion, the author first introduced the regular measurement methods for 13 screened attributes, then the experts proposed recommendations based on personal experience. For most attributes, experts generally agree with the author's proposed measurement criteria. However, some experts have suggested additional considerations.

- E2 and E6 believe that when measuring the number of floors, it is essential not only to consider the total but also to differentiate between above-ground and below-ground floors. The costs between these two types of floors can vary significantly in actual construction and should be measured separately.

- E5, E6, and E14 recommend that when assessing market status, careful consideration should be given to changes in exchange rates and inflation. These factors directly impact material and labour costs, potentially causing fluctuations in project costs. Additionally, financing costs, contract agreements, and project timelines are also influenced by these changes and must be thoroughly considered in cost estimation to ensure accuracy and project control.

- E13, an expert from China, suggests dividing the Location attribute into two levels for measurement. Firstly, considering the differences in consumption levels in different cities, it is divided into various levels in

the first tier. In the second tier, the expert further specifies the building's location based on differences between the city centre and suburbs. Therefore, a more detailed division of the building location helps more accurately capture the unique cost factors in the project's region, enhancing the accuracy and reliability of cost estimation.

All in all, the metrics are adapted to the measurement of historic buildings in the model development phase and the measurement of new projects in the model application phase, as shown in Table 3-4. It is important that the proposed metrics be adapted to the specific conditions of different countries. Table 3 describes the standards that can be measured numerically and Table 4 shows the standards that can be measured using text categorization.

## DISCUSSION

In the two phases of our investigation, we delved into the identification of building attributes for their utility in conceptual cost estimation and the establishment of measurement criteria for these attributes. By actively engaging experts in the field, we were able to refine the selection of relevant attributes and define precise measurement guidelines. This comprehensive approach has significantly enhanced the accuracy and reproducibility of cost estimates.

The implications of our research extend to the realms of cost control and forecasting, offering valuable insights for both project planning and decision-making processes. The meticulous extraction of applicable building attributes and the elucidation of specific measurement criteria contribute to a more robust foundation for cost estimation methodologies. This newfound clarity not only aids in improving the overall reliability of cost estimates but also facilitates a more systematic and informed approach to decision-making throughout various stages of project development.

The significance of our findings becomes particularly evident in their potential impact on the advancement of machine learning (ML) models for conceptual cost estimation. The precisely identified attributes and their measurement criteria serve as crucial groundwork, laying the foundation for the future development of innovative ML models. These models have the potential to further refine and automate the conceptual cost estimation process, offering a promising avenue for continued advancements in the field of construction project management.


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**Table 3:** The measurement of numeric attributes

| Attributes | Specification | Measurement |
|---|---|---|
| Duration | Time of construction | Monthly-based |
| Number of the floor | On the ground | Quantities |
| | Under the ground | Quantities |
| Building height | Height from roof deck to outdoor floor level | Metre-based |
| Floor area | The footprint of the building | Square metre |
| Total floor area | Total area of the building | Square metre |
| Market status | Inflation rate | (%) |
| | Lending rate | (%) |

Source: from research result

## CONCLUSION

In the development of machine learning cost estimation models, the currently proposed building attribute sets have the following shortcomings: they do not classify building attributes based on the needs of different cost types, and they do not provide clear measurement standards for these attributes. Therefore, this study aims to address these issues using a two-round, focused group discussion approach to select a set of building attributes suitable for conceptual cost estimation and establish measurement standards. The study ultimately identified 13 building attributes that can be obtained before the completion of building design. These attributes are used for assessing completed buildings during the model development phase and for evaluating new projects during the model application phase. This research provides a foundational framework for the development of construction conceptual cost estimation models, thereby enhancing the accuracy of machine learning cost estimation models.

While this study has successfully addressed the deficiencies in existing machine learning cost estimation models by identifying a set of building attributes for conceptual cost estimation and establishing clear measurement standards, it is essential to acknowledge its limitations. One notable limitation is the exclusive focus on attributes relevant to conceptual cost estimation, without delving into the intricacies of cost estimation beyond the completion of the design phase. Future research endeavours should aim to bridge this gap by conducting more in-depth investigations into the attributes influencing cost estimates in the post-design stages. This comprehensive approach would provide a more holistic understanding of the factors impacting construction project costs throughout the entire lifecycle. Looking ahead, researchers should consider extending their focus to include attributes specific to post-design stages, facilitating a more comprehensive cost estimation model. This expansion could encompass factors

such as construction materials, labour costs, and technological advancements that play a pivotal role in determining project costs beyond the conceptual phase.

**Table 4:** The measurement of text attributes

| **Attributes** | **Measurement** | | | |
|---|---|---|---|---|
| Tendering strategy | Open tendering | Invitation to tender | Negotiation | Competitive negotiation |
| | ( ) | ( ) | ( ) | ( ) |
| Project type | New Construction | Alterations | Extensions | |
| | ( ) | ( ) | ( ) | |
| Type of use of the building | Residential | Office | Commercial | Industrial |
| | ( ) | ( ) | ( ) | ( ) |
| Location 1 | First Tier Cities | New Tier 1 Cities | Second-tier cities | Third-tier cities |
| | ( ) | ( ) | ( ) | ( ) |
| | Fourth-tier cities | Fifth-tier cities | | |
| | ( ) | ( ) | | |
| Location 2 | City centre | Outskirts | | |
| | ( ) | ( ) | | |
| Soil type | Sand | Clay | Rock | |
| | ( ) | ( ) | ( ) | |
| Topography | Flat | Hillside | Mountain | |
| | ( ) | ( ) | ( ) | |
| Weather impact (Severe weather prone areas) | Rainstorms | Snowstorms | Windstorms | None |
| | ( ) | ( ) | ( ) | ( ) |
| Earthquake impact | Seismic zone | Non-seismic zone | | |
| | ( ) | ( ) | | |

*Source: from research result*

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# DEVELOPMENT AND TREND ANALYSIS OF CHINA'S QUANTITY SURVEYING CONSULTING INDUSTRY

**Dongmei Huangfu[1], Yun Fah Chang[2*], Sok Li Lim[3]**

[1, 2, 3] *Faculty of Business & Law,*
TAYLOR'S UNIVERSITY, MALAYSIA
[1] *Faculty of Architectural Engineering Institute,*
DIANCHI COLLEGE OF YUNNAN UNIVERSITI, CHINA

## Abstract

The Chinese economy has experienced rapid growth since its reform in 1992. In 2010, China surpassed Japan and became the world's second-largest economy with a GDP of RMB 40.12 trillion and a per capita disposable income of RMB 19,109.44. With the promotion of the Belt and Road Initiative, China's infrastructure-related enterprises began to enter the international market in large numbers, directly driving the rapid development of China's construction industry as well as its quantity surveying (QS) consulting industry. Through literature review and the government public reports, the data of QS consulting industry status in China from 2011 to 2021 attained and summarised, including the number of enterprises, business revenue, QS consulting business composition, and the number of registered quantity surveyors. It turned out that the QS consulting industry maintained steady growth. Simultaneously, it also showed significant progress about the business income and number of professional personnel, especially after related policies for advancing the entire process of QS consulting launched. Additionally, with the methodology of time series model with ARIMA, the QS consulting industry development trends for the next five years was forecasted. Finally, in order to further promote the industry's development and deal with the challenges, this study presents three suggestions: pooling resources to improve the level of international business competition, expand business scope and innovating business growth points, strengthen the building of professional and technical personnel.

***Keywords***: China, Consulting Industry, Quantity Surveying, Trend Analysis

[2] Associate Professor at Taylor's University. Email: yunfah.chang@taylors.edu.my

## INTRODUCTION

After 30 years of reform and opening up, China has let the world witness the miracle of its all-round rapid economic, technological and social development. In 2010, China achieved the goal of surpassing Japan and becoming the world's second largest economy with the GDP of RMB 40.12 trillion and per capita disposable income of RMB19,109.44 (Wu & Li, 2020). Ten years later, China's GDP and per capita disposable income reached RMB101.60 trillion and RMB32,189, respectively in 2020 (Wu & Li, 2020).

Driven by the Belt and Road Initiative (BRI), China's construction enterprises, especially those related to infrastructure and property, began to enter the international market in large numbers. With the process of internationalization, China's construction industry has ushered in rapid development in the past few years. According to the "13th Five-Year Plan of Construction Industry Development" (2016-2020) released by the Ministry of Housing and Urban-Rural Development and statistics released by China Construction Industry Association, China's overall construction GDP growth hits RMB26.39 trillion in 2020 as compared to RMB19.36 trillion in 2016. As the downstream of the construction industry, the development of quantity surveying (QS) consulting industry also benefits from the value created by the construction industry (Wu & Li, 2020), which in turn has led to the increase in the demand for quantity surveyors. Therefore, China's higher education institutions and QS consulting firms are urgently needed to produce a sufficient pool of domestic quantity surveyors with international capabilities. Then more quantitative research is required, especially to understand the future trend of the QS industry. While, the current studies on China's QS consulting industry are mostly qualitative research lacking the latest statistical data support. According to the "13th Five-Year Plan for Construction Industry Development" released by the Ministry of Housing and Urban-Rural Development, PRC and the Statistical Analysis of "Construction Industry Development" released by CCIA from 2016 to 2021, the total output value of the construction industry completed by qualified general contracting and specialized contracting enterprises increased from19 trillion RMB to 29 trillion RMB (MOHURD, 2021; CCIA, 2022). The number of construction enterprises increased from 83 thousand to 129 thousand (MOHURD, 2021; CCIA, 2022).

This study aims to understand the current development of China's QS consulting industry through the analysis of data obtained from various sources, and then forecast the development trend of the industry in the next five years. This will provide better insights of the industry and set an important reference for the training of QS talents for the domestic and international markets. Finally, some challenges faced by the China's QS consulting industry will be highlighted before concluding remarks.

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## DEVELOPMENT STATUS OF CHINA'S QUANTITY SURVEYING CONSULTING INDUSTRY

Through analyzing the government public reports and literature review, the data of QS consulting industry status in China from 2011 to 2021 was attained and summarized, including the number of enterprises, business revenue, QS consulting business composition, and the number of registered quantity surveyors.

### Number and Business Income of Quantity Surveying Consulting Enterprises

This section mainly combs and analyses the number and business income of QS consulting enterprises. The number of enterprises, during 2011-2021, increased from 6,490 to 11,400 (Figure 1), an increase of nearly 0.62 times. Generally speaking, the growth rate is stable but not large (Liu & Wu, 2020). While in 2019, the growth rate of enterprise numbers declined obviously. Mainly because of the Covid-19 outbreak, it has a great impact on China's economic development, also on the QS consulting industry (Zhang, 2020). However, in 2020, the number of QS consulting enterprises increased significantly. The development of QS consulting enterprises are showing a new vitality (Wu & Li, 2020). For the business income of QS consulting enterprises during 2011 to 2021, rising from 80.69 billion RMB to 305.67 billion RMB (Figure 1), which showed an upward trend, an increase of about 4 times, realizing a long-span development (Si, 2014).

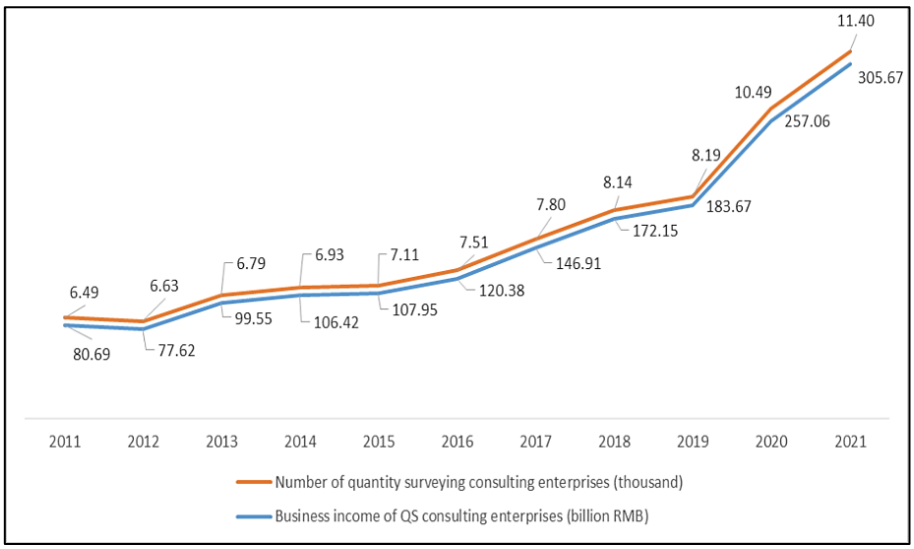


**Figure 1**: Number and business income of quantity surveying consulting enterprises
*Source: (MOHURD, 2012- 2022)*


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## Quantity Surveying Consulting Business Composition

As Table 1 shows, from the income composition of QS consulting business, during the period from 2011 to 2021, the revenue increased from 30.55 billion RMB to 114.30 billion RMB (Liu & Wu, 2020). Among them, the income amount and proportion of housing construction projects, municipal projects, highway projects, thermal power projects, water conservancy projects and other professional projects also showed different trends.

**Table 1**: Income composition of quantity surveying consulting business (billion RMB)

| Year | Total | Income of housing construction project | Proportion | Income of municipal project | Proportion | Income of highway project | Proportion |
|---|---|---|---|---|---|---|---|
| 2011 | 30.55 | 17.74 | 58.08% | 3.91 | 12.80% | 1.29 | 4.21% |
| 2012 | 35.16 | 20.75 | 59.02% | 4.57 | 13.01% | 1.50 | 4.27% |
| 2013 | 41.97 | 24.98 | 59.51% | 5.76 | 13.73% | 1.82 | 4.34% |
| 2014 | 47.93 | 28.55 | 59.57% | 6.80 | 14.20% | 2.03 | 4.23% |
| 2015 | 51.64 | 30.21 | 58.50% | 7.74 | 14.98% | 2.24 | 4.34% |
| 2016 | 59.57 | 34.89 | 58.57% | 9.37 | 15.72% | 2.77 | 4.65% |
| 2017 | 66.12 | 37.98 | 57.44% | 11.13 | 16.83% | 3.22 | 4.87% |
| 2018 | 77.25 | 44.96 | 58.20% | 12.82 | 16.59% | 3.80 | 4.92% |
| 2019 | 89.25 | 52.44 | 58.75% | 14.95 | 16.75% | 4.36 | 4.89% |
| 2020 | 100.27 | 59.79 | 59.62% | 17.01 | 16.97% | 5.02 | 5.01% |
| 2021 | 114.30 | 67.75 | 59.28% | 19.79 | 17.32% | 5.61 | 4.91% |
| 2011 | 30.55 | 1.08 | 3.54% | N/A | N/A | 6.53 | 21.37% |
| 2012 | 35.16 | 1.11 | 3.17% | 0.67 | 1.91% | 6.59 | 18.73% |
| 2013 | 41.97 | 1.24 | 2.95% | 0.83 | 1.97% | 7.33 | 17.48% |
| 2014 | 47.93 | 1.17 | 2.44% | 0.97 | 2.02% | 8.41 | 17.54% |
| 2015 | 51.64 | 1.37 | 2.65% | 1.13 | 2.19% | 8.96 | 17.35% |
| 2016 | 59.57 | 1.52 | 2.54% | 1.29 | 2.17% | 9.73 | 16.34% |
| 2017 | 66.12 | 1.48 | 2.23% | 1.50 | 2.27% | 10.82 | 16.36% |
| 2018 | 89.25 | 2.13 | 2.39% | 1.77 | 2.28% | 12.20 | 15.80% |
| 2019 | 100.27 | 2.56 | 2.56% | 2.15 | 2.40% | 13.22 | 14.82% |
| 2020 | 114.30 | 2.62 | 2.29% | 2.46 | 2.45% | 13.43 | 13.39% |
| 2021 | 30.55 | 1.08 | 3.54% | 2.83 | 2.48% | 15.69 | 13.73% |

*Source: (MOHURD, 2012- 2022)*

From 2010 to 2012, the income of housing construction projects and municipal projects accounted for 68.58%, 70.9% and 72.03% of the income of

QS consulting business respectively, and the income of these two majors took an absolute advantage. Highway, thermal power, metallurgy and other professional projects accounted for about 10% of the total (Si, 2014). Although from 2011 to 2021, the income of housing construction project and municipal project showed a slightly increasing trend, while among them, the income of housing construction project basically maintained at about 58%, and the municipal project increased slightly. Moreover, the income proportion of highway project and water conservancy project is on the rise, but the increase is not large. The proportion of municipal project professional income showed an obvious upward trend, while the proportion of thermal power project and other professional income showed an overall downward trend. The municipal projects businesses expanding is mainly subject to the industry threshold and barriers, as well as lack of professional and technical personnel (Si, 2014).

**Employees and Registered Quantity Surveyors**

In China, since 1997, the implementation of quantity surveyors qualification system, engaging in the construction of the engineering construction activities, design, construction, QS consulting, project cost management, and other units and departments, must be in valuation, evaluation, review control and management, and other supporting jobs with quantity surveyors qualification of professional and technical personnel (Wu & Li, 2020). Quantity surveyors are senior personnel engaged in QS professional work in China. Their current situation can reflect the general level of QS industry development in China (Liu & Wu, 2020). Therefore, this section mainly analyses the number of employees and first-class registered quantity surveyors of QS consulting enterprises from 2011 to 2021.

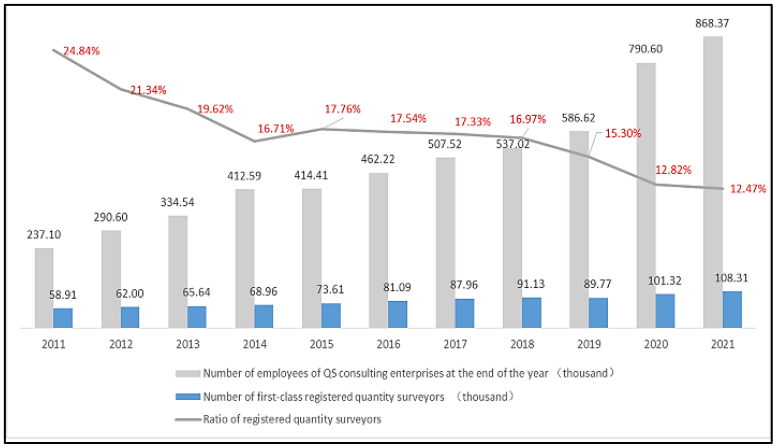


**Figure 2**: Number and growth rate of employees and quantity surveyors of quantity surveying consulting enterprises
*Source: (MOHURD, 2012- 2022)*


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From the perspective of QS consulting enterprises' employees, during 2011 to 2021, the number increased from 237.10 thousand to 868.37 thousand. While the number of first-class registered quantity surveyors in QS consulting enterprises increased from 58.91 thousand to 108.31 thousand, with ups and downs in the past 11 years. Except for 2019, the decline was large, while the overall trend was on the rise (Figure. 2). But the proportion of registered quantity surveyors in the workforce fell from 24.8% to 12.47%. This shows that the personnel without professional qualifications in QS consulting enterprises should account for a considerable proportion, and the situation of existing professional and technical personnel is not consistent with the intellectual service characteristics of QS consulting (Si, 2014).

## TIME SERIES TREND PREDICTION

Based on the above statistical data attained from 2011 to 2021 through government public reports and literature review, then a time series model with ARIMA is used to forecast and analyse the development trend of the QS consulting industry in the next five years (2022-2026). Because this article deals with time series data, and most time series data are non-stationary, in order to avoid the problem of spurious regression in the regression equation, it is necessary to conduct a unit root test before further analysis to select stationary variables for regression (Wang, 2005). Therefore, for the collected non-stationary data, it is necessary to first conduct a stationary test and apply a transformation to make it stationary. After that, you can proceed with model identification, order determination, optimization, and finally select an ARIMA model for forecasting.

### Data stationary test

By examining the time series plot of the original data from Chinese QS consulting companies, it is evident that the data does not exhibit stationary. Therefore, it is necessary to perform differencing.

**Table 2**: Augmented Dickey-Fuller test statistic (ADF) results

| Y | Difference order | ADF | Prob.* | t-Statistic | | |
|---|---|---|---|---|---|---|
| | | | | 1% | 5% | 10% |
| **Business income** | 0 | 3.253 | 1.000 | -4.939 | -3.478 | -2.844 |
| | 1 | 1.175 | 0.996 | -5.354 | -3.646 | -2.901 |
| | 2 | -4.617 | 0.000*** | -4.665 | -3.367 | -2.803 |
| **Number of enterprises** | 0 | 1.753 | 0.998 | -4.939 | -3.478 | -2.844 |
| | 1 | 0.775 | 0.991 | -5.354 | -3.646 | -2.901 |
| | 2 | -4.472 | 0.000*** | -5.354 | -3.646 | -2.901 |
| **Number of employees** | 0 | 1.251 | 0.996 | -4.473 | -3.29 | -2.772 |
| | 1 | -2.51 | 0.113 | -4.473 | -3.29 | -2.772 |
| | 2 | -4.322 | 0.000*** | -4.665 | -3.367 | -2.803 |

*Source: Author*

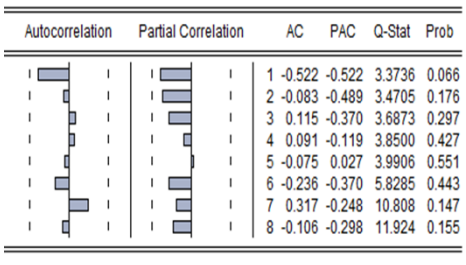
First-order differencing and second-order differencing are applied to the original data to make it stationary. The Augmented Dickey-Fuller (ADF) test is used to determine whether the first-order differenced and second-order differenced series are stationary (Wang, 2005). The results for the business income of QS consulting enterprises, the number of QS consulting enterprises, and the number of employees in QS consulting enterprises are presented in Table 2.

Based on the variables of "Business income of QS consulting enterprises", "Number of QS consulting enterprises" and "Number of employees in QS consulting enterprises", the results of this sequence test are as follows. When differencing at order 0 and order 1, the significance level with a p-value does not exhibit significance, and we cannot reject the null hypothesis (Wang, 2005). This indicates that the sequence is non-stationary.

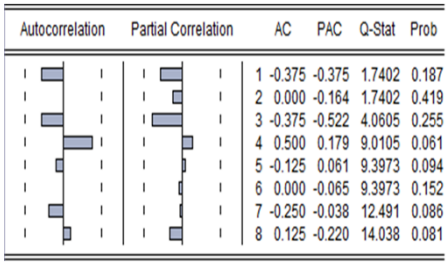
However, when differencing at order 2, all the three variables' shows significance level with p-value of 0.000*** which are highly significant, and we can reject the null hypothesis (Wang, 2005). This indicates that the sequence becomes stationary after second-order differencing. From the table, it is evident that after second-order differencing, the p-value is less than 0.05, which leads us to reject the null hypothesis (Wang, 2005; Daniel, 2019). This confirms that the data is now a stationary time series, and d=2 has been determined. With the time series transformed into a stationary form, we can proceed with fitting an ARIMA model, with d=2 as a confirmed parameter for all the three variables.

**ACF and PACF**

The next step involves determining the values of p and q for the time series. Typically, the determination of p and q values for a time series is done using the method of visual inspection, specifically by examining the autocorrelation and partial correlation plots of the second-order differenced data (Wang, 2005; Daniel, 2019), as shown in Figure 3.




(a)




(b)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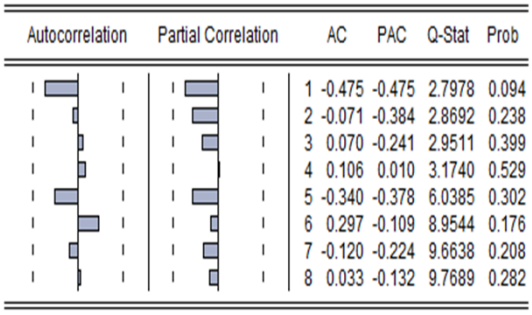


(c)

**Figure 3**: ACF and PACF of d(Y): (a) Business income of quantity surveying consulting enterprises; (b) Number of quantity surveying consulting enterprises; (c) Number of employees in quantity surveying consulting enterprises

*Source: Author*

Combining the information from the plots and applying the AIC and BIC criteria, the optimal model is selected by choosing the values of p and q that minimize both AIC and BIC coefficients (Wang, 2005; Daniel, 2019). In this case, p=0 and q=1 were found to be the optimal values. Additionally, the model fitted to the second-order differenced data was determined to be the best fit, resulting in the final model being ARIMA (0, 2, 1) for the three variables.

**Model evaluation and testing**

Before using the ARIMA (0, 2, 1) model to forecast, it is essential to evaluate the model. Model evaluation assesses the goodness of fit of the model, typically by checking if the residual values of the prediction model follow a distribution that resembles random errors (Wang, 2005; Daniel, 2019). A better fit of the model is indicated when the residual values closely resemble random errors. Conversely, if the residuals show systematic patterns, it suggests that some factors have been overlooked in the model (Wang, 2005). To evaluate the fitted model, you can examine the residuals to see if they behave like white noise. If the model's fit is good, the residual sequence should be a white noise sequence, meaning that the residuals are uncorrelated, and the model has captured the information in the series effectively. On the other hand, if the residual sequence is not white noise, it indicates a poor fit, and the model has not extracted the information adequately (Wang, 2005; Daniel, 2019). In such cases, it may be necessary to redevelop the model. According to the ARIMA model (0, 2, 1) test table (Table 3), based on the three variables of "Business income of QS consulting enterprises", "Number of QS consulting enterprises" and "Number of employees in QS consulting enterprises", the analysis of the Q-statistic results reveals the following: Q6 does not exhibit significance at the significance level, indicating that we cannot reject the hypothesis that the model's residuals are a white noise sequence. Meanwhile,

the three models' goodness of fit $R^2$ are 0.931, 0.688 and 0.858 respectively, suggesting excellent model performance and all the three models largely meet the requirements (Daniel, 2019).

**Table 3**: ARIMA (0, 2, 1) model test

| Item | Symbol | Value | | |
|---|---|---|---|---|
| | | **Business income of enterprises** | **Number of enterprises** | **Number of employees** |
| | **Df Residuals** | 7 | 7 | 7 |
| **Sample size** | **N** | 11 | 11 | 11 |
| **Q statistic** | **Q6(P value)** | 0.572(0.449) | 0.028(0.868) | 0.382(0.536) |
| **Information criterion** | **AIC** | 83.213 | 26.518 | 103.87 |
| | **BIC** | 83.805 | 27.11 | 104.462 |
| **$R^2$** | **$R^2$** | 0.931 | 0.688 | 0.858 |

*Note: ***, ** and * represent the significance level of 1%, 5% and 10%, respectively*

*Source: Author*

**Table 4**: Model parameter

| | **Coefficient** | **std.** | **t** | **P>\|t\|** | **0.025** | **0.975** |
|---|---|---|---|---|---|---|
| **Constant** | 5.691 | 1.71 | 3.329 | 0.001 | 2.23 | 9.042 |
| **ma.L1.D2.Business income** | -1 | 0.329 | -3.041 | 0.002 | -1.644 | -0.355 |
| **Constant** | 0.079 | 0.073 | 1.075 | 0.282 | -0.065 | 0.222 |
| **ma.L1.D2.Number of enterprises** | -0.997 | 0.355 | -2.809 | 0.005 | -1.692 | -0.301 |
| **Constant** | 7.691 | 5.387 | 1.428 | 0.153 | -2.868 | 18.249 |
| **ma.L1.D2.Number of employees** | -1 | 0.348 | -2.876 | 0.004 | -1.682 | -0.318 |

*Note: ***, ** and * represent the significance level of 1%, 5% and 10%, respectively*

*Source: Author*

In summary, the three ARIMA (0, 2, 1) models that have been established exhibits a high level of goodness of fit. The three models can be utilized to forecast the "Business income of QS consulting enterprises", "Number of QS consulting enterprises" and "Number of employees in QS consulting enterprises", for the next 5 years respectively. The three models' formula are as shown in Eq. (1), Eq. (2) and Eq. (3).

$$Y_1(t) = 5.691 + 2Y_1(t-1) - Y_1(t-2) + \varepsilon_1(t) - \varepsilon_1(t-1) \quad (1)$$
$$Y_2(t) = 0.079 + 2Y_2(t-1) - Y_2(t-2) + \varepsilon_2(t) - 0.997\varepsilon_2(t-1) \quad (2)$$
$$Y_3(t) = 7.691 + 2Y_3(t-1) - Y_3(t-2) + \varepsilon_3(t) - \varepsilon_3(t-1) \quad (3)$$

where $t = 1,2,3, \ldots, n$. and $\varepsilon$ is the error term.


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**Results of model prediction**

Using the three previously fitted models, the forecast of the "Business income of QS consulting enterprises", "Number of QS consulting enterprises" and "Number of employees in QS consulting enterprises" for the next 5 years can be generated. Figure 4 displays the forecasted data for the most recent 5 periods based on the time series model.

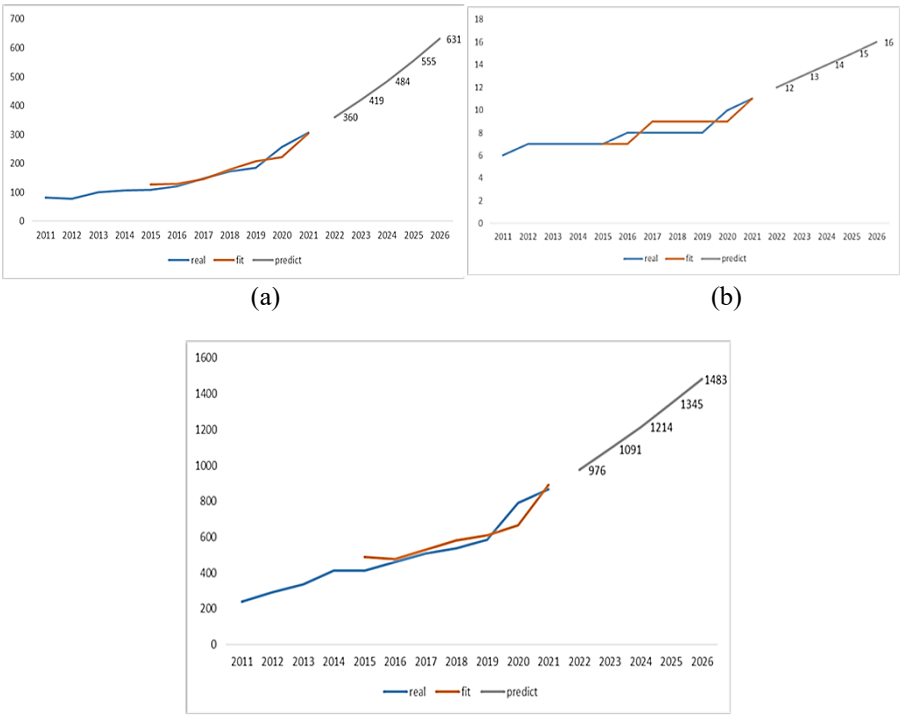


**Figure 4**: Forecast for the next 5 years (billion RMB): (a) Business income; (b) Number of enterprises; (c) Number of employees

To sum up, the overall development of QS consulting companies in 2022-2026 shows a steady upward trend, and the detailed forecast data are shown in the Table 5.

**Table 5**: Trend prediction

| Year | Business income (billion RMB) | Number of enterprises (thousand) | Number of employees (thousand) |
|---|---|---|---|
| **2022** | 360 | 12 | 976 |
| **2023** | 419 | 13 | 1,091 |
| **2024** | 484 | 14 | 1,214 |
| **2025** | 555 | 15 | 1,345 |
| **2026** | 631 | 16 | 1,483 |

*Source: Author*

### Discussion

Through analysing the government public reports and literature review, the data of QS consulting industry status in China from 2011 to 2021 was attained and summarized, which showed a steady growth. In the face of complex international and domestic environment and arduous development tasks, the QS consulting industry maintained a steady and rapid growth under the situation of increasing downward economic pressure (Wu et al., 2020). Additionally, as the related policies for advancing the entire process of QS consulting launched and the market requirement, the overall development of QS consulting companies in 2022-2026 shows a steady upward trend, which explained the results of ARIMA model prediction.

Data used in this forecast was based on the official published data for the 10 years from 2011 to 2021, and without using the 2022 annual report data released in September 2023. The main reason is that the statistical survey system used in the report data of 2022 had been adjusted, which was different from previous years (CCIA, 2023), the statistical scope of data had been adjusted, so the data of 2022 is not included in the basic data of this forecast.

## CHALLENGES

While the overall development is statistically positive, however, there are also challenges behind the situation.

Firstly, the growth rate slowdown of fixed asset investment will affect the development potential of traditional QS consulting business. This is evidence based on the findings by Zhu et al. (2020) who elaborated that there are problems such as unbalanced development, coexistence of order and disorder, backward information construction and talent bottleneck in China's QS industry development. And as Adesi et al. (2019) stated that the concentration of traditional QS services in the building construction sector was due to the unwillingness of QS professional service firms to diversify into the non-construction sectors. Moreover, the rapid development of information technology, such as big data and artificial intelligence, not only provides powerful tools for the innovation and development of the industry, but also poses


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a great threat to the traditional business (Zhang, 2021). Hence, based on this notion, and according to the data shown above, housing construction project was always occupied the main share of the construction industry market, with a steady proportion. However, as the real estate regulation policy continued be tightened in recent years, it has affected the QS consulting business development. While there will be expansion of infrastructure construction, such as municipal project, road project, water conservancy projects and so on, especially the development situation in municipal project which is good during recent years. Therefore, the QS consultation enterprises should conform to its development, on the basis of stable housing business, expand municipal project and other business areas to strive for the sustainable growth of quantity surveying consulting business (Wu, & Li, 2020).

Secondly, the rise of the whole process business and overseas markets opened up new growth opportunities and challenges for the QS consulting industry. This is evidence based on the "Belt and Road Initiative" which unleashed new vitality for the development of the overseas construction industry investment (Liu & Wu, 2020). Hence, based on this notion, the business scope of the QS industry is not only limited to the domestic market, but also should conform to the development of the construction industry, concentrate resources, expand the business out, and gradually go international (Habizah, 2021; Muhamad-Halil et al., 2022). However, there are few large QS consulting enterprise groups with strong overall strength and high business income, and even fewer enterprises with international degree (Si, 2014). Therefore, facing with the challenges, we should promote the formation of overseas enterprise groups and overseas talents training, improve the competitiveness of the overseas industry (Marcel, 2013; Xueqiang et al., 2023).

Thirdly, new challenges to the business ability and professional knowledge level of the QS related talents. This is evidence based on the findings by Ke et al. (2016) who pointed out that China urgently needs to formulate reasonable and effective talent training and development strategies for QS professionals according to the current talent demand of QS consulting enterprises. Hence, based on this notion, for the core competitiveness of QS consulting enterprises is talent. The real high-end talents in QS consulting need to be interdisciplinary talents who are good at technology, economy, law and management at the same time (Zhang, 2021). Therefore, registered quantity surveyors are the core technical talents of QS consulting enterprises (Wu & Li, 2020). However, from the above proportion of registered quantity surveyors to practitioners, the number of registered quantity surveyors is relatively small. Therefore, it will also become one of the factors affecting the core competitiveness of enterprises. Therefore, in the face of the above opportunities and challenges, the demand for QS talents may show a trend of polarization. Those who lack core technical ability and innovative thinking will be eliminated

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in the increasingly fierce competition, while those who have strong comprehensive professional ability and innovative thinking ability will win in the competition (Wu & Li, 2020).

## CONCLUSION AND SUGGESTION

Through analysing the government public reports and literature review, this study attained and summarized the data of QS consulting industry status in China from 2011 to 2021, including the number of enterprises, business revenue, QS consulting business composition, and the number of registered quantity surveyors. It turned out that the QS consulting industry maintained a steady growth. Additionally, in order to predict the QS consulting industry development trends for the next five years, methodology of time series model with ARIMA was used, which also showed a trend of steady growth. As the related policies for advancing the entire process of QS consulting launched, it also showed significant progress about business income and the number of professional personnel. Finally, based on the industry status and development trend forecast, combined with relevant policy analysis, in order to further promote the industry's development, following suggestions are put forward.

### Expand Business Scope and Innovate Business Growth Points

The Central Urban Work Conference clearly proposed to carry out major public facilities and infrastructure projects, strengthen the construction of urban rail transit, sponge cities and urban underground utility tunnels, speed up the renovation of rundown areas and dilapidated houses, and promote the comprehensive renovation and engineering maintenance of old residential communities in an orderly manner. The new innovation point, growth pole and growth belt of QS consulting industry are taking shape (Liu & Wu, 2020). Housing construction engineering has always occupied the main share of the construction industry market, which is also the main source of income for QS consulting enterprises (Zheng, 2020). However, as the continued tightening real estate regulation policy in recent years, as well as the continuous expansion of infrastructure construction, municipal engineering, road engineering, water conservancy projects in areas such as construction quantity present a growth trend, especially in municipal engineering recent years, the development situation is good, the rapid increase of income accounted, QS consultation enterprises should conform to its development, on the basis of stable housing business, expanding municipal engineering and other business areas to strive for the sustainable growth of QS consulting business (Ekundayo, 2020).


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**Pooling Resources to Improve the Level of International Business Competition**

The Ministry of Housing and Urban-Rural Development of the People's Republic of China issued the "13th Five-Year Plan of Quantity Surveying Enterprise Development" points out: during the 13th Five-Year Plan period (2016-2020), China's long-term sound economic fundamentals have not changed, and its development prospects remain bright. New urbanization and the "Belt and Road Initiative" have unleashed new impetus and vitality for the development of fixed asset investment and the construction industry, and the demand for structural and institutional reform and transformation and upgrading of the construction industry is growing (Liu & Wu, 2020). Therefore, the business scope of the QS industry is not only limited to the domestic market, but also should conform to the development of the construction industry, concentrate resources, expand the business out, and gradually go international. Since the management reform of QS industry in 2002, remarkable achievements have been made, and the degree of marketization of QS consultation is relatively high (Habizah, 2021; Muhamad-Halil et al., 2022). However, there are few large QS consulting enterprise groups with strong overall strength and high business income, and even fewer enterprises with international degree. Therefore, we should give full play to the basic role of market allocation of various resources, promote the merger and reorganization of QS consulting enterprises, so as to promote the formation of large enterprise groups, improve the status and competitiveness of the industry (Marcel, 2013; Xueqiang et al., 2023).

**Strengthen the Team Building of Professional and Technical Personnel**

The development of information technology, such as big data and artificial intelligence, not only provides powerful tools for the innovation and development of the industry, but also puts forward new requirements and challenges to the professional and technical personnel in the QS consulting industry (Ekundayo, 2020). It is urgent to increase the number and improve the quality of professional and technical personnel with registered quantity surveyors as the core. There is a lack of interdisciplinary high-level talents who are familiar with the theory and practice of quantity surveying consulting industry, and certain management experience and innovation consciousness. As for the backbone of intermediate business, there is a lack of technical talents who understand modern engineering technology, with rich professional knowledge and solid skills, and are familiar with modern economic and legal knowledge (Zheng, 2020). Therefore, it is necessary to establish a training and continuing education system to adapt to different levels of personnel, such as carry out national exchanges, in line with international standards, learn from the British Royal Chartered Surveyors, Hong Kong quantity surveyors training system, and gradually establish a high-end talent team (Ekundayo, 2020; Muhammuddin et al., 2023; Wu & Li, 2020).

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Data Availability Statement: The data in the statistical bulletin of QS consulting are the data of enterprises that have participated in the statistics, not all the data of the QS consulting industry, which inevitably differs from the actual situation of the market, and may have a certain impact on the data analysis of the paper. However, due to the authority of the statistical system of QS consultation, the data in the statistical bulletin of QS consultation should reflect the overall situation of the development of the industry.

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# BIG DATA ANALYTICS (BDA) FRAMEWORK FOR CONSTRUCTION COST ESTIMATION IN MALAYSIA

**Muhammad Hadi Mustafa[1], Faizul Azli Mohd Rahim[2], Ain Farhana Jamaludin[3], Kwang Yi Hin[4]**

[1,2,4]*Centre for Building, Construction & Tropical Architecture (BuCTA),*
[3]*Centre For Sustainable Urban Planning & Real Estate (SUPRE),*
*Faculty of Built Environment,*
UNIVERSITI MALAYA

## Abstract

The construction industry is undergoing significant changes due to the growing volume of data, necessitating the adoption of Big Data Analytics (BDA) for improved project management. Construction projects are inherently uncertain, often resulting in cost overruns. This research focuses on the development of a framework for implementing big data analytics in the estimation of construction costs within the Malaysian construction sector. To achieve this goal, a quantitative research approach was employed, which involved an examination of the industry's awareness of construction cost estimation, comprehension of big data analytics processes in the context of cost estimation, and an exploration of the challenges and potential solutions associated with the integration of BDA. The resultant framework for construction cost estimation via BDA is a dynamic and evolving tool. It is refined iteratively based on insights derived from a questionnaire survey distributed to Consulting Quantity Surveying Practice (CQSP) registered with the Board of Quantity Surveyors Malaysia (BQSM). The BDA framework emerges as a fundamental tool for cost estimators, notably quantity surveyors, facilitating the digital transformation of the cost estimation process and substantively enhancing the precision of contemporary cost estimation methodologies.

***Keywords***: Big Data, Analytics, Construction Cost Estimation, Cost Overrun, Framework

[1] Senior Lecturer at Universiti Malaya. Email: hadimustafa@um.edu.my

## INTRODUCTION

The global construction industry plays a pivotal role in shaping the Gross Domestic Product (GDP) and Gross National Product (GNP) of numerous countries worldwide, thus serving as a critical driver of economic growth. Through the fundamental objectives of generating output, creating employment opportunities, and elevating living standards, the construction sector makes substantial contributions to sustainable economies on a global scale (Basaif et al., 2020). However, it is noteworthy that, as emphasized by Michael Burke, Co-Chair of the World Economic Forum Infrastructure and Urban Development Community, the current business models and strategies within the construction industry may not suffice to meet the evolving demands of the future (Buehler et al., 2018). Hence, industry stakeholders are compelled to proactively prepare for disruptions and assume a responsible role in fostering societal progress, stimulating economic development, and upholding environmental stewardship.

The construction industry's impact extends far beyond economic statistics, encompassing a broader mandate that encompasses adaptability, responsibility, and a commitment to advancing society, fostering sustainable growth, and safeguarding the environment in the face of changing global dynamics. The global landscape is swiftly advancing towards the Fourth Industrial Revolution (IR 4.0), driven by the emergence of transformative technologies and innovations. These technological advances are reshaping business models, elevating operational efficiency, and enhancing productivity across industries. Notably, the construction sector is on the cusp of being profoundly impacted by this revolution (Buehler et al., 2018). In light of this imminent transformation, it is imperative for industry stakeholders to seize the opportunity and embrace innovative technologies such as big data and Building Information Modelling (BIM) as integral components of their operations. These technologies hold the potential to elevate project quality, efficiency, and health and safety standards.

In the Malaysian context, the Construction 4.0 Strategy Plan represents a strategic blueprint, aligning the Malaysian construction industry with the tenets of the Fourth Industrial Revolution (IR 4.0). This plan offers a structured framework, fostering collaboration among industry players, government agencies, and academia to effectively respond to the rapid digitalization underpinning IR 4.0. Significantly, the Construction 4.0 Strategy Plan spotlights 12 emerging technologies applicable throughout the project life cycle, each contributing enhanced value to construction endeavors. Notably, among these technologies, big data takes center stage (Construction Industry Development Board Malaysia, 2020). The convergence of IR 4.0 and the construction industry underscores the imperative of adapting to technological advances and harnessing them for sustained growth, innovation, and excellence in project execution, especially in countering cost overruns.

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## BACKGROUND OF STUDY

Poor cost management is a vital problem that has struggled the construction industry worldwide for the past few decades, especially methods related to cost overrun (Mustafa et al., 2023). The nature of construction industry is full of uncertainty throughout the construction project life cycle. These uncertainties make the cost management process to be difficult, which subsequently leads to cost overrun (Ali, 2018). Throughout recent decades, the construction industry has encountered substantial challenges to its reputation, predominantly because of the prevalent and consequential issue of cost overruns within construction projects (Ali, 2018). To underscore the pervasive global nature of this matter, Table 1 offers a compilation of documented occurrences of cost overruns, spanning beyond Malaysia to various international contexts.

**Table 1**: List of Cost Overrun in Construction Project

| Year | Projects That Have Experience Cost Overrun | Percentage of cost overrun | Reference |
|---|---|---|---|
| | **Malaysia** | | |
| **2014** | Kuala Lumpur International Airport 2 (KLIA 2) | Cost overrun from initial 1.6 billion to 4 billion (150%) | (Pua, 2017) |
| **2014** | 359 Recent Completed Projects in Malaysia | Range from -80.38% to 88.76% | (Shehu et al., 2014) |
| **2020** | 89% Construction projects in Malaysia | 5%-10% | (Kamaruddeen et al., 2020) |
| | **Other Countries** | | |
| **1927-1998** | 258 transport projects located in twenty countries | Average of 28% | (Flyvbjerg et al., 2003) |
| **2000-2013** | 122 Public Project in Qatar | N/A | (Ullah et al., 2018) |
| **2014** | 49 Road Construction Project in Australia | Average of 13.55% | |
| **N/A** | Great Belt link in Denmark | 54% | |

Cost overrun has become a major hidden danger for all types of construction and has led to severe consequences for the construction industry. One of the major contributors to cost overrun is inaccurate cost estimation. The lack of data integration and interpretation, difficulty in handling the complex data in cost estimating process and lack of experience and time to estimates is hindering the project to achieve accurate cost estimation (Reyes-Veras et al., 2021, Garyaev & Garyaeva, 2019). Therefore, the construction industry should consider the adoption of big data analysis for cost estimation to effectively handle complex data and enhance the cost estimating process.


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By implementing advance analytics technology, big data is able to provide a more accurate cost estimation for materials, labour and machinery and subsequently minimise the risk and lower down the range of cost overrun (Garyaev & Garyaeva, 2019; Jumas et al., 2018). In fact, big data adoption has been recognised as a potential solution to the increasing demand for current projects needs in construction industry (Reyes-Veras et al., 2021, Basaif et al., 2020). For instance, various research has proved that big data and predictive analytics (BDPA) shows positive impact on reducing the project's risk and able to predict the possible solution for the project accurately. However, unfortunately, the growth of big data in the construction industry is still in an infant stage and severely lagging compared to other industries (Maaz et al., 2018).

## LITERATURE REVIEW

### Construction Cost Estimation

Cost estimation is defined as the process of calculating and estimating budget that matches the financial capability required for a particular project to be successful without facing any possible financial constraint by taking into consideration of the direct cost, indirect costs and all other factors that might affect the project (Ullah et al., 2018). In project management, cost estimation encompasses the summation of all associated costs, incorporating both direct and indirect expenses, through the utilization of suitable estimating methodologies and reliable data.

Generally, a team of experienced cost estimators, which consists of quantity surveyors, project managers, engineers, architects, and Certified Professional Estimators (CPEs), will be involved in the process of construction cost estimation. These individuals have an extensive understanding in costs related issues throughout the project life cycle (Concord Group, 2023; Jumas et al., 2018). With the involvement of experts in the construction cost estimation, it can greatly increase the accuracy for the estimation.

An accurate cost estimation shall carefully identify, examine, and analyse all these costs and beyond that including fluctuation of materials price, location, climate, transportation, human resources, and equipment arrangement, building code, availability of utilities, politic and economy consideration (Concord Group, 2023). Apart from that, when the information is available, some experienced estimator will also take into consideration of soil condition, material lead time and surface topography in their construction cost estimation.

The importance of accurate construction cost estimation can be seen in many aspects; for instance, accurate cost estimation is crucial for decision-making, especially in calculating the project budget to ensure optimum resource allocation (Lee, 2020; Jumas et al., 2018). Besides, accurate construction estimation ensures that the project considers both foreseen and unforeseen cost, thus minimising the possibility of financial disruption and safeguarding the profit

margin for the project (ProEst, 2020). Furthermore, accurate construction cost estimation reduces the potential of variation orders or extension of project timeline. This will eventually lead to the better reputation of the business (Jumas et al., 2018). In short, accurate cost estimation often brings clarity, assurance, and success to the construction project.

The demand for greater project visibility and project performance has grown over the years in construction industry. Stakeholders are looking for more reliable and accurate cost estimates to forecast the project financial feasibility and gain confidence for their financial investment as there are limited resources and tighter financing than in the past. The stakeholders need to make sure that every cent they spent are being used wisely with maximum return (Mustafa et al., 2020). However, many barriers hinder the cost estimator in achieving accurate cost estimation in construction industry. Table 2 shows the barrier to achieving accurate cost estimation.

**Table 2:** Barrier in achieving accurate cost estimation

| No | Barrier in achieving accurate cost estimation | Reference |
|---|---|---|
| **1** | 1. Weak Cost Planning Knowledge Base<br>2. Poor Cost Databases and Understanding<br>i. Unavailability of cost data<br>ii. Unavailability of cost analysis<br>iii. Poor understanding of the variables to consider in cost analysis<br>iv. Organizations' poor understanding on the concept of cost planning<br>3. Inadequate Designs and Planning<br>4. External Conditions | (Kissi et al., 2016) |
| **2** | 1. Inefficient techniques<br>2. Perception of model techniques<br>3. Unavailability of cost data<br>4. Lack of understanding and unstable economic | (Agyekum et al., 2018) |
| **3** | 1. Not having access to historical cost databases<br>2. Unreasonable program baselines<br>3. Vague or incomplete scope | (Kamaruddeen et al., 2020) |

*Source: KICEM Journal of Construction Engineering and Project Management*

## Big Data Analytics (BDA)

Big Data is different from normal data, where it refers to a rapid growing data with vast amount of data sets that comprise a variety of heterogeneous formats, including structured, unstructured, and semi-structured data (Oussous et al., 2017). Due to the complex nature of Big Data, typical statistic tools are no longer to be effective in managing Big Data, hence requiring more advanced technologies and algorithms.


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Many industries have been discussing the potential of big data in solving the problems that arise due the digitalisation and change them into a more intelligent methods of working. The data explosion brought on by the introduction of advanced technology in the modern world has marked the beginning of the big data era (Ismail et al., 2018). The data explosion refers to the significant increase in the volume of data generated and collected in various fields and industries due to advancements in technology (Ismail et al., 2018). This explosion is characterized by the exponential growth of data, both structured and unstructured, which presents new challenges and opportunities for analysis and utilization. For instance, referring to Taylor (2022), the volume of data generated reached a record of 64.2 zettabytes in the year 2020, and global data production is projected to grow up to 180 zettabytes in years 2025 (Taylor, 2022). Before the Big Data revolution, businesses were facing problems in handling enormous data sets effectively and storing all their data archives for long periods, since traditional technologies are expensive and have limited capacity with rigid management tools (Oussous et al., 2017).

In Malaysia, the amount of data created and used by the construction industry has grown tremendously due to the increasing usage of advanced technologies such as the Internet of Things, Cloud Computing and many other smart devices (Oussous et al., 2017). In tandem with the data explosion, the emergence of the big data phenomenon is anticipated to catalyse the digital transformation of the construction industry, fostering a favorable impact (Ismail et al., 2018).

Big data can be categorised into two main classes: big data analytics and big data engineering. In the context of this research, the primary focus will be on the domain of big data analytics. Big data analytics involve the development of multiple classification and forecasting systems to analyse, interpret and forecast the trends and patterns of the data. Big data analytics assists an organisation in extracting relevant information from the data base and monitor the pattern and foresee the impact on the business (Oussous et al., 2017). Besides, big data analytics only extract important insight from a complex source of raw big data (Pathak, 2021). In addition, Murkred and Zheng (2017) provided a definition of big data analytics as "the practice of assessing or analysing vast volumes of data to uncover concealed patterns, consumer preferences, market trends, and undisclosed relationships."

**Process of Big Data Analytic**

The fundamental distinction between big data analytics and traditional analytics becomes evident through the way data are analysed and managed. In nature, the framework for big data analytics is more complex compared to traditional analytics. The first step of performing big data analytics is data sourcing, which is an important process in big data analytics, where most data scientists have

categorised data into 3 distinct types: structured, semi-structured and unstructured data. In fact, big data is more likely to be a combination of structured, unstructured, and semi-structured data than to appeal as any data individually (CIDB, 2020). Structured data refers to data that is linear and kept in a relational database, semi-structured data refers to data that has certain structural properties but insufficient to be kept in a relational database, while unstructured data refer to data that are hard to make any connection with and difficult to process it.

Subsequently, to reduce storage requirements, expedite compilation, and enhance the efficiency of file transfers, the collected data will undergo compression to minimize the necessary storage bits for its representation. The obtained data will be processed and structured into statistical or spreadsheet applications, such as Excel, before moving on to the data processing stage. This process is known as data compression (Lee, 2020). The following step is data cleansing, where it involves the process of identifying, and removing the irrelevant, inaccurate, incomplete, and inconsistent data to improve the data quality (Siddiqa et al., 2016).

During the data processing phase, the exploratory data analysis will be carried out to analyse the data and summarise the key features of the data. Data processing models and algorithms is another part of data processing phase where it acts as a process for problem solving method (Lee, 2020). In this phase, the data processing platform such as Apache Hadoop and Apache Spark can be employed.

Lastly, the processed and cleaned data is now ready to proceed into the analysis phase. Data analysis can be categorised into four categories: descriptive, diagnostic, predictive, and prescriptive. Each category has their own stipulated functions and analyse the data with different model and algorithms, hence information acquired from each analysis will be different as well (Lee, 2020; Siddiqa et al., 2016). To better visualise the data, the sophisticated data will undergo data visualisation by transforming the data into accessible and intelligible information for decision-making in the form of charts, graphs, dashboards, or reports, which can be done with big data analytics application or statistical application as shown in Figure 1.


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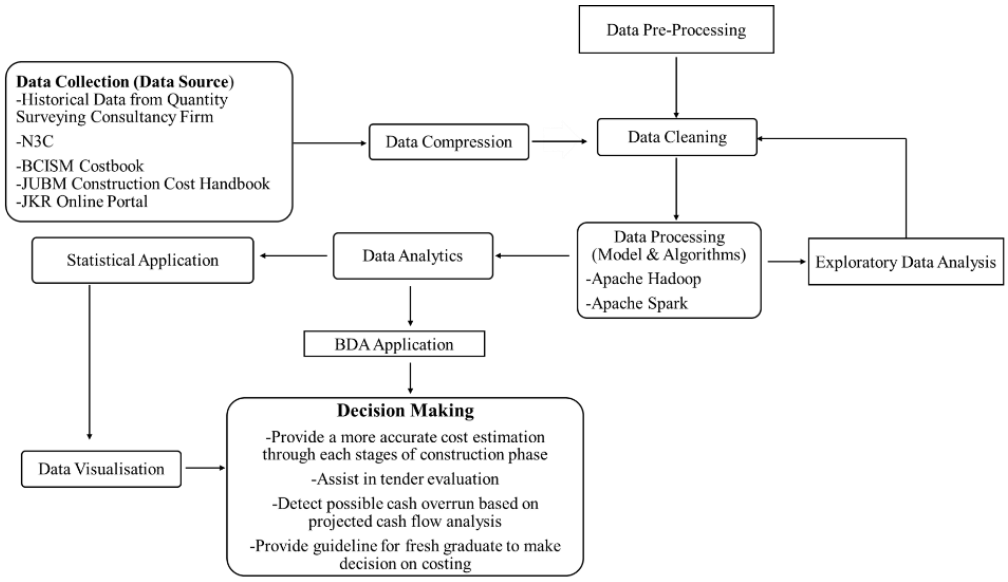


**Figure 1:** Framework of BDA on Construction Cost Estimation
*(Modified from J. Lee, 2020 & Siddiqa et al., 2016)*

## METHODOLOGY

Questionnaire surveys were administered based on literature review to acquire the requisite data for fulfilling the research's aim and objectives. The digital questionnaire survey in the format of a Google Form were distributed via email and LinkedIn to 400 Consulting Quantity Surveying Practice that are registered with BQSM in Malaysia. A follow-up email and message were sent after one week to boost the response rate. 198 responses received out of 400 questionnaires sent, the response rate was 49.5%. The responses were automatically recorded in the Google Form. Lastly, a comparison between the primary data (data acquired from the questionnaire) and secondary data collection is conducted to provide a comprehensive conclusion in developing an improvised framework of BDA for Construction Cost Estimation based on the work by Lee (2020) & Siddiqa et al. (2016).

## RESULTS AND DISCUSSION

The survey conducted as part of this research sought to gain insights into the prevailing patterns of cost overruns in construction projects within the Malaysian context. A crucial aspect of this inquiry involved inquiring about the implementation of BDA in construction cost estimation which involves the comprehension of big data analytics processes in the context of cost estimation, and an exploration of the challenges and potential solutions associated with the

integration of BDA. The survey respondents, primarily representing professionals in the construction industry yielded significant data, shedding light on the prevalent scenario of cost overruns within the Malaysian construction sector. The subsequent analysis of the survey responses revealed notable trends in this regard.

**Understanding on big data analytics processes in construction cost estimation in Malaysia.**

**Table 3**: Understanding of BDA processes in cost estimation.

| Big Data Analytics (BDA) Processes | Mean | Median | Standard Deviation | Rank |
|---|---|---|---|---|
| Data Collection | 3.55[b] | 4.00 | 0.816 | 1 |
| Data Compression | 3.18 | 3.00 | 0.841 | 4 |
| Data Cleaning | 3.05 | 3.00 | 0.851 | 5 |
| Data Processing | 3.43 | 4.00 | 0.820 | 2 |
| Data Analytics | 3.25 | 3.00 | 0.875 | 3 |
| BDA Application | 2.78[c] | 3.00 | 0.877 | 6 |

Based on the surveys, Table 3 shows that the overall understanding of implementing Big Data Analytics (BDA) in construction cost estimation is relatively low, with most respondents reporting only an average level of understanding on the BDA processes. This finding is similar with previous conducted research which show that the understanding of big data within the Malaysian construction industry was to be moderate (Nadia Maaz et al., 2018). The survey shows that, “Data Collection” process (μ= 3.55) have achieved the highest level of understanding among the 6 BDA processes followed by “Data Processing” process (μ= 3.43), "Data Analytics" (μ= 3.25), "Data Compression" (μ= 3.18), "Data Cleaning" (μ= 3.05), and "BDA Application" (μ= 2.78).

**The challenge faced by the construction industry to adopt big data analytics in construction cost estimation.**

According to the survey result as tabulated in Table 4, all the proposed challenges have received a median score of 4.00, indicating their significant impact that hinder the adoption of Big Data Analytics (BDA) in the construction in cost estimation. The constraints were measured analytically and ranked. Out of the 16 proposed challenges in adopting BDA, the top five most significant challenges are as follows: “Limited integration and interoperability between different data sources and systems” (μ=3.98), “Difficulty in obtaining data and maintaining data quality and consistency” (μ=3.96), “Resistance to change and lack of buy-in from stakeholders” (μ=3.95) “High initial and associated cost to adopt BDA” (μ=3.93) and "Lack of standardisation in data formats and quality" (μ=3.93).


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High initial cost and lack of standardization share the same rank since their results on mean is similar. Meanwhile, the top five most notable challenges primarily revolve around issues concerning about data integration, data availability, data quality, awareness of BDA, and the high initial cost. It is of utmost importance to confront and overcome these obstacles to effectively introduce BDA into the construction industry. Through addressing these challenges head-on, organisations can unlock the full potential of BDA and optimise on its advantages, resulting in enhanced decision-making processes and increased efficiency in construction cost estimation.

**Table 4**: Significant level of constraints in adopting Big Data Analytics (BDA) in construction cost estimation.

| **Constraints in Adopting Big Data Analytics (BDA)** | **Mean** | **Median** | **S. D.** | **RII** | **Rank** |
|---|---|---|---|---|---|
| Limited integration and interoperability between data sources and systems | 3.98 | 4.00 | 0.587 | 0.7960 | 1 |
| Difficulty in maintaining data quality and consistency | 3.96 | 4.00 | 0.667 | 0.7919 | 2 |
| Resistance to change and lack of buy-in from stakeholders | 3.95 | 4.00 | 0.624 | 0.7909 | 3 |
| High initial and associated cost to adopt BDA | 3.93 | 4.00 | 0.741 | 0.7869 | 4 |
| Lack of standardisation in data formats and quality | 3.93 | 4.00 | 0.748 | 0.7869 | 4 |
| Insufficient knowledge and expertise in BDA systems and process | 3.91 | 4.00 | 0.674 | 0.7828 | 6 |
| Limited understanding of the potential benefits of BDA | 3.84 | 4.00 | 0.701 | 0.7677 | 7 |
| No specific BDA guidelines for construction cost estimate | 3.83 | 4.00 | 0.580 | 0.7657 | 8 |
| Difficulty in ensuring data privacy and cyber security | 3.83 | 4.00 | 0.761 | 0.7657 | 8 |
| Difficulty in managing and analysing unstructured data | 3.83 | 4.00 | 0.837 | 0.7657 | 8 |
| Inadequate infrastructure and technology to support BDA | 3.82 | 4.00 | 0.841 | 0.7636 | 11 |
| Resistance from stakeholder to share data due to concerns about privacy and security | 3.81 | 4.00 | 0.808 | 0.7616 | 12 |
| Low acceptance of BDA in construction industry | 3.80 | 4.00 | 0.758 | 0.7606 | 13 |

| **Constraints in Adopting Big Data Analytics (BDA)** | **Mean** | **Median** | **S. D.** | **RII** | **Rank** |
|---|---|---|---|---|---|
| Limited availability of skilled BDA professionals in construction industry | 3.80 | 4.00 | 0.688 | 0.7606 | 13 |
| Insufficient accurate cost data for analysis | 3.72 | 4.00 | 0.697 | 0.7444 | 15 |
| Difficulty in aligning BDA strategies with organisational goals and objectives | 3.62 | 4.00 | 0.729 | 0.7242 | 16 |

**Solutions to enhance the adoption of BDA for construction cost estimation in Malaysia.**

According to the results as tabulated in Table 5, it shows that all the solutions assessed received a median value of 4.00. This indicates that each of these solutions plays a significant role in enhancing the usage of BDA. The solutions were measured analytically and ranked. Out of the 14 proposed solution to enhance the adoption of BDA for construction cost estimation in Malaysia, the top five most significant solutions are ranked as follows: "Provide training and education programs to enhance the knowledge and skills of construction professionals in BDA." ($\mu$=4.16), "Establish industry-wide standards and guidelines for BDA-based cost estimation" ($\mu$=4.11), "Provide technical assistance and support to construction industry in the adoption and implementation of BDA-based cost estimation tools and processes" ($\mu$=4.10), "Develop a BDA-based cost estimation tool that is user-friendly and can be easily integrated into existing software and systems." ($\mu$=4.04) and "Conduct research and development to enhance the capabilities and accuracy of BDA-based cost estimation tools and processes." ($\mu$=4.03).

**Table 5:** Significant level of solution in enhancing the usage of BDA in cost estimating in Malaysia construction industry.

| **Solution in enhancing the usage of Big Data Analytics (BDA)** | **Mean** | **Median** | **S. D.** | **RII** | **Rank** |
|---|---|---|---|---|---|
| Provide BDA training and education programs to construction professionals. | 4.16 | 4.00 | 0.600 | 0.8323 | 1 |
| Establish industry-wide standards and guidelines for BDA-based cost estimation. | 4.11 | 4.00 | 0.498 | 0.8212 | 2 |
| Provide technical assistance and support for BDA-based cost estimation tools and processes. | 4.10 | 4.00 | 0.510 | 0.8192 | 3 |
| Develop user-friendly BDA-based cost estimation tool and software. | 4.04 | 4.00 | 0.667 | 0.8081 | 4 |


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| **Solution in enhancing the usage of Big Data Analytics (BDA)** | **Mean** | **Median** | **S. D.** | **RII** | **Rank** |
|---|---|---|---|---|---|
| Conduct research and development on BDA-based cost estimation tools and processes. | 4.03 | 4.00 | 0.513 | 0.8061 | 5 |
| Initiative to foster a culture of innovation in new technologies, such as the adoption of BDA | 4.02 | 4.00 | 0.617 | 0.8030 | 6 |
| Encourage data sharing and collaboration among stakeholders | 4.02 | 4.00 | 0.672 | 0.8030 | 6 |
| Establish a centralised database for construction cost data that is accessible to all stakeholders in the industry. | 4.01 | 4.00 | 0.600 | 0.8010 | 8 |
| Improve data security and privacy by keeping the big data in an encrypted file | 3.99 | 4.00 | 0.790 | 0.7990 | 9 |
| Develop communication and outreach strategies to promote the benefits of BDA-based cost estimation. | 3.97 | 4.00 | 0.649 | 0.7949 | 10 |
| Implement standardised data formats to ensure consistency and accuracy of data. | 3.97 | 4.00 | 0.528 | 0.7949 | 10 |
| Provide incentives for stakeholders to adopt BDA-based cost estimation tools and processes. | 3.95 | 4.00 | 0.693 | 0.7909 | 12 |
| Establish partnerships with academic institutions and research organisations to advance the use of BDA in construction cost estimation. | 3.94 | 4.00 | 0.618 | 0.7879 | 13 |
| Establish a regulatory framework that supports the use of BDA in construction cost estimation and ensures compliance with data privacy and security regulations. | 3.85 | 4.00 | 0.701 | 0.7707 | 14 |

The top five significant solutions identified in this research that can contribute to the development of a comprehensive strategy for enhancing the integration of BDA in the construction industry can be summarised as providing BDA training, establishing BDA standards, offering BDA technical support, developing user-friendly BDA processes, and conducting research and development on BDA applications. These solutions have been derived from the survey results and are crucial for ensuring the successful implementation of the BDA framework, resulting in precise cost estimation practices. The improvised framework of BDA for Construction Cost Estimation is then developed based on the work by Lee (2020) & Siddiqa et al. (2016) as shown in Figure 4.

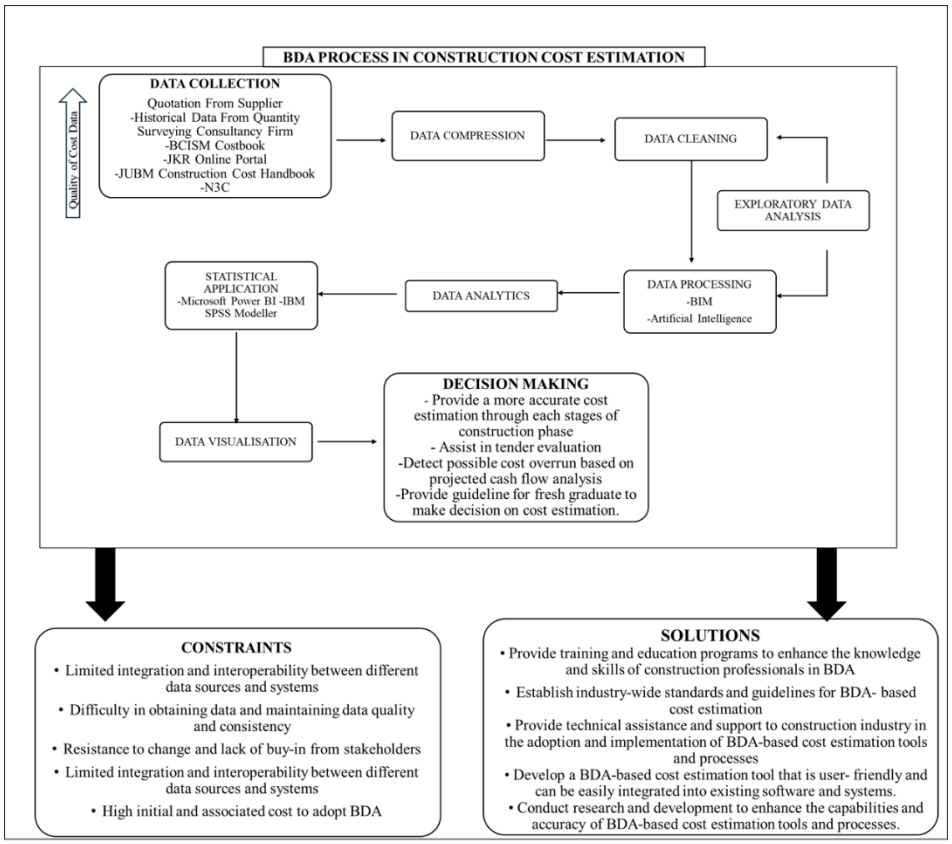


**Figure 4:** Proposed BDA Framework for Construction Cost Estimation

## CONCLUSION

This research concludes and indicates a relatively low level of overall understanding regarding the implementation of Big Data Analytics (BDA) in construction cost estimation in Malaysia. Moreover, among the 16 proposed challenges in adopting BDA, the top five most significant challenges include limited integration between different data sources, difficulties in data acquisition, resistance to change, high initial and associated costs, and the lack of standardization in data formats and quality. Finally, the survey findings highlight the top five most significant solutions to enhance the adoption of BDA for construction cost estimation in Malaysia: providing training and education programs, establishing industry-wide standards and guidelines, offering technical assistance, developing a user-friendly and easily integrated BDA-based cost estimation tool, and conducting research and development to enhance the capabilities of BDA-based cost estimation tools and processes. The BDA framework emerges as a fundamental tool for cost estimators, notably quantity


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surveyors, facilitating the digital transformation of the cost estimation process and substantively enhancing the precision of contemporary cost estimation methodologies.

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# ENVIRONMENTAL MAINTENANCE APPRAISAL ON LIME-BASED MORTAR REPAIR FOR HERITAGE BUILDINGS CONSERVATION

**Brit Anak Kayan[1], Siti Norbaya Mohd Konar[2], Zainah Binti Ibrahim[3], Nadia Binti Razali[4], Alan Mark Forster[5]**

[1,2]*Faculty of Built Environment, Centre for Building, Construction, and Tropical Architecture (BucTA),*
UNIVERSITI MALAYA
[3]*Department of Civil Engineering, Faculty of Engineering,*
UNIVERSITI MALAYA
[4]*Malaysian Institute of Chemical and Bioengineering Technology,*
UNIVERSITI KUALA LUMPUR
[5]*School of the Energy, Geoscience, Infrastructure and Society,*
HERIOT-WATT UNIVERSITY, EDINBURGH, SCOTLAND

## Abstract

Gradually, sustainable maintenance in the heritage buildings conservation moving forward to achieve The Sustainable Development Goals (SDGs), 2030 Agenda. The aim of this paper is to determine sustainable lime-based mortar repair in heritage buildings conservation based on calculation procedures of Green Maintenance model within cradle-to-site boundaries of Life Cycle Assessment (LCA). The calculation appraises Environmental Maintenance Impact (EMI) of selected case studies. This underpins informed decision-making in low carbon repair options in heritage buildings conservation. EMI appraisal of Green Maintenance Model in this paper is not confined to heritage buildings and can be applied to any building of different technologies and materiality. Moreover, EMI appraisal in this paper may enhance understanding of the relationship between lime-based mortar repair and their environmental performance. Significantly, this paper establishes interdisciplinary conservation strategies for heritage buildings located at UNESCO World Heritage Site (WHS).

***Keywords:*** Environmental Maintenance Impact (EMI), lime-based mortar repair, heritage buildings, Life Cycle Assessment (LCA), Green Maintenance, Sustainable Development Goals (SDGs)

[1] Corresponding Author. Email: brit284@um.edu.my

## INTRODUCTION

An assessment of Heritage buildings, its history and conditions are essential in the study of buildings conservation. In Malaysia, the conservation procedure of heritage buildings follows the guidelines provided by the National Heritage Department Malaysia (NHDM) (Harun et al., 2020). Cultural heritage is an evolving resource that supports identity, memory, and a 'sense of place', and has a crucial role in achieving sustainable development. The Sustainable Development Goals (SDGs) adopted by the United Nations in 2015, is a plan of action for the economy, environment, and society, ICOMOS (Version, 2021).

Sustainable maintenance of heritage buildings means having a low impact on the environment by minimising the use of energy and releasing small amounts of embodied carbon. Embodied carbon refers to Carbon Dioxide ($CO_2$) emissions released through the process of extraction, manufacturing, and transportation of materials (Kayan et al., 2018). To evaluate the sustainable maintenance of heritage buildings in relation to the Green Maintenance Model, it is, therefore, necessary to understand the cumulative effect of routine maintenance operations in terms of environmental impact. The model places the priority on the selection of materials and repair technique options for maintenance in conservation based on the level of $CO_2$ emissions (Sari et al., 2023).

The most used materials over the ages have been lime-based mortar, that used with the natural stones, bricks, or manufactured blocks (Michelina Monaco & Marianna Aurilio, 2021). It is also associated with a considerable scale of production and corresponding $CO_2$ emissions (Forster et al., 2020). Today, about 35% of global energy consumption and related $CO_2$ emissions are caused by the construction sector including conservation of heritage buildings. The life cycle Analysis (LCA) is an evaluation tool capable of assessing the $CO_2$ emissions during the whole life cycle of a building (Angrisano et al., 2021). Therefore, to address sustainable repair in the heritage conservation, this attempts to identify sustainable lime-based mortar repair in terms of EMI. Importantly, this underpins informed decision-making in low carbon repair options as well as establishes interdisciplinary conservation strategies for heritage buildings conservation.

## LIME-BASED MORTAR REPAIR APPRAISAL BASED ON GREEN MAINTENANCE MODEL: LCA APPROACH

The Green Maintenance Model applied to support the SDGs which call for preserving the cultural significance embedded in the fabric of heritage buildings while conserving other valuable resources (Kayan et al., 2018b). The concept takes philosophical factor, cost factor, and low environmental impact factor into evaluation. The repair techniques undertaken that included the three factors in figure 1 will be considered as being the most sustainable.


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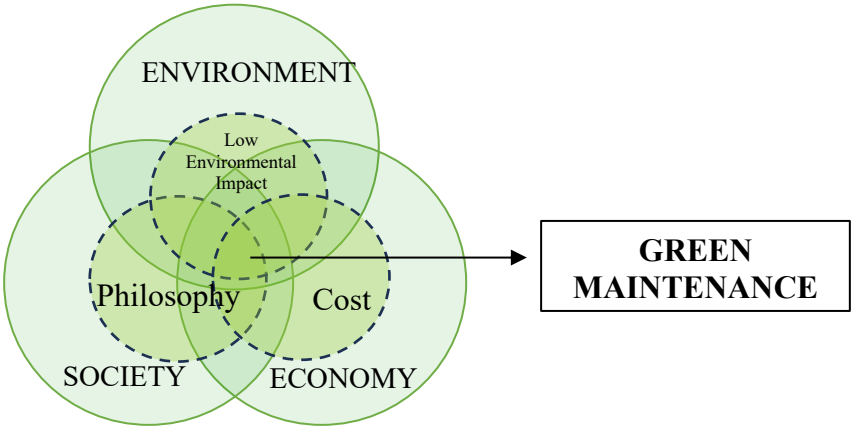


**Figure 1:** The Green Maintenance Model, Parameters for Evaluating the Maintenance Interventions for Heritage Buildings
*Sources: Adopted by (Kayan et al., 2017)*

The Green Maintenance methodology addresses the relationships between $CO_2$ emissions and repair technique options, which offers some insight into the choice of lime-based mortar repair for heritage buildings. As proved on the service figure 2;(Kayan et al., 2018), each intervention's lifespan (*l*) and embodied carbon expenditure (Ce) may be used to understand how they relate to one another.

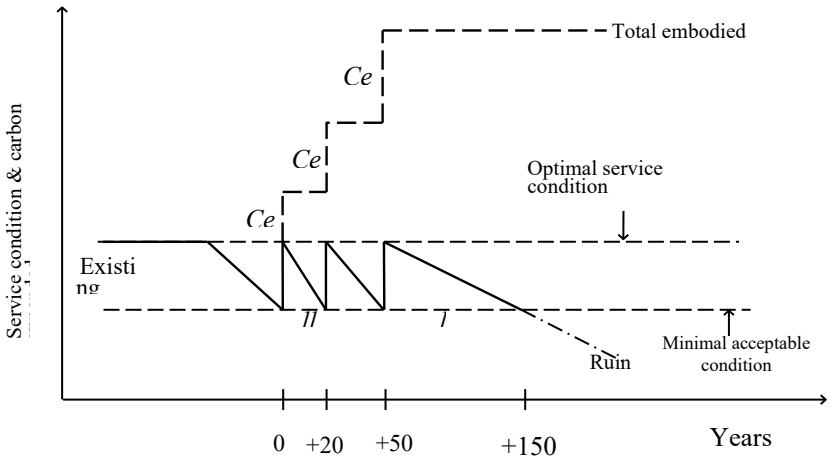


**Figure 2:** Relationship Between Longevity of Repair and Embodied Carbon Expenditure
*Source: (Kayan et al., 2018)*

Whenever the building is in ruin stage, the building must be repaired to achieve the minimal standard and optimal service condition. Along the way the process will contribute to the cumulative total embodied carbon. The less frequency of the repair the less total cumulative embodied carbon.

### *Lime-Based Mortar Repair for Conservation of Heritage Buildings Relationship with Carbon Dioxide (Co2) Emission*

Lime-based mortar has been utilized for heritage buildings (Ventol et al., 2011) and applied in the conservation phase. It must be carefully studied regarding the best general techniques, in order to maximise the life span of the materials used to ensure the $CO_2$ emission is minimal during conservation (Grazzini *et al., 2022)*. The LCA was carried out in this paper to reduce the $CO_2$ emission caused by the operational, transportation, and activities (Cradle-to-site) in the conservation phase (Gómez de Cózar et al., 2019).

The calculation was performed using a functional unit of 1 $m^2$ and a building lifetime of 100 years. The calculations follow the LCA methodology outlined by LCA standards, NS 3720, Sustainability of construction works - Methodology for the assessment of performance of buildings (EN 15978), and/or ISO 14040/44 (Fufa et al., 2021). The LCA provides environmental impacts evaluation associated with all the stages of a product's life in all stages of the process from the extraction and processing of raw materials, to the manufacturing, packaging and marketing processes (Trovato et al., 2020).

Ideally, formulaic expression of mathematical framework is formulated to establish rationale of environmental impact profiling in defining the efficiency of lime-based mortar repair; based upon how green they are in terms of embodied carbon expenditure i.e., through mitigation and reduction of $CO_2$ emissions (Kayan, 2013).

## CASE STUDIES

Melaka and George Town also have been listed as Malaysian UNESCO World Heritage Sites on 7 July 2008. The selection of the case studies in this research are made to achieve sustainability by using the life cycle assessment (LCA) of lime-based mortar repair in conservation of heritage buildings. Case studies are mainly selected in the core and buffer zone of Malaysian UNESCO World Heritage Site of Historic City of Melaka and George Town, Pulau Pinang.

### *Hong Kong and Shanghai Bank Corporation (HSBC)*

The Hong Kong and Shanghai Bank Corporation (HSBC) building on Jalan Kota was constructed as a bank during the British era and it was built around 1912. The designed on the plan rectangular symmetry. The conservation of the HSBC was in 2009 it includes repairs, and replacement of damaged elements and


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structures with the same material which is lime-based mortar as the original. The major work repair of the outer wall by using lime-based mortar for the whole building. Figure 3 show the building structure of HSBC. During the conservation phase of HSBC, used of aggregates and sand were commonly rounded and contained small portions of a variety of materials such as stone dust, chalk, seashell, and ash. The proportion of binder to filler was 2:1 and 3:1.

**Figure 3: Hong Kong and Shanghai Bank Corporation (HSBC)**
*Sources: Authors, 2023*

***Rumah Teh Bunga, George Town***

'Rumah Teh Bunga' is also known as the Penang Malay Gallery, and it's classified under the residential category. It is located at No. 138, Hutton Road, George Town, Penang. It was built in 1893 by one of the richest Jawi Peranakan, Tuan Abdul Wahab, in the late nineteenth century (Volume, 2022). The major conservation that related to the use of lime-based mortar was in 2005 that involve the whole building wall. Figure 4 show the 'Rumah Teh Bunga' building structure.

**Figure 4:** 'Rumah Teh Bunga' Building
*Sources: Authors, 2023*

## QUANTIFICATION OF CO2 EMISSION FOR LIME-BASED MORTAR REPAIR: EMBODIED CARBON COEFFICIENTS

According to Kayan et al. (2017), the cradle-to-site boundary of LCA, which includes the extraction, processing, and production of raw materials as well as the transportation of those resources to the building site, it is used to calculate the $CO_2$ emissions. There are various number of approaches to minimize the embodied $CO_2$ emissions through building repair, even if frequent maintenance interventions result in greater embodied carbon expenditure (Forster et al., 2013). It is well knowledge that the components of mortars, namely the binders and aggregates, the binder/aggregate and water/binder ratios and mostly influenced by porosity, which is in turn influenced by pore size, pore space distribution, and pore structure connectivity determines the mechanical and physical characteristics (Santos et al., 2018).For the case study buildings that used lime-based mortar repairs, the optimal values of the $CO_2$ emissions per kg km were obtained by using the pertinent LCA approach to ensure uniformity in the calculation processes. The functional unit of $kgCO_2e/kg/m^2$ will be use for the calculation of $CO_2$ emission and it was defined in kilograms of $CO_2$ emissions, equivalent per kilogram of lime-based mortar repair materials per $m^2$ of repaired masonry surface/area.

### *$CO_2$ Emission Factor from Lime-Based Mortar Repair Within Cradle-to-Gate*

For the purpose of this research, carbon emission factors per kg km or $kgCO_2/kg/km$ were utilized based on per tonne-km for all 5 tonnes HGV/lorry based on UK average laden of vehicle loads (IFEU et al., 2014); (Defra, 2012); UK Government Greenhouse Gases (GHG) Conversion, 2016). Lime-based mortar repair materials supplied only by nominated suppliers were considered; entailing the shortest and most direct distance travelled for their transportation using similar transportation modes from the primary resourcing location to the building site (*di* in km). Thus, the carbon emission factor for transportation (Table 3) will be constant in all equations used in this research. To fulfil the goal of LCA approach, the functional units of $kgCO_2e/kg/m^2$ were defined in kilograms of $CO_2$ emissions, per kilogram of lime-based mortar repair materials, used on 1m2 of wall surface area. Using this functional unit, embodied carbon expenditure expended in lime-based mortar repair within cradle-to-gate boundary of LCA can be calculated based on the following Equation 1.


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$$\Sigma \text{ ECEcradle} - \text{to} - \text{gate} = \boldsymbol{m_i} \times \boldsymbol{ecc_i} \times \mathbf{A_i}$$

Where,
$\boldsymbol{m_i}$ = mass (kg) of lime repair materials
$\boldsymbol{ecc_i}$ = embodied carbon coefficient ($kgCO_2e/kg$ per $m^2$) of lime-based mortar repair within cradle -to-gate of LCA
$\boldsymbol{A_i}$ = Area ($m^2$) of the repaired wall surface area

Table 1 shows the respective embodied carbon coefficients ($kgCO_2e/kg$) for lime plaster repair materials of the selected case study buildings.

**Table 1:** Embodied Carbon Coefficients ($kgCO_2e$/ kg) of Lime-Based Mortar Repair Materials

| Embodied carbon coefficient, *ecci* (kgCO2e/kg) | | | |
|---|---|---|---|
| Materials / Case Study | **Lime** | **Sand** | **Brick Dust** |
| HSBC Building | 0.69 | 0.00493 | 0.169 |
| Rumah The Bunga | 0.69 | 0.00493 | 0.169 |

*Sources: Adopted from Jones, C., & Hammond, G. (2019). Inventory of Carbon and Energy (ICE) V3.0*

The Embodied carbon Coefficients, *ecci* for the lime is 0.69 $kgCO_2e/kg$, for the sand and aggregate is 0.00493 $kgCO_2e/kg$ and for the brick dust is 0.169 $kgCO_2e/kg$ for both building. The values of embodied carbon coefficient, $ecc_i$ in this research are evidently not precise (average figures) when applied to a general category of lime-based mortar repair materials. They were mainly derived from relevant manufacturers and applicable inventories such as Inventory of Carbon and Energy (ICE) Volume 3.0 by (Jones, C., & Hammond, G. 2019). Meanwhile, lime-based mortar repair materials for the respective buildings were determined based on specifications by conservation methods and techniques for wall structures and elements in Section 3.2 of "Guidelines on Heritage Building Conservation" (JWN, 2014).

***Transportation Data***

Table 2 shows material utilise in lime-based mortar repair of the selected case study with their respective primary resourcing locations and transportation distances, $d_i$ (in km) to the building site. Transportation distance was calculated to the nearest kilometre, i.e., the shortest road distance travelled by land transportation, generated from Google Maps with the conversion of a mile to approximately 1.609 km. The mode of transportation for materials is usually a 5-tonne lorry (with a carbon emission factor of Ef, 0.43326 $kgCO_2e/kg/km$ for HSBC and 0.43326 for Rumah Teh Bunga).

**Table 2:** Distance of The Material to Buildings Case Study

| Case Study | Materials | Resources Location | Site $d_i$ (KM) | Total Distance (KM) | Remarks |
|---|---|---|---|---|---|
| HSBC Building | Sand | Bukit Senggeh, Selandar, Melaka | 37.8 | 92.6 | Sourced, produced and manufactured locally |
| | Lime | Kuari ISB Sdn. Bhd., Alor Gajah, Melaka | 46.2 | | |
| | Brick Dust | Nurul Huda Sdn. Bhd., Alai Kandang, Melaka Tengah, Melaka | 8.6 | | |
| Rumah Teh Bunga | Sand | Hong Heng Group, 25A&B, Jalan Pulai Hartamas 1 Medan Pulai Hartamas, 31300 Ipoh, Perak | 111 | 268 | Sourced, produced and manufactured locally |
| | Lime | Global Mix Sdn. Bhd, Lot PT 142868 Sungai Raja, 31300 Simpang Pulai, Perak Darul Ridzuan | 157 | | |
| | Brick Dust | 140, Jalan Hutton, 10050 George Town, Pulau Pinang | 0 | | Sources made from the building brick |

*Sources: Authors, 2023*

Resourcing location of lime mortar materials is determined based on where they are produced, processed, and manufactured, e.g., lime (quarry), sand (sand mining site), and brick dust (processing plant/building site), respectively. Results in Table 2 indicate that the greater the transportation distance (268km), the greater the $CO_2$ emission during materials delivery. In the case of the HSBC building and Rumah Teh Bunga, the raw material (lime, sand, and brick dust) used for building conservation is taken from the nearest resourcing location (salvage) to lowest the $CO_2$ emission.

It must be noted that the transportation distance from the secondary resourcing locations, such as from various warehouses, ports, airports, or other points of procurement, either from numerous suppliers or manufacturers was not considered. The increases of $CO_2$ emission are due primarily to fossil fuel (Fong et al., 2008). The impact of the transportation of raw materials to the site is non-negligible and, according to (Guerlain et al., 2019) it accounts for at least 30% total represented $CO_2$ emissions were associated with transportation of local materials respectively.

### *$CO_2$ Emission Lime-Based Mortar Repair Within Gate-to-Site*

Total embodied carbon ($kgCO_2e/kg$) for lime-based mortar repair with inclusion of transportation data (emission factor and distance), total embodied carbon expenditure ($kgCO_2e/kg$) expended on lime plaster repair within gate-to-site could be calculated using the following Equation 2: Embodied Carbon Expenditure within Gate-to-Site. Table 3 shows the Embodied Carbon Expenditure for lime-based mortar repair materials transportation.


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$$\Sigma \text{ ECEgate} - \text{to} - \text{site} = m_i \text{ x } ef_i \text{ x } d_i$$

Where;
$m_i$ = mass (kg) of the lime repair materials transported in every km distance
$ef_i$ = carbon emission factor per kg km for lime plaster materials transportation within cradle-to-gate; in this case is a lorry up to 5 tonnes ($kgCO_2e/kg/km$)
$d_i$ = shortest distance (km) for delivery of lime plaster

**Table 3:** Embodied Carbon Expenditure, *efi* ($kgCO_2e/kg/km$) for lime-based mortar repair materials transportation

| Case Study | Material | $ef_i$ ($kgCO_2e/kg/km$) | Remark |
|---|---|---|---|
| HSBC Building | Sand | 0.43326 | Based on 5 tonne HGV/lorry, (%) weight laden - average laden and values |
| | Lime | | |
| | Brick Dust | | |
| Rumah Teh Bunga | Sand | 0.43326 | Based on 5 tonne HGV/lorry, (%) weight laden - average laden and values |
| | Lime | | |
| | Brick Dust | | |

*Sources: Authors, 2023*

***Total $CO_2$ Emission Lime-Based Mortar Repair Within Cradle-to-Site***

The overall total of embodied carbon expenditure for the repaired wall surface area of the selected case studies within cradle-to-site could be calculated using the following Equation 3: Overall Total of Carbon Expenditure from Cradle-to-Site.

$$\Sigma \text{ ECEcradle} - \text{to} - \text{site} = \Sigma \text{ ECEcradle} - \text{to} - \text{gate} + \Sigma \text{ ECEgate} - \text{to} - \text{site}$$

Where;
$\Sigma$ ECEcradle−to −site = Overall total of Embodied Carbon Expenditure ($kgCO_2e$) in lime repair within cradle-to-site boundary of LCA

To test the efficiency of lime-based mortar repair options base on selected maintenance period will be analyse further in the Total Environmental Maintenance Impact (EMI) (table 7).

## RESULT

The results of this study were developed using generated LCA data of embodied carbon expenditure ($kgCO_2e/kg$), principally, to improve the efficiency of lime-based mortar repair of the selected case studies in terms of embodied carbon expenditure.

***Total Mass, $m_i$ (kg) and Mass kg/m² of Lime-Based Mortar Repair Materials***

Table 4 shows that $m_i$ kg of lime repair materials for each case study relies upon different number of lime repair applied on total repaired wall surface area ($A_i$) ($m^2$). This indicates that $A_i$ ($m^2$) and number of lime repair ($tn$) were highly influenced by total mass, $m_i$ (kg) of materials used in lime-based mortar repair for all selected buildings. Theoretically, increment in total $CO_2$ emissions from lime-based mortar repair within cradle-to-site boundary of LCA is highly influenced by increasing numbers of applied lime repair ($tn$) on exterior wall surface of the selected buildings (as shown by results in Table 4).

**Table 4: Total Mass, $m_i$ (kg) and Mass kg/m² of Lime-Based Mortar Repair Materials for Case Studies**

| | Mass, $m_i$ (kg) | | | | Mass kg/m² | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Case Study | **1 Coat** | **2 Coats** | **3 Coats** | **Total** | **Wall surface area, $A_i$ ($m^2$)** | **1 Coat** | **2 Coats** | **3 Coats** | **Total** |
| HSBC Building | 2578.64 | 6702.94 | 1030.44 | 10312.02 | 126.28 | 20.42 | 53.08 | 8.16 | 81.66 |
| Rumah Teh Bunga | 2625.86 | 7877.56 | 1125.86 | 11629.28 | 160.80 | 25.92 | 58.58 | 13.66 | 98.16 |

*Sources: adopted by (Kayan et al., 2021)*

***Functional units of embodied carbon per m2 of repaired wall surface (kgCO2e/kg/m2)***

Table 5 establishes functional units of $kgCO_2e/kg/m^2$ or normalised overall total of embodied carbon expenditure in lime-based mortar repair, undertaken on $1m^2$ of wall surface repaired area of the respective selected buildings. The results of this table indicate that overall total functional unit of embodied carbon is influenced by lime-based mortar materials profile and transportation data.

**Table 5:** Functional Units of Embodied Carbon Per m2 (KgCO2e/Kg/m2) of Repaired Wall Surface of Case Study Buildings

| Life Cycle Assessment (LCA) Boundary | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Case Study | **Lime-Based Mortar Materials** | **Lime Plaster Materials Ratio** | **Mass (kg)/$m^2$** | **Distance to Building Site, $d_i$ (km)** | **Embodied Carbon Coefficient (kgCO2e/kg)** | **Carbon Emission Factors, $ef_i$ ($kgCO_2e$/kg/km)** | **Cradle-to-Gate Total ($kgCO_2e$/kg $m^2$) (A)** | **Gate-to-Site Total kgCO2e/kg/m2 (B)** | **Cradle-to-Site Overall Total $kgCO_2e$/kg/$m^2$ (A+B)** |
| HSBC Building | Sand | 1 | 16.33 | 46.20 | 0.690 | 0.43326 | 11.268 | 326.870 | 338.138 |
| | Lime | 3 | 48.99 | 37.80 | 0.005 | | 0.2410 | 802.320 | 802.561 |
| | Brick Dust | 1 | 16.33 | 8.60 | 0.169 | | 2.760 | 60.850 | 63.610 |


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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Rumah Teh Bunga | Sand | 1 | 16.33 | 157.00 | 0.690 | 0.43326 | 11.268 | 1136.200 | 1147.468 |
| | Lime | 3 | 48.99 | 111.00 | 0.005 | | 0.2410 | 2409.910 | 2410.150 |
| | Brick Dust | 1 | 16.33 | 0.00 | 0.169 | | 2.760 | 0.000 | 2.760 |

*Sources: Authors, 2023*

***Longevity***

The longevity of lime plaster repair. In order to test efficacy of adopted LCA, the longevity of lime plaster repair (function of number of frequencies of repair) was evaluated within an arbitrary period (in this case 100 years). This can be expressed in the following Equation 4: Longevity of lime -based mortar repair.

$$fx = \frac{x_{years}}{i}$$

Where;

$f_x$ =longevity of lime plaster repair options for respective numbers of lime coatings applied within an arbitrary period

$x_{years}$ = arbitrary period (years) of maintenance intervention lime repair options

$i$ = interval years of lime plaster repair

Using Equation (4), the longevity of lime repairs within an arbitrary 100-year period was generated (refer table 6).

**Table 6:** Overall total of EMI ($kgCO_2e$) for Lime Plaster Repair Within Cradle-to-Site of Selected Arbitrary 100-Year Period

| Case Study | Lime-Based Mortar Materials | Total EMI (kgCO2e) within cradle-to-site of lime plaster materials ΣECEcradle−to−site | Frequency of lime plaster repair in every arbitrary 100-year period $f_x$ | Overall total EMI (kgCO2e) within cradle-to-site of selected arbitrary 100-year period ΣEMI 100years= ΣECEcradle−to− site X $f_x$ |
|---|---|---|---|---|
| HSBC Building | Sand | 101347.403 | 4 | 405389.612 |
| | Lime | 42700.067 | | 170800.268 |
| | Brick Dust | 8032.6708 | | 321130.6832 |
| Rumah Teh Bunga | Sand | 387552.281 | 4 | 1550209.12 |
| | Lime | 184512.854 | | 738051.416 |
| | Brick Dust | 443.808000 | | 1775.2320 |

*Sources: Author, 2023*

***Total Environmental Maintenance Impact (EMI)***

Total EMI ($kgCO_2e$) in this study was calculated using respective longevity of repair within the arbitrary period. This can be expressed in the following Equation 5: Total Environmental Maintenance Impact (EMI)

$$\Sigma \text{ EMI} = \Sigma \text{ ECEcradle - to - site x } f_x$$

Where;
$f_x$ = longevity of lime plaster repair for respective numbers of lime coatings applied within the arbitrary period
$\Sigma$ EMI = Total EMI ($kgCO_2e/kg$)

Table 7 shows the total EMI within cradle-to-site of LCA for every lime coating applied on the wall surface of the selected buildings. In the context of whole life cycle, the number and thickness of applied lime coating as well as mixture ratio of lime plaster materials used will determine the durability of wall surface area. Theoretically, the higher the longevity of repair the fewer the number of repairs needed.

**Table 7:** Total EMI ($kgCO_2e$) of Lime-Based Mortar Repair Within Cradle-to-Site

| Functional Units (kgCO2e/kg m2) and LCA Boundary | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Case Study | **Lime-Based Mortar Materials** | **Wall surface area, $A_i$ ($m^2$)** | **Cradle-to-Gate (A)** | **Gate-to-Site (B)** | **Cradle-to-Site A+B=(C)** | **Total EMI ($kgCO_2e$) and LCA boundary** | | | **Total EMI ($kgCO_2e$) for all Materials** |
| | | | | | | **Cradle-to-Gate $A_i$ X A** | **Gate-to-Site $A_i$ X B** | **Cradle-to-Site $A_i$ X C** | |
| HSBC Building | Sand | 126.28 | 11.27 | 326.87 | 338.14 | 1423.18 | 41277.14 | 42699.06 | 304159.40 |
| | Lime | | 0.24 | 802.32 | 802.56 | 30.43 | 101316.97 | 101347.28 | |
| | Brick Dust | | 2.76 | 60.85 | 63.61 | 348.53 | 7684.14 | 8032.67 | |
| Rumah Teh Bunga Building | Sand | 160.80 | 11.27 | 1136.20 | 1147.47 | 1810.61 | 182700.96 | 184513.18 | 1145016.77 |
| | Lime | | 0.24 | 2409.91 | 2410.15 | 38.75 | 387513.53 | 387552.12 | |
| | Brick Dust | | 2.76 | 0.00 | 2.76 | 443.81 | 0.00 | 443.81 | |

*Sources: Author, 2023*

It must be emphasised that the total EMI in this study could only be accurate if all the lime-based mortar repairs were undertaken immediately after their life expectancy has concluded. This also must depend on the adopted LCA calculation procedure's ability to draw rationale upon number of lime coatings applied and their respective longevity of repair.


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## DISCUSSION

Results from Table 7 show that EMI of lime-based mortar repair of the selected heritage buildings is determined mainly by wall surface area, $A_i$ ($m^2$) and number of lime coatings (*tn*). Meanwhile, LCA testing results are significant as they indicate different parameters of lime coating materials of lime-based mortar repair, i.e., mass, $m_i$ (kg), mass kg/$m^2$, functional units kg$CO_2$e/kg/$m^2$, embodied carbon coefficient, $ecc_i$ (kg$CO_2$e/kg) and transportation data (distance to building site, di km and carbon emission factors of mode of transportation, $ef_i$ (kg$CO_2$e/kg/km) and longevity of repair within arbitrary periods, $f_x$.

All these parameters as certain the efficacy of lime-based mortar repairs options in terms of embodied carbon expenditure ($CO_2$ emissions). Practically, the most effective lime-based mortar repairs in terms of low carbon repair and sustainable maintenance management of heritage buildings are the one that most suitably accommodates adopted LCA approach and all parameters. It must be emphasised that many examples of applied lime coatings are still functioning satisfactorily in heritage buildings that are several hundred years old. Meaningfully, generated total EMI based on Equation (3) shows the significance influences of long-term cumulative impact in terms of embodied carbon expenditure for sustainability of lime-based mortar repairs option in heritage buildings.

Research results demonstrated that calculation procedures underpinned by LCA approach have the ability to determine the cumulative EMI. Adopted LCA approach had established its beneficial value, i.e., practically effective in evaluating efficacy of lime-based mortar repairs in terms of embodied carbon expenditure within selected boundaries of LCA and arbitrary maintenance periods. When placed in the context of a 100-year maintenance period, testing of LCA approach results in Table 7 show that Sanitary Board Building has the highest overall total EMI of 2290035.77 kg$CO_2$e, with the utmost frequency of lime-based mortar repair, $f_x$ of 4.

Conversely, HSBC Building produced the lowest overall total EMI of 897320.295 kg$CO_2$e with moderate frequency of lime-based mortar repair, $f_x$ of 4. The general, lime commonly procured and resourced locally incurs small-scale production and contributes to less carbon emissions. It is revealed that transportation of imported of lime and sand for Rumah Teh Bunga building had contributed to significantly high embodied carbon expenditure. Thus, this research makes a strong case for procuring locally sourced materials in repair of heritage buildings, which should be encouraged as it will reduce $CO_2$ emissions.

## CONCLUSION

The results of this study show that generated total embodied carbon expenditure expended from lime-based mortar repair of selected heritage buildings can be evaluated and tested based on LCA approach. It is discovered that the highest

longevity of lime-based mortar repair technique had resulted in the lowest embodied carbon expenditure within the cradle-to-site boundary of LCA and arbitrary maintenance period.

Meanwhile, generated EMI has shown its ability to reduce embodied carbon expenditure, thus providing guidance for the flexible selection of sustainable repair options. This provides a useful tool for making decisions on materials and suppliers for the conservation of heritage buildings.

Beneficially, this research will help heritage building maintenance managers or lime-based mortar repair materials manufacturers to utilise embodied carbon expenditure data and give preference to locally sourced, produced, and manufactured materials over imported materials to reduce the cumulative amount of carbon emissions.

As our society moves towards an environmentally focused economy and sustainable maintenance management solutions and to achieve SDGs, this will be welcomed. As sustainable repair options in the building industry become more prevalent, the adopted LCA approach of this study can be converted into a supplementary financial cost in the maintenance decision-making process.

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# INDICATORS, CHALLENGES AND STRATEGIES IN IMPLEMENTING NET-ZERO CARBON CONSTRUCTION PROJECTS

**Azliza Abdullah[1], Liyana Mohamed Yusof[2], Rahimi A. Rahman[3]**

[1,2,3]*Faculty of Civil Engineering Technology,*
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH
[3]*Faculty of Graduate Studies,*
DAFFODIL INTERNATIONAL UNIVERSITY

## Abstract

The global construction industry, responsible for over 10% of worldwide greenhouse gas emissions, particularly in carbon dioxide (CO2) from energy use, contributes a substantial 38% to global emissions. Unchecked emissions pose a serious risk of hastening climate change impacts. To secure a habitable future, collective responsibility is incumbent upon all construction stakeholders to mitigate the carbon footprint. The prospect of a more sustainable environment lies in proactive emission reduction and the pursuit of net-zero carbon construction. This study investigates the indicators, challenges, and strategies in implementing net-zero carbon construction projects Employing an explorative qualitative approach, twenty project managers and environmental officers were interviewed, and thematic analysis identified management, project attributes, and technology as crucial indicators. Despite increased global awareness, the implementation of net-zero carbon in construction faces significant challenges, including financial constraints, governance issues, management, lack of competency, and limited access to green technologies. Effective strategies necessitate incorporation of governance, knowledge, management, and technology elements. Ultimately, this study enhances understanding of the construction industry by delineating indicators, challenges, and strategies in achieving net-zero carbon construction.

***Keywords*:** Net-Zero Carbon, Construction, Indicators, Challenges, Strategies

[2] Senior lecturer. Email: liyanam@umpsa.edu.my

## INTRODUCTION

The construction industry, encompassing the development and construction of various infrastructure, residential, and commercial projects, carries a significant burden in terms of greenhouse gas emissions. These emissions include gases such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), which contribute to the greenhouse effect and subsequent climate change. The construction industry's activities, ranging from material production to on-site operations, result in a notable share of global emissions. Carbon dioxide emissions resulting from the consumption of energy play a crucial role in climate change. When analysing the construction industry's impact specifically in terms of CO2 emissions from energy usage, it becomes apparent that the industry is a significant contributor. The processes involved in constructing buildings, manufacturing construction materials, and operating construction machinery require substantial energy inputs. As a result, the construction industry alone contributes an alarming 38% to the total global CO2 emissions (United Nations Environment Programme, 2020).

If greenhouse gas emissions from the construction industry and other sectors are not effectively controlled and reduced, there is an increased likelihood of exacerbating the adverse effects of climate change (Chen *et al*., 2023). Climate change manifests in numerous ways, including rising global temperatures, sea-level rise, more frequent and severe extreme weather events, disruptions to ecosystems, and negative impacts on human societies and economies. By not addressing and curbing greenhouse gas emissions, the construction industry runs the risk of amplifying these detrimental effects and compromising the well-being of the planet and its inhabitants. Therefore, achieving net-zero carbon is crucial for addressing environmental problems and reducing greenhouse gas emissions. To achieve net-zero carbon, there are three strategies: avoiding, reducing, and removing CO2 emissions (Mengis *et al.*, 2022). This involves reducing the carbon footprint of the building materials, as well as the energy used during construction, operation, and eventual demolition.

By actively working to decrease emissions, the construction industry can contribute to mitigating climate change and its associated impacts. This involves adopting cleaner and more efficient technologies, implementing sustainable practices throughout the construction process, and reducing reliance on fossil fuels. Reducing the use of carbon emissions in construction activities is a crucial step toward achieving a more sustainable environment for both present and future generations. Several studies have proposed measures to reduce carbon emissions in the construction industry, such as reducing the use of concrete and rebar in construction projects (Kim *et al.*, 2020), promoting awareness of the sources of carbon footprint in the construction industry (Sizirici *et al.*, 2021), and proposing energy savings and emission reductions in a targeted manner (Chen *et al.*, 2022). By minimising emissions resulting from construction activities, such

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as energy consumption, transportation, and waste management, the industry can significantly reduce its carbon footprint and environmental impact. The development of low-carbon building materials, such as interlocking compressed earth bricks, has also been proposed as a way to reduce carbon emissions in the construction industry (Asman *et al.*, 2020).

The construction industry can contribute to creating a more sustainable environment. Such efforts can help mitigate the impacts of climate change and provide a better world for present and future generations, fostering a harmonious balance between human development and environmental stewardship. This highlights the urgent need for emission management and reduction to mitigate the risks associated with climate change. Achieving net-zero carbon in construction requires a holistic approach that involves collaboration between architects, engineers, contractors, and building owners to ensure that all aspects of the project work together to achieve the goal of net-zero carbon emissions. Consequently, this study aims to identify the indicators, challenges and strategies in the implementation of a net-zero carbon construction project. To achieve this objective, semi-structured interviews were conducted with twenty industry respondents, and thematic analysis was used to interpret the results from the interviews. The study results could help to identify the indicators and thus assist in developing suitable strategies to avoid, reduce, and remove CO2 emissions in construction projects.

## LITERATURE REVIEW

The concept of net-zero carbon in construction involves achieving carbon neutrality throughout a building's life cycle, including the construction, operation, and embodied energy stages. This goal is accomplished by minimizing energy consumption, using renewable energy sources, and offsetting remaining emissions (Chen *et al.*, 2023). This includes considering carbon emissions from energy consumption during the manufacturing of construction materials and construction process. The goal of net-zero carbon extends beyond sectors that are already advanced in reducing emissions and focus on "harder-to-treat" sectors such as buildings (Fankhauser *et al.*, 2021). Previous studies have shown that construction activities contribute significantly to global energy consumption and carbon dioxide emissions, making it crucial to reduce carbon emissions in the construction industry (Chen *et al.*, 2023). One of the strategies proposed by Jankovic *et al.* (2021) includes a fabric-first approach, focusing on building envelope design and considering alternative building materials such as biochar, bioplastic, agricultural waste, animal wool, fly ash, and self-healing concrete can also help to reduce carbon emissions. It is also notable that controlling the carbon emission through monitoring and efficient planning by monitoring operational hours at construction sites can reduce the operational energy. The UKGBC Net Zero Carbon Buildings Framework provides guidance for achieving net-zero


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carbon in operational energy and construction emissions (Cohen *et al.*, 2021). The use of energy-efficient technologies can also play a crucial role in reducing initial costs and increasing energy efficiency (Mishchenko *et al.*, 2018) (Ling *et al.*, 2019). However, transitioning to net-zero carbon cities requires systemic transformation and strategic sequencing of mitigation actions (Seto *et al.*, 2021). The development of effective carbon policies is essential to ensure that decreasing emissions is a legal necessity and that all construction companies use emissions control measures to meet carbon standards and regulations (Mustaffa *et al.*, 2022). By understanding the current practice and implementation of these strategies, the construction industry can significantly reduce its carbon emissions and contribute to mitigating climate change.

Based on the literature review, there are several knowledge gaps in research related to net-zero carbon in construction practice. Lack of policies and guidelines for net-zero energy buildings in hot and humid climates, particularly in developing countries highlighted the need for further study of specific strategies and standards to achieve net-zero carbon in these regions (Feng *et al.*, 2019). Limited research can be found on effective strategies and technologies for achieving net-zero carbon in "harder-to-treat" sectors such as buildings and construction compared to more advanced sectors such as manufacturing (Fankhauser *et al.*, 2021). The scarcity of lifecycle-based studies on the environmental effects of net-zero energy buildings calls for more research that considers the life cycle impacts of such buildings, including embodied carbon and other environmental factors (Thiel *et al.*, 2013). Additionally, it applies to the construction industry as the need to control and reduce carbon emissions must start from the design, manufacturing of construction materials, construction process, technology and operational stage of the building. The most important issue to highlight pertaining to the knowledge gap in this topic is, most of the studies were done by taking into consideration throughout the design, manufacturing and operational stage of the building instead of during the construction stage (Jankovic *et al.*, 2021). However, it has been evident that construction activities on site have been one of the significant contributors to carbon emission. Although there are studies that has been done for carbon management, it has been found that there is a lack of direct work specifically on net-zero carbon in construction. Therefore, this study aims to address these knowledge gaps through further research that will enhance the understanding of net-zero carbon in construction during the construction stage.

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# RESEARCH METHODOLOGY

## Research Design

Research methodology refers to the systematic plan or framework that researchers follow to conduct their research and achieve their research objectives. It involves selecting appropriate research methods, data collection techniques, and data analysis procedures to address the research questions or hypotheses (Lindhult and Axelsson, 2021). The choice of research methodology design depends on the nature of the research problem, the research objectives, and the available resources. This study adopted semi-structured interviews to gather data and analyse using thematic analysis. The data from this study were derived from twenty interviews, which all respondents involved in construction management and also environmental officers to gain their insight on the implementation of net-zero carbon in construction practice. The next approach was to analyse with thematic analysis to gain a deep understanding of the research topic and reach qualitative conclusions based on the perspectives and experiences of the respondents.

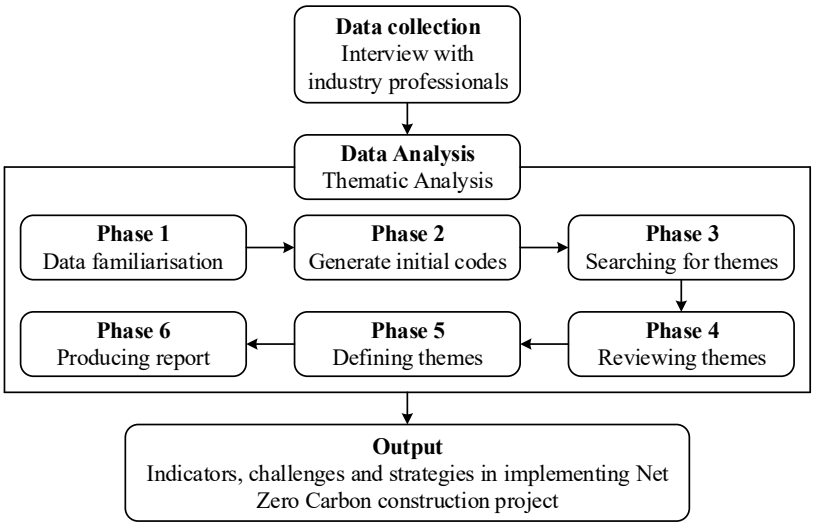


**Figure 1:** Overview of the Research Methodology

## Data Collection

Semi-structured interviews with construction industry professionals were conducted for data collection, aiming to comprehend current carbon management practices on construction sites. Three open-ended questions were asked: 1) What are the indicators in determining the implementation of a net-zero carbon construction project? 2) What are the challenges in implementing a net-zero carbon construction project? and 3) What are the strategies to implement a net-


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zero carbon construction project? Follow-up questions were included for diverse responses and in-depth understanding (Zamani *et al.* 2023; Anathan *et al.* 2023). Virtual platforms facilitated interviews, later summarised and validated by respondents. Twenty carefully selected project managers and environmental officers participated between Q4 2022 and Q1 2023 to ensure varied perspectives. The concept of data saturation in theory-based interview studies suggest two key factors: the initial analysis sample size and the stopping criterion (Francis *et al.*, 2010; Radzi *et al.* 2024). From the interview data collected, the subthemes were evaluated regularly, defined and polished. The themes were then tested if it worked with the coded extracts and the complete data set, and reviewed data to look for additional themes. This process leads to a conclusion that data saturation has been achieved. Respondent profiles, chosen based on professional backgrounds in construction site management and environmental monitoring, were identified via LinkedIn. Rigorous criteria ensured relevance. Connection requests with research goals were sent post-identification. This targeted approach not only ensured a pertinent sample but also swiftly engaged participants. New respondents were acquired through networking with initial participants.

**Table 1:** Respondent Profile

| No | Gender | Position | Background | Years of Experience |
|---|---|---|---|---|
| R1 | Female | Assistant Manager | Client | 11 |
| R2 | Male | Project Manager | Contractor | 20 |
| R3 | Male | Project Manager | Contractor | 30 |
| R4 | Male | Project Engineer | Contractor | 22 |
| R5 | Male | Engineer | Client | 20 |
| R6 | Male | Project Manager | Contractor | 22 |
| R7 | Male | Head of Quality Management | Client | 17 |
| R8 | Male | Resident Engineer | Contractor | 20 |
| R9 | Male | Engineer | Client | 22 |
| R10 | Male | Project Manager | Contractor | 22 |
| R11 | Female | Environmental Executive | Consultant | 4 |
| R12 | Female | Environmental Officer | Contractor | 2 |
| R13 | Female | Environmental Officer | Contractor | 2 |
| R14 | Female | Environmental Officer | Contractor | 2 |
| R15 | Male | Environmental Officer | Consultant | 5 |
| R16 | Female | Professional Environmental Engineer | Consultant | 20 |
| R17 | Male | Health and Safety Manager | Client | 23 |
| R18 | Female | Health and Safety Executive | Consultant | 4 |
| R19 | Male | Senior Executive (Safety and Sustainability) | Client | 18 |
| R20 | Female | Environmental Officer | Contractor | 4 |

### Data Analysis

Thematic analysis is a commonly used approach in qualitative data analysis studies in the field of construction management (Saufi *et al.* 2023; Bunjaridh *et al.* 2023). It involves identifying, analysing, and reporting themes or patterns within the data. Thematic analysis was conducted based on the steps recommended by Braun and Clarke (2006). The first step is to get familiar with the data obtained from interviews. Then, initial codes were generated to capture the interesting features or ideas in the dataset. The dataset was then organised and potential themes were proposed by examining the patterns and connections between codes. Themes were then reviewed and refined, ensuring they are coherent and representative of the data. Each theme was clearly defined and named, making them distinct and accurate. This step was continuously repeated to review and refine the themes for consistency. The analysis was documented by describing each theme with supporting statements from the respondents. This adaptable approach allows for a systematic analysis of qualitative data, aiming to generate meaningful themes that contribute to research understanding, relating to the research question and objectives.

## RESULTS AND DISCUSSION

### Indicators for the Implementation of Net-Zero Carbon Construction Projects

To comprehend the carbon emission issue on the construction industry, the indicators must first be identified. Figure 2 illustrates the indicators of the implementation of net-zero carbon in construction projects. Eleven subthemes were identified and grouped into three themes that are management, project characteristic, and technology. The management theme has several subthemes, including project lifecycle, maintenance, monitoring procedures, and waste. The subthemes under the project characteristics theme include the surrounding area and types of construction. Finally, the technology theme is subdivided into subthemes that include construction materials, design, energy consumption, machinery and transport. The specifics of each theme are covered in the following sections.

#### *Management*

The construction industry can effectively manage and reduce its carbon emissions by considering the project's life cycle, maintaining equipment, implementing monitoring policies, and adopting efficient waste management practices. From the interviews done, it is found that emphasising the understanding of emissions associated with each stage of the project helps to establish effective solutions for reducing carbon emissions. Regular maintenance ensures the efficient operation of equipment, thereby reducing energy waste and emissions. An organised maintenance routine makes it easier to find and fix problems that could lead to


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higher emissions. The development of mitigation strategies requires the application of monitoring mechanisms for infrastructure projects moreover for sites located in environmentally sensitive regions. Apparently, this study also found that effective waste management practices including recycling and waste segregation play a crucial role in accomplishing net-zero carbon construction. By maximising recycling efforts, the demand for new raw materials is reduced, thereby lowering carbon emissions and contributing to a more sustainable built environment.

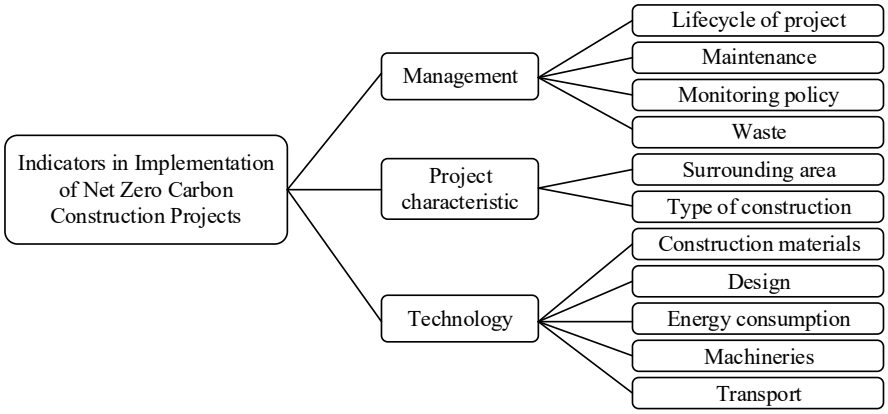


**Figure 2:** Summary of Indicators in the Implementation of the Net-Zero Carbon Construction Project

***Project Characteristic***

Understanding the potential carbon emissions associated with a construction project is crucial, and it depends on factors such as the type and location of the project. This understanding enables project planners and stakeholders to effectively identify areas where carbon reduction strategies can be implemented. The result shows that the location of the building site has a big impact on carbon emissions, especially if it is close to a road or highway where there may be more transportation-related carbon release. Additionally, carbon emissions are also influenced by the type of construction, with high-rise structures often releasing higher emissions than other types. However, it is important to note that carbon emissions from high-rise buildings are temporary and mainly occur during the two to three years of construction. Conversely, horizontal developments such as monorails and highways contribute to sustained carbon emissions throughout their operational lifespan.

***Technology***

By addressing various technological aspects, including the selection of building materials, sustainable design, energy management, machinery utilisation, and

transportation planning, construction projects may significantly advance toward reaching net-zero carbon objectives. The study concluded the crucial role of construction material selection in carbon emission control, promoting eco-friendly alternatives with certified credentials. On-site processes like cement mixing are noted as potential sources of heat and increased emissions. Optimising site plan design becomes imperative for reducing the carbon footprint, enhancing energy efficiency, promoting resource conservation, and facilitating the seamless integration of renewable energy sources. Monitoring energy consumption from primary sources, such as tracking electricity usage through meter bills, allows effective identification of high-energy usage areas. This facilitates the implementation of energy-saving measures, utilizing energy-efficient equipment and adopting renewable energy systems for carbon emission reduction. Accurate measurement of emissions requires converting machinery usage into carbon emission factors. Another factor mentioned is the age of the machineries since the older machine tends to be less effective and produce more emissions than the newer machine. Transportation-related activities record enables project teams to identify opportunities for optimising logistics, reducing travel distances, and exploring sustainable transportation options like electric or hybrid vehicles. As a result, efficient transportation planning significantly contributes to minimising carbon emissions associated with construction-related travel.

## Challenges for the Implementation of Net-Zero Carbon Construction Projects

The implementation of net-zero carbon in construction has gained significant attention and importance due to the urgent need to reduce carbon emissions. However, the implementation in a construction project has proven to be a challenge for several reasons as shown in Figure 3. Twelve subthemes were identified and grouped into five themes. Financial, governance, management, people, and technology are the themes of this variable. Cost and profit are two subthemes in financial. Enforcement and policy are the subthemes for governance. The subthemes for management include progress and multiplayer. The subthemes for people are awareness, competency, and mindset. Established technology, mobility, and suitability are the subthemes for technology. The specifics of each theme and subtheme are covered in sections that follows.

### *Financial*

Overcoming the financial challenges associated with implementing net-zero carbon construction necessitates a shift in perspective and a holistic approach to assessing costs and benefits. This study reveals the importance of taking into account the long-term financial savings and environmental advantages that may be realised through decreased energy usage, decreased operational costs, and enhanced sustainability credentials outweighing the possibility of higher initial


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expenses. One of the challenges revolves has to do with how expensive it is to buy new, environmentally friendly equipment. Contractors may decide to keep employing old technology and equipment due to the high expense. Additionally, concerns regarding profitability and ROI pose challenges in the implementation of net-zero carbon construction projects. Stakeholders or opponents may show unwillingness to pay the higher expenses involved with adopting sustainable practices, as the financial returns may take longer to materialise.

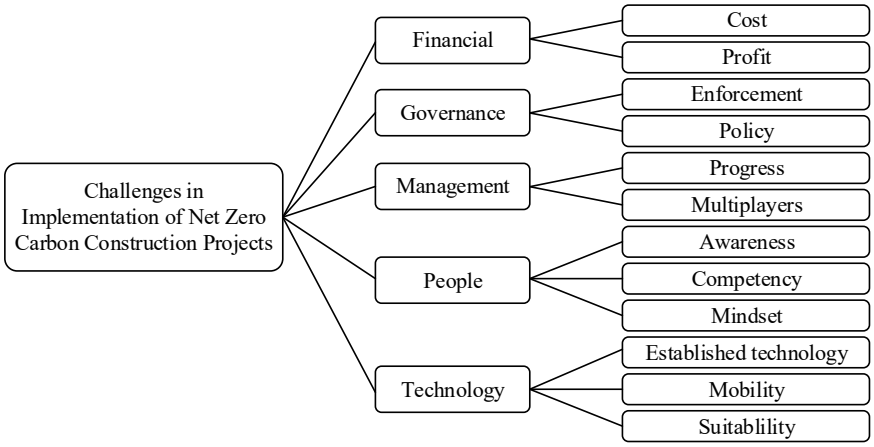


**Figure 3:** Summary of challenges in the implementation of the net-zero carbon construction project

### *Governance*

Governments should give priority to strong enforcement mechanisms, including monitoring, reporting, and compliance frameworks to successfully handle the challenges in achieving net-zero carbon construction. To develop comprehensive policies that provide a clear roadmap for reaching net-zero carbon construction, this study suggests the importance of collaborating with industry experts, researchers, and relevant stakeholders. However, one of the challenges encountered is the lack of effective enforcement of government policies pertaining to net-zero carbon construction. This challenge arises from various factors, including limited resources, insufficient monitoring mechanisms, and coordination issues among different levels of government. Additionally, another challenge lies in the formulation and clarity of government policies. The shift to net-zero carbon construction must be fuelled by clear and well-defined regulations that outline the targeted reductions in carbon emissions and provide guidelines for implementing green building and construction practices.

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***Management***

Apprehending the management challenges in implementing net-zero carbon construction necessitates a shift in mindset and effective communication among project stakeholders. Environmental officers must actively participate in the project team by presenting the advantages of sustainable practices with clear justifications and supporting data. However, from the respondents' point of view, the challenge arises from the conflict between environmental considerations and the desire to expedite the construction progress. Additionally, this study has also identified another challenge that stems from the lack of awareness and support from other team members. Other team members might not completely appreciate the severity of these concerns, even while the environmental officer is aware of the dangers and necessity of controlling carbon emissions. Cooperation and support from stakeholders, industrial and environmental experts are essential to be developed.

***People***

Implementing net-zero carbon practices presents several people-related problems that need a comprehensive strategy-based approach. According to the findings of this study, strategies include putting in place education and outreach initiatives catered to various stakeholder groups, removing language barriers, encouraging cooperation and information sharing within the sector, and advocating for supportive policies and regulations. One of the is the lack of awareness among workers and other project stakeholders regarding the importance of net-zero carbon practices. Environmental officers presented at the construction site can promote awareness and provide guidance on sustainable practices. However, language barriers with general workers can pose challenges in effectively communicating awareness and instructions. Another challenge as highlighted by the respondents is the lack of knowledge and expertise to create thorough recommendations for the construction industry on how to properly neutralise carbon emissions. Additionally, a significant challenge lies in the attitudes and mindsets of the individuals involved in construction projects. Although sustainable practices are good for the environment, they may not yield immediate financial benefits, which discourages implementation. Some contractors may only comply with sustainable practices when enforced by authorities.

***Technology***

Technology-related challenges in implementing net-zero carbon construction practices necessitate a combination of research, innovation, and collaboration. The study identified several challenges, one of which being the restricted availability and uncertainties surrounding green technologies. Given that net-zero carbon construction practices are relatively recent, there may be a lack of expertise in the field and a shortage of professionals knowledgeable in


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implementing these technologies. Another challenge arises from the constrained working environments often found on construction sites, which make it difficult to mobilize equipment, particularly larger machinery required for sustainable practices. Furthermore, some construction sites may have restrictions that make it impossible to use certain technology, like solar panels. Factors such as restricted areas or unpredictable weather conditions can affect the feasibility and effectiveness of specific renewable energy solutions.

## Strategies for the Implementation of Net-Zero Carbon Construction Projects

In order to achieve net-zero carbon construction, it is essential to establish and implement effective strategies. These strategies aim to balance out carbon emissions and removal by lowering or offsetting the carbon emissions caused by construction projects. The strategies to assist in achieving net-zero carbon in construction are illustrated in Figure 4. Four themes were developed from the sixteen subthemes that were found. The themes of this variable include financial, governance, management, people, and technology. Some of the subthemes under management are maintenance, planning, emission control, reduce, reuse and recycle as well as replanting. Knowledge has subthemes concerning awareness, educate, and training. Governance has three subthemes: enforcement, penalty, and rewards. The subthemes for technology include energy saving, machineries, materials, renewable energy, and sustainable construction. The sections that follow describe the details.

### *Management*

Effective implementation of net-zero carbon construction in the construction sector requires proactive planning, collaborative stakeholder engagement, and a steadfast commitment to sustainable practices. Integrating these strategies into the project management process from early planning stages is crucial for optimizing carbon reduction potential. Maintenance practices, including adhering to a defined schedule and routine checks, such as air filter and exhaust system replacements, are imperative to ensure optimal machinery performance, contributing significantly to emission reduction. A thorough understanding of carbon emission sources in construction projects is essential, necessitating measurement and examination at every project life cycle stage. Emissions control and reduction initiatives, including the use of renewable energy sources such as solar or wind power, are vital for achieving net-zero carbon goals. Waste management practices prioritising reduction, reuse, and recycling are recommended, with construction waste segregation and recycling whenever feasible. Additionally, tree-planting initiatives contribute to carbon neutralization and enhance ecological value by stabilising soil, preventing erosion, reducing landslide risks, and aiding in carbon repossession.

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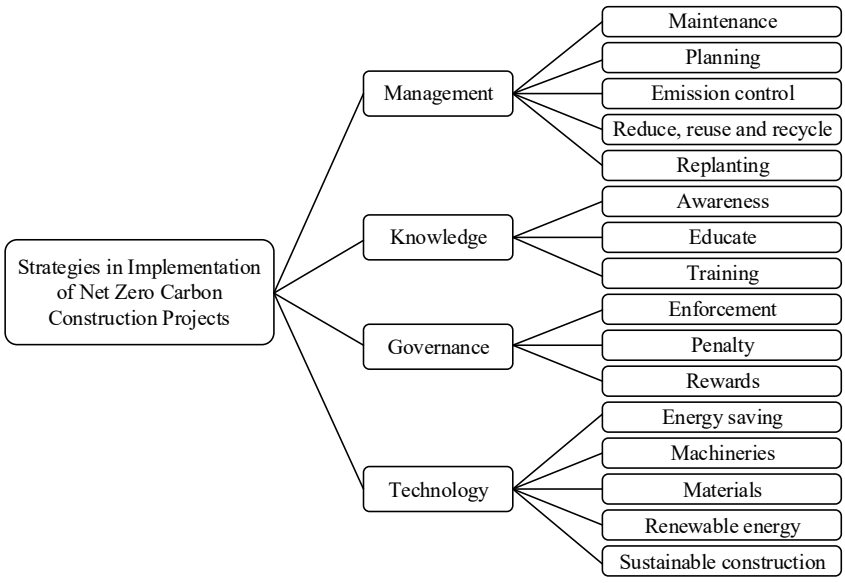


**Figure 4:** Summary of strategies in the implementation of the net-zero carbon construction project

### *Knowledge*

Implementing strategies for achieving net-zero carbon in the construction industry necessitates a knowledge-based approach that empowers individuals and organizations with the necessary understanding and skills. Based on the results, the construction industry may foster a culture of sustainability and innovation by raising awareness, providing education, and offering relevant training programs. It is profound to raise awareness among all parties involved in construction projects through various means such as courses, workshops, and training programs specifically focused on sustainable construction practices and the importance of reducing carbon emissions. The findings also highlight the importance of universities incorporating subjects relevant to sustainable building in their curriculum, ensuring that future professionals are equipped with the vital knowledge and understanding of net-zero carbon principles. Training and guidance on reducing carbon emissions at construction sites may be provided by organisations such as Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST). They may impart knowledge on best practices, technology, and techniques that align with net-zero carbon goals to project teams, contractors, and workers. These programs can focus on specific areas such as energy-efficient design, integration of renewable energy, sustainable material selection, waste management, and carbon accounting.


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### *Governance*

Governance strategies play a crucial role in facilitating the implementation of net-zero carbon construction projects by creating a supportive framework. According to the results, these strategies include enacting specific environmental acts, implementing penalties for excessive carbon emissions, and offering rewards for sustainable practices. To effectively address carbon emissions, governments should enact specific environmental acts or regulations that specifically focus on reducing carbon emissions in the construction industry. Existing environmental acts should be carefully reviewed and revised to incorporate clear instructions and guidelines regarding allowable carbon emissions. Penalties or taxes on carbon emissions can serve as a strong motivator for the construction industry to aggressively decrease their carbon footprint. Contractors and project owners should be held accountable for their carbon emissions, and penalties should be imposed if emissions exceed the established baseline. Offering rewards or recognition to project owners who successfully implement measures to reduce carbon emissions can be an effective strategy. Project owners may be encouraged to prioritise and invest in sustainable construction methods through green building certifications or other sustainability certifications. This not only encourages the use of net-zero carbon solutions but also helps projects become more reputable and marketable.

### *Technology*

The construction industry can make substantial strides in reducing carbon emissions, bringing them closer to achieving net-zero carbon goals through the strategic adoption of technology. These strategies encompass various areas, as found in this study, including energy-saving practices, machinery evaluation, sustainable materials, renewable energy adoption, and advanced construction methods. Vital to emission reduction on construction sites, energy-saving practices involve simple yet impactful measures such as powering down equipment during breaks and idle periods. Rigorous evaluation of machinery ensures compliance with environmental and efficiency standards. Exploring alternative materials like green cement or cementless concrete presents a significant opportunity for carbon footprint reduction, with green cement offering lower carbon intensity. The respondents suggested for incorporating renewable energy solutions into construction machinery, emphasizing their role in curbing carbon emissions. Inclusion of specifications for renewable energy technologies in construction contracts serves as an incentive for on-site adoption. Furthermore, embracing modern building techniques such as Industrialized Building Systems (IBS) and Prefabricated Prefinished Volumetric Building (PPVC) contributes to emission reduction by relocating a substantial portion of construction activities to controlled manufacturing facilities, thereby minimizing energy consumption and waste generation.

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## CONCLUSION

In conclusion, this study emphasises the importance of implementing net-zero carbon construction practices within the construction industry for a greener and sustainable future. It highlights key indicators, challenges, and strategies that are pertinent to this issue. Indicators such as construction type, location, and the influence of diverse construction technologies provide actionable insights into effective carbon reduction strategies. However, the implementation process encounters hurdles such as financial constraints, governance issues, human-related impediments, and technological constraints. Overcoming these challenges necessitates a shift in perspective, effective communication, and collaboration among stakeholders. Proposed strategies encompass proactive planning, infusion of sustainable practices into project management, educational initiatives, training programs, and the establishment of supportive governance frameworks. Attaining net-zero carbon construction mandates the adoption of energy-efficient practices, utilisation of sustainable materials, incorporation of renewable energy solutions, and the integration of advanced construction technologies. Success hinges on collaborative efforts, information exchange, and a shared vision of sustainability among stakeholders. The construction industry, by embracing these practices, can significantly propel itself towards net-zero carbon goals, contribute to greenhouse gas reduction, combat climate change, and forge healthier, more resilient built environments for future generations.

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# MAPPING ECOSYSTEM SERVICES' ASSESSMENTS: CURRENT PRACTICE AND FUTURE PROSPECTS IN MALAYSIA

**Wan Nur Ayuni Wan Ab Rashid[1], Junainah Mohamad[2]**

[1]*College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA SHAH ALAM, MALAYSIA
[2]*Department of Built Environment Studies and Technology,*
*College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA PERAK BRANCH, SERI ISKANDAR CAMPUS, MALAYSIA

## Abstract

Malaysia is one of the countries rich with biodiversity. Currently, the ecosystem services (ES) are found to be degraded in Malaysia and are expected to decline further over the coming century due to the changing political scenarios. The present study focuses on ES assessments in Malaysia, we systematically review literature to summarise achievements to date, identify key research gaps, and reveal pathways for policy uptake. Based on the findings, the current practices and developments in the mapping of ES assessment was identified. The results of research that incorporated practitioner engagement through interviews to learn about their perspectives on valuers' current practices related ecosystem service valuation were included as part of the research analysis. Analysis for this article also took into account conclusions from further semi-structured interviews with valuers working in the field of valuation as well as the most recent developments in application. Thus, we suggest that further research could focus on monetary valuation method. Economic valuation results will provide useful information about changes to welfare. Benefits transfer can be a practical, swift and cheap way to get an estimate of the value of ecosystems service, particularly when the aim is to assess a large number of diverse ecosystems.

***Keywords***: Ecosystem Service Methodology, Ecosystem Service Assessment, Ecosystem Service Valuation, Decision Making, Mapping, Malaysia

[2] Corresponding author. Email: mjunainah@uitm.edu.my

## INTRODUCTION

The Ministry of Natural Resources and Environment Malaysia, (2020) reported Malaysia is a megadiverse country. Malaysia is one of the countries of rich biodiversity together with another six countries in five nations (Brunei, Timor Leste, Indonesia, Philippines, and Singapore). Otherwise, Malaysia is included in Southeast Asia (SEA) known as a region of rich biodiversity. SEA includes four of the thirty-six global biodiversity hotspots according to the Conservation International. Agriculture, fisheries, and forestry play important roles in the economies of many SEA countries (Dang et al., 2021). Abdullah et al., (2015), reported the World Development Indicator recognised that Malaysia is one of the richest countries in the world in terms of biodiversity per unit area.

Valuing Ecosystem Service (ES) has been an important focus of economic analysis in recent decades. The numerous reviews have synthesised ES assessments by highlighting global distributions of ES economic valuation (Egan et al., 2022; Friess et al., 2020; Matthew et al., 2018; Nur Shafiza et al., 2023; Robles Zavala & Chang Reynoso, 2018). Millennium Ecosystem Assessment, (2005) shown the framework of ecosystem services (ES) for communicating links between ecosystems and human well-being is widely used (Bakar et al., 2017). The benefits of ES assessments are provided systematic information to mainstream ES into decision-making (Dang et al., 2021). The growing number of ES assessments globally demonstrates their importance.

The study, therefore, employed both a systematically review literature to summarise achievements to date, identify key research gaps, and reveal pathways for policy uptake and interview method, requiring face-to-face semi-structured interviews. In recent years, an important trend has emerged towards mapping and assessing ecosystem services in general (Mayer & Woltering, 2018). The mapping of ES assessment especially interm of monetary values for ES value has become an active research topic. Mapping and valuation offer the additional opportunity of analyzing trade-offs between different ecosystem services in a spatially-explicit form. In this paper we review studies that map assessment of ES in Malaysia. We define mapping of ES values as the valuation of ES in monetary terms across a relatively large geographical area that includes the examination of how values vary across space. Thereby, mapping of ES values reveals additional information as compared to traditional site-specific ES valuation, which is beneficial for designing efficient policies and institutions for maintaining ES supply. In addition, we make an interview to verify the current practice and get valuers' perspective on current ecosystem service valuation.


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# LITERATURE REVIEW

## Review Framework for Ecosystem Service and Ecosystem Categories in Malaysia

### *Ecosystem Types*

According to CAFF, (2015) reported TEEB database regarding ES as known as biomes. Biomes were classified based on the ecosystem classification of The Economics of ES and Biodiversity TEEB relished in 2010 with minor modifications: (1) combining marine and coastal ecosystems and (2) separating TEEB's cultivated ecosystem into agriculture and agroforest to better represent cultivation systems in SEA. Therefore, the ecosystem classifications used in this review include: (1) agriculture (rice, vegetation, and other crops etc.), (2) agro-forest (oil palm, rubber etc.), (3) forest, (4) inland water (lakes & rivers), (5) marine/coastal/island (coral reefs, seagrass, shores), (6) urban, (7) wetland (coastal wetland: mangrove & marsh and inland wetland: peatland & swamp), (8) mixed (research/publication comprises more than one ecosystem).

### *Ecosystem Services (ES)*

According to the Millennium Ecosystem Assessment, (2005) ecosystem service strongly contributes to human well-being. Natural ecosystems produce various ecosystem services (ES) (CAFF, 2015). Nevertheless, due to the public good characteristics of many ES and their vulnerability to externalities, such as air, soil and water contamination, the costs of ES degradation are not sufficiently incorporated into individual or public decision-making. As a result, ES in all parts of the world is being degraded to a suboptimal extent, causing loss of ES supply. Various national and supranational policies have been introduced to protect natural ecosystems, which have only been partially effective (Suaree et al., 2023). For example, Tong, (2020) stated up to date, Malaysia has ratified approximately 17 biodiversity-related multilateral environmental agreements (MEAs) to provide protection for its biodiversity.

However, the declining forest cover and the relatively high number of threatened species in Malaysia may indicate that biodiversity conservation is not working. Other than that, Malaysia is a federal country with the Federal Constitution as the highest law of the land. Article 76(1) of the constitution provides the power for the federal and state governments to legislate laws in accordance with the division of powers specified under the Ninth Schedule. In theory, the Ninth Schedule provides clear demarcation of jurisdictions between the federal and state governments (Hoe et al., 2023). However, in practice, there appears to be overlapping jurisdictions, which complicate implementation and enforcement of these constitutional powers (Safuan et al., 2022). Reversing the degradation of ecosystems requires ''significant changes in policies, institutions, and practices that are not currently under way'' (Millennium Ecosystem Assessment, 2005).

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One of the main challenges in designing effective policies derives from the complexity of integrating multidimensional environmental impacts into decision making processes. Typically, decisions are based mainly on information that is well understood and known with high certainty, for example information on readily observable financial or market transactions. Ecological externalities are typically insufficiently considered because of uncertain estimates regarding expected impacts, difficulties in interpreting results from various disciplines and difficulties in translating impacts into changes in social welfare. Monetary valuation of ES is a method to overcome such difficulties. It enables the aggregation of multidimensional costs and benefits of alternative measures within a one-dimensional welfare measure (Pearce et al., 2006). Although the practice of monetary valuation and its underlying framework are subject to debate and criticism (Spash and Carter, 2001; Sagoff, 2004), the concept of monetary valuation and cost-benefit analysis is widely accepted and subject to intensive research activity. The estimation of accurate ES values, however, is not straightforward, in part due to spatial heterogeneity in biophysical and socioeconomic conditions. The spatial perspective of variation in ES values is relatively new and has not been extensively researched. Insufficient knowledge exists about how ES values differ across space and what their spatial determinants are (Bockstael, 1996; Bateman et al., 2002; Plummer, 2009; De Groot et al., 2010).

**Ecosystem Service Assessment Approach**

A range of methods are available for assessing ES, from mapping and modelling the supply and demand of ES to evaluate the economic and non-economic importance (Dang et al., 2021). These assessment approaches were divided into four main categories:

1. Economic valuation included contingent valuation, travel cost, market price, choice experiment, benefit transfer, and other economic valuation methods.
2. Mapping included five categories: ES models (e.g., InVEST); other modelling approaches (e.g., hydrological models, species distribution models, agent-based modelling); statistical models (e.g., regression models); proxy mapping (e.g., matrix-based approaches or look-up tables to present ES based on land use/land cover maps); and other mapping approach (e.g., deliberative mapping, spatial interpolation).
3. Assessments of human perception included questionnaire surveys, observations, interviews, and focus groups. Which has been included in this review, studies must have delivered quantitative results such as maps, economic values or semi-quantitative results as scores or grading scales.


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4. Other quantitative assessment methods are based on biophysical parameters and involve field measurements, monitoring, and modelling but do not generate a map or valuation of ES. From our database, the following methods are in this category: water balance models, dynamic coupled vegetation and global hydrology models, simple score tables, Bayesian Belief Networks, value quantification from interviews or references.

***Ecosystem Service Valuation Approach in Malaysia***

Most studies on ES valuation prior to 2009, according to Dang et al., (2021), concentrated on monetary valuation. Since 2009, there has been a change in the way that ES assessments are investigated; more studies are now utilizing both integrated approaches (ES mapping, modeling, assessments of human perception, and other quantitative assessments) and other assessment approaches (economic valuation and mapping, assessments of human perception and mapping, economic valuation and other quantitative assessments). The most popular economic valuation methods in the research ecosystem service sector are benefit transfer, market prices, and contingent valuation (Viti et al., 2022). Consequently, there has been an increasing focus on ES assessments in the scientific research and policies of the region; however, no comprehensive evaluations that track progress and set objectives for the upcoming ES assessments in Malaysia have been created (Lee et al., 2022).

From the overview, the valuation of ES is justified by the fact that, first, the worth of natural resources is not recognized (Leh et al., 2018), and second, human-caused damage is not documented (Abu Bakar & Wall, 2019; Yacob et al., 2009). The community's level of awareness of these issues is still minimal (Arabamiry et al., 2013). Furthermore, property rights and the cost of externalities that are not factored into resource pricing are not clearly defined ES, that support public goods. In the economic evaluation of ES, achieving a just balance between benefits and drawbacks is crucial since we live in a world of scarcity and have to make choices about how to effectively manage it. What level of benefit is required? And what sort of effect is expected? Economic valuation is responsible for determining the optimal combination of ecosystem service flows, provided that this combination optimizes the total value received by resource consumers (Perez Verdin et al., 2016).

## RESEARCH METHODOLOGY

The methodology included a desk-study analysis of peer-reviewed and grey literature pertinent to ecosystem services in Malaysia (e.g., online databases and reference lists). The results of research that incorporated practitioner engagement through semi-structured in-depth interviews methods to learn about their perspectives on valuers' present practices related ecosystem service valuation

were included in the literature analysis. Analysis for this article also took into account conclusions from further semi-structured interviews with valuers working in the field of valuation as well as the most recent developments in application.

***Desk-Study Analysis***

The key review publications of the search strategy were using both online database and reference lists searching, First, the researchers searched on the ISI Web of Science with the following keywords: Malaysia country AND "ecosystem service*" in the title, keyword, and abstract, and published 2018 to July 2023 about 773 publications. The search strategy is as follows: TS = (ecosystem AND service AND in AND Malaysia*). The final number of publications selected for detailed review was 76 of which 6 publications included multiple case studies and only 10 publications reported on economic value. Review results were recorded and organised in an Excel database.

***Face to face interviews Analysis***

Three key government valuers, including representatives from JPPH Kuala Lumpur, JPPH Sabah, and JPPH Sungai Petani, were interviewed to understand their current practices in ecosystem service valuing. The snowball sampling method was used to gather data from experts in cost-benefit analysis, valuation, and ES officers. The interviews provided valuable insights for developing a comprehensive method for ES valuation, highlighting the importance of face-to-face, semi-structured, in-depth interviews (Urbis et al., 2019).

The concepts that define the current method of ES valuation were the focus of in-depth, semi-structured, open-ended interviews. The length (usually 25–30 minutes) allows for the emergence of complicated concerns (Creswell, 2013). "What are the key elements of ES value, in your opinion?" was the interview opening question. Next, the respondents were questioned regarding the method that was applied to carry out the ES valuation. Subsequent inquiries centered around suggestions for future actions.

## ANALYSIS AND DISCUSSION

***Quantitative Review on Mapping ES Values Studies in Malaysia***

The on-going efforts on the mapping and assessment of ES are totally dependent upon reliable and scientific data. This action needs to integrate with growing scientific evidence on biodiversity as a key component for resilient ecosystems and delivery of ecosystem services. It is on the basis for valuing the multifunctionality of ecosystems for sustaining long-term human well-being. The present study has developed engagement with the scientific community and further strengthened the knowledge and evidence base for policy and decision-making. The function mapping is exploring the potential for valuation and natural


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capital accounting at national level. This builds on the biophysical mapping and assessment of the state of ecosystems and of their services in the context of Biodiversity Strategy especially for marine ecosystem (Jabatan Taman Laut Malaysia, 2015) using latest developments on ecosystem accounts at global level and concrete examples of stakeholder (NK et al., 2019; Tong, 2020).

In the total 76 publications analysed, which include 70 separate case studies. The studies differ significantly with respect to their spatial scope, the ES assessed and the methodologies applied. Figure 1 shows the spatial distribution of the case studies across the nation. The colour indicates the type of research study area.

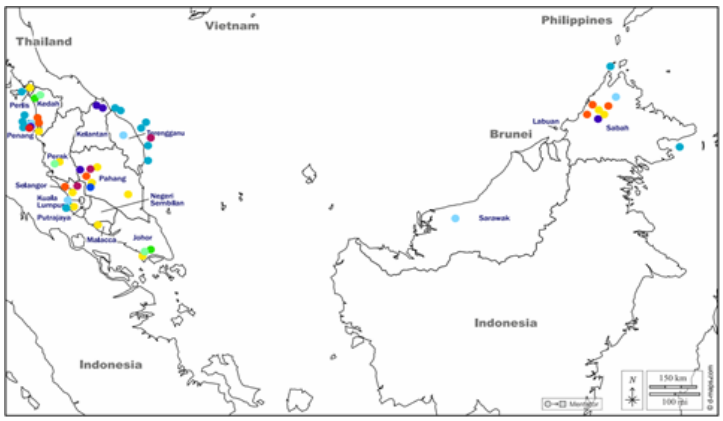


**Figure 1:** Spatial distribution of case study areas of ES in Malaysia
*Source: Author Analysis*

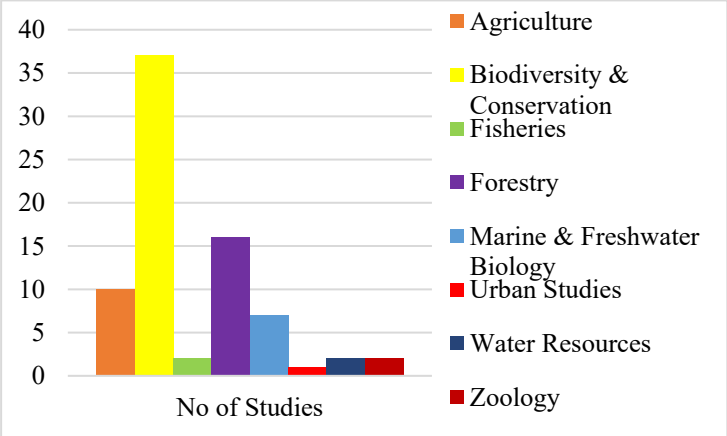


**Figure 2:** Number of ES mapped per case study in Malaysia
*Source: Author Analysis*

Most studies focus on biodiversity and conservation as shown in Figure 2, which is various purposes of finding and method used. On average, each study maps values for eight ES. Many studies focus on biodiversity and conservation about (37) such as coral conservation. Teh et al., (2018), reported conservation value could be partially funded from tourism. In addition, some studies aim to investigate the diversity and abundance of corals (Khodzori et al., 2019). The findings can help and provide useful information on the current status of corals for a better management plan and by showing the substantial economic value, it can provide an important incentive for protecting biodiversity especially in Malaysia and worldwide. Second followed by forestry about (16) research. Dang et al., (2021), mentioned current government policies more concerning conservation strategy and Malaysia focused on the forest and agro-forest systems. For instance, Malaysia and Indonesia are the largest producers of palm oil in the world. As shown in Figure 3, forest research is about second lower than mangrove research in Malaysia. The frequency with which each ES has been mapped is shown in Figure 2. Moreover, fishermen face difficulties because of mangrove deforestation. Mangrove forests are important to fishermen for sustaining rich seafood supplies as a source of income (Zaiton et al., 2019). Economic Valuations are crucial in providing information for better policy options to decision-makers in designing sustainable ES management for the benefit of the future generations in Malaysia (Matthew et al., 2019).

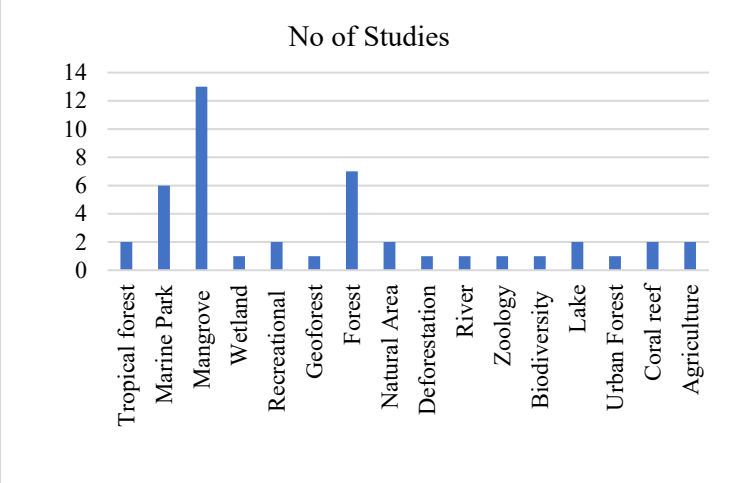


**Figure 3:** Methodologies used to assess ecosystem in Malaysia
*Source: Author Analysis*


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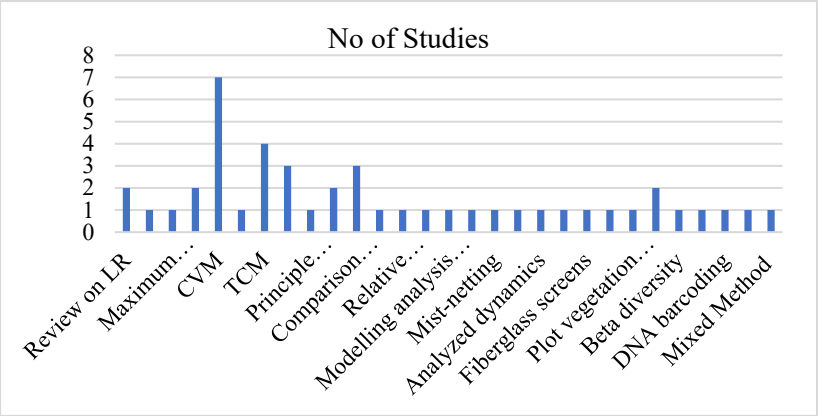


**Figure 4:** Methodologies used to assess ecosystem in Malaysia
*Source: Author Analysis*

The literature lacks consensus on the best ES mapping method for specific purposes and circumstances. Factors like data availability, ES variables, study area characteristics, resources, policy context, and scientific purpose determine the choice. The advantages and disadvantages depend on the study's quality and background. Diversification of ES mapping can strengthen data-bases for ES assessments, providing a range of potential outcomes in Malaysia and contributing to global ES assessments. The present study identified twenty-nine methods (Figure 4), of which the methods can be categorised in four different assessment approaches.

1) Economic valuation approaches which included contingent valuation (Abdulkarim, 2017; Abdullah et al., 2015; Chong Leon et al., 2005; Hassin et al., 2020; Mamat et al., 2020; Musa et al., 2020; Samdin, 2008; Vianna et al., 2018; Yacob et al., 2009; Zaiton et al., 2019), travel cost (Leh et al., 2018; Matthew et al., 2019; Othman & Jafari, 2019; Solikin et al., 2019), choice management experiment (Arabamiry et al., 2013), benefit transfer (Salisu Barau & Stringer, 2015), and other economic valuation methods. Prior to 2009, studies primarily focused on monetary valuation of ES. However, since then, there has been a shift towards using other assessment approaches, including ES mapping, modelling, and human perception assessments (Dang et al., 2021). Malaysia's most commonly used economic valuation methods include contingent valuation, market price, and benefit transfer, primarily used for cultural services and supporting/habitat services. Contingency valuation is widely used due to its flexibility and ability to estimate total value, including non-use value. Market price is used for monetary valuation of provisioning services, while benefit transfer is

used for regulating services like climate regulation. Benefit transfer offers a quick assessment of economic value.

2) Mapping included five categories: ES models (DNA barcoding)(Lim et al., 2016); other modelling approaches (e.g., hydrological models (Faridah Hanum et al., 2019), species distribution models (Wilkinson et al., 2018), agent-based modelling (Pariatamby et al., 2020); statistical models (e.g., regression models); proxy mapping (e.g., matrix-based approaches or look-up tables to present ES based on land use/land cover maps) (Shehab et al., 2021) ; and other mapping approach (e.g., deliberative mapping, spatial interpolation).
3) Assessments of perception included questionnaire surveys, observations, interviews, and focus groups. To be included in this review, studies must have delivered quantitative results such as maps, economic values or semi-quantitative results as scores or grading scales. (1) The 'observation method' directly looks at human actions and behaviour. For instance, Otero et al., (2018) observed people who are engaged in a particular activity such as mangrove, representing forest monitoring and management. (2) The 'document method' estimated ES values from certain individuals or groups by analysing texts, images, or other forms of materials (Lee et al., 2022; Matthew et al., 2019). To assess ES, this method often integrates social media with interviews, questionnaires, etc. (Salisu Barau & Stringer, 2015). Human perception assessments have been integrated with ES mapping in Malaysia to create realistic future scenarios for ES assessments. This information informs land use planning and identifies areas directly affected by ES decline.
4) Other quantitative assessments included methods based on biophysical parameters and involve field measurements (Wilkinson et al., 2018), monitoring (Lavoue et al., 2022), and modelling (Shehab et al., 2021) but do not generate a map or valuation of ES.

***Ecosystem Service Valuation Approach in Reality***

The main results are Malaysia's government system was extremely well-organized and controlled, although method adaptation was not widely implemented. According to the informant, the benefits that humans receive from the environment, whether they be provisional (such as food, timber, raw materials, and medicinal products), regulating (such as mitigating extreme events, controlling water quality, and sequestering carbon), cultural (such as recreation, spirituality, and aesthetics), or supporting (such as habitat conservation and primary production), are collectively referred to as ecosystem services. A fish aquarium, for example, is a tiny ecosystem with services for humans. The challenge to economists is to assign "correct" monetary value of environmental


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service flows. If these values are priced "correctly" long term social benefits will be sustened? There are three approach of economic value which are market-based approach, revealed preferred approach (surrogate market) and stated preference approach. These approaches are applied for a particular type of economic value. In addition, ES are the contribution that ecosystem make to human well-being (Borger et al., 2014; Jabatan Taman Laut Malaysia, 2015; Mamat et al., 2020). All classifications make a distinction between "provisioning", "regulating", "supporting (habitat)", "cultural" services. Although the idea of ES value adaptability was frequently and readily brought up in workshops and interviews, it was actually seldom included in the main ecosystem service valuation (Celliers et al., 2020). Mamat et al., (2020) added that economic benefits of ES are not readily quantified because of the unavailable market price. Therefore, in order to address these issues, it becomes imperative to re-define and co-construct knowledge on the allocation and access to ES valuation (Barau & Stringer, 2015). Vianna et al., (2018) suggested more standardise valuation studied becomes available, these data may assist the development of models that could predict the potential of ES value.

## CONCLUSION

In the present study, 67 publications on Ecosystem service (ES) assessments in Malaysia were reviewed with a focus on their assessment approaches. Since 2018, the growing methodologies used in ES assessments in Malaysia have diversified with increased stakeholder participation and a growing number of spatially explicit assessments and how their results support decision making in the nation.

To fully recognize the advantages of ES, it is also critical to assess its economic value through expert analysis. The multifunctionality and complexity of many environmental resources make it challenging to predict how the wide range of goods and services that they offer will affect human welfare. Although the capitals' data and information were instantly helpful, local government representatives were able to question their goals regarding ES valuation through the engagement process itself.

This paper's analytical approach served as both a tool for increasing awareness of the activities and conditions necessary for local governance in ES management and a crucial channel for discussion amongst local government officials. The evaluation ought to be a tool for insight. Creating such a tool is a component of the capital framework's upcoming study. The researchers' and the municipal employees' frequent interaction facilitated learning and the application of adaptive management. This approach's strength, particularly the traffic-light system, lies in its limited responses and very simple implementation. If valuers are not used to test and update the categories, this could potentially be seen as a vulnerability.

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However, ES assessments in Malaysia still face geographical bias, thematic bias, data constraints and limited coverage of some spatial and temporal scales. Biodiversity governance in Malaysia is still complicated regarding delivery of the National Policy on Biological Diversity 2016–2025 with the involvement of different ministries and agencies, especially with the changing political scenario. Management approaches, priorities in planning and decision-making, and fiscal and budgetary structure vary from ministry to ministry (Tong, 2020).

Otherwise, data constraints in Malaysia have led to a preference for proxy-based ES assessments, which provide limited information for policy makers. The lack of multi-spatial and temporal scale analyses, particularly high-resolution ones, may hinder decision-making. To improve policy support, Malaysia needs more evidence-based assessments with trade-off analyses and validation, aided by ES modelling.

The study suggests that standardised ecosystem services (ESs) assessments can be improved by providing guidance on mapping and assessing ESs, adopting ES assessments into planning and decision-making, improving data accessibility, creating science-policy dialogues, and enhancing stakeholder engagement. Further research could focus on monetary valuation, which can provide valuable information about welfare changes and benefit transfer for assessing diverse ecosystems.

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# MODELLING HOUSING MISMATCH FOR AFFORDABLE HOUSING DEMAND AND SUPPLY IN MALAYSIA

**Ahmad Fawwaz Saleh[1], Ainoriza Mohd Aini[2], Rohayu Ab Majid[3], Muhammad Hadi Mustafa[4], Ain Farhana Jamaludin[5]**

[1,2,4,5] *Centre for Sustainable Planning and Real Estate (SUPRE),*
*Faculty of Built Environment,*
UNIVERSITI MALAYA, MALAYSIA
[3]*College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA, MALAYSIA

## Abstract

The housing mismatch between housing demand and supply in recent years has become a crucial agenda for enhancing the availability of affordable housing in Malaysia. This research paper presents a study on the factors that affect individuals and housing developers that keep them from owning and supplying affordable housing. This cross-sectional study validates the existence of a housing mismatch in Malaysia from a view of housing demand and supply. This study employed 400 respondents on housing demand and 120 respondents from housing developers who represented housing suppliers. The Partial Least Square Equation Modelling (PLS-SEM) method was used to develop the model and validate the data. By performing the composite reliability and convergent validity through PLS-SEM, 25 attributes from housing demand and 22 attributes from housing supply were found significant for the development of the structural housing mismatch model. The final output was established by findings their coefficients determination, path coefficient, effect size and predictive relevance towards variables of housing mismatch. The result indicates five factors with nine attributes in housing demand and 11 attributes from housing supply contributed to the existence of a housing mismatch at 12%. Finally, by incorporating an analysis of the significant findings, it becomes clear that identifying the features of housing mismatch from both sides enables the government to have strategic interventions. This underlines the importance of recognising the key features in guiding authorities aimed at minimising housing disparities.

***Keywords***: Housing mismatch, affordable housing, product factors, spatial geographical location, regulation and requirement, and hire regulatory cost

[1] Lecturer at Universiti Malaya. Email: fawwaz.um.edu.my

## INTRODUCTION

These days, the affordable housing mismatch can be used to gauge a community's quality of life. The term “housing mismatch” is used for the imbalanced market between housing demand and housing supply. This issue is frequently studied from various perspectives by past academics (Bangura & Lee, 2024; Geh, 2016; Bloxham et al., 2011). Most past scholars are highly concerned with housing prices, particularly the existence of affordable housing mismatch, especially in urban areas. Since, the largest investment for households in Malaysia was property. This study highlighted significant research into its findings. For instance, in another country like Australia, households contributed over 60% of their financial resources to own residential properties (Lee, 2017). This raised questions about the affordability of housing in Malaysia.In Malaysia, concerns over affordable housing have been less prevalent until lately, when the value of transactions rose by 23.6% between 2021 and 2022, which was almost double times faster than the average growth rate between 2020 to 2021 (Henry Butcher, 2024). By the end of 2022, Peninsular Malaysia had over 110 delayed projects, 435 sick projects, and 112 abandoned projects recorded under the Ministry of Housing and Local Government, and most of these developers had declared bankruptcy or liquidated (Bernama, 2023). The government's updated policies, which commit to providing more affordable housing with quality on par with high-end houses, have exacerbated the situation (Majid R. et al., 2023). According to NAPIC (2022), the average price in Malaysia has increased to RM 434,758. This result was followed by an increment over residential overhang until a 24.7% change from 2020 to 2021, with 38,863 units unsold. The government repeatedly assures the populace to meet the rising demand for reasonably priced homes under RM 300,000. Thaker (2021) has found that housing demand is recorded at 48% more than the supply, which is only 28%, explaining the reason why private developers abandoned numerous projects for affordable housing.

However, housing prices are only among the most common issues that cause the imbalance of housing demand and housing supply. Studies have shown that the existence of housing mismatch, especially an imbalance development on affordable housing, could be affected by housing bubbles (Pitros and Arayici, 2016;), credit risk to banks (Lee et al., 2021), vulnerable to crime (Daud et al., 2022), an insufficient supply of affordable houses (Ismail et al., 2023; Rahim et al., 2019), etc.

Thaker (2021) explained that numerous studies that examine the primary variables influencing housing costs and affordability in Malaysia tend to focus more on demand-side and macroeconomic factors than supply-side factors. There are not any in-depth studies that support the view from both perspectives concurrently. Due to the variance and complexity of the housing mismatch situation and the strong correlations between many of its attributes, a thorough framework model is required for assessing the mechanism of housing mismatch

from both sides. With reference to the setting of urban areas in Malaysia, this study aims to understand the relationship and significant effect from both perspectives of housing demand and supply together that contributed to the existing proportion of housing mismatch to bridge the gap above. Individuals and housing developers are the respondents. The literature review, research methods, research findings, discussion and conclusion are roofed in the sections.

## FACTOR AFFECTING HOUSING MISMATCH

Five factors have a significant effect towards housing mismatch from both housing demand and housing supply. They are the following: product-related considerations, private financial requirements, government regulations and requirements, spatial geographic location, and other bearing costs (Majid et al., 2023; Saleh et al., 2022). These factors are prominent in understanding housing mismatch based on their demographical profiles.

The lack of demand for affordable house units could be due to a mismatch of product type and location (Thean, 2017). From here, product factors have an impact towards the selection of stakeholders to decide the quality of the product. Individuals are highly connected in their ability to recognise housing products (Ariff et al. 2016). Meanwhile, housing developers have limited ability to provide social housing due to profit-oriented (Zainul & Idris, 2017). Other than that, past researchers have provided that product-related factors that affected demand and housing supply were tenure, house design, built-up areas, no of rooms, allocation of site plan and layout plan, restriction of interest, allowable density, external view, topography; and open spaces (Majid et al., 2023; Saleh et al., 2017; Matel, 2020).

Another point to look at was spatial geographical location. Rosli et al. (2024) suggest the local government should organise a plan to achieve a balanced equilibrium between housing development and the proximity of the working places, commercial areas and city centre. The authors believe that allocating proper planning locations for housing development could enhance the quality of life, particularly for low-income people. Thus, assessment of location should be frequently assessed in terms of accessibility, such as proximity to a major business district, the neighbourhood, and the access to resources for education and entertainment (McCluskey et al., 2000).

Next, another factor that affects housing mismatch is the financial requirement set up by bank institutions for end-finance and bridging finance. Several financial institutions do not lend and serve low-income customers because they have no proper documentation of income (Gopalan and Venkataraman, 2015). Moreover, the difficulty of providing a downpayment of 10% and cash for another hidden charge, such as legal fees, is challenging for low-middle-income communities (Khoo, 2020). In addition, housing developers also have their requirements to follow in order to apply for bridging loans. BNM


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(2018) revealed that the bank has approved RM 516 billion for residential end-financing and only RM 88 billion for bridging finance. This amount shows a huge gap in the housing supply to develop affordable housing.

Other than that, government requirement and regulation factors also play the main roles in the proportion, either from federal or state government made in-charge with all the policy and procedure. Jamalludin et al. (2016) explained that the procedure housing developers must endure to get approval from the board takes up to two months. Then, to get development approval from the local authority, it takes 10 months maximum. It actually more or less prevents the housing developers from developing affordable houses. Finally, other bearing costs and hire regulatory costs are borne by the people and housing developers, as mentioned in the conceptual framework below. For housing developers, some local authorities have increased development charges, which may impact the total cost of development (Rahman et al., 2021).

## CONCEPTUAL FRAMEWORK OF AFFORDABLE HOUSING MISMATCH

In essence, this conceptual framework is an expansion and adaption from the preliminary framework given by Saleh et al. (2016) and Saleh et al. (2017) and supported by Majid et al. (2023). The framework has 38 attributes for housing demand and 35 attributes that come under housing supply, and they can analyse the existence of housing mismatch.

In the light of the above figure 1, the following research hypotheses are proposed:

- $H^1$ – Attributes of housing demand have a significant impact on the people's perspectives for purchasing affordable houses.
- $H^2$ – Attributes of housing supply have a significant impact on the housing developers' perspectives' for developing affordable houses.
- $H^3$ – Both housing demand and housing supply have a significant impact on the existence of housing mismatch in a country.

Figure below show the conceptual framework that compiled all the attributes indicated by the expertise and literature.

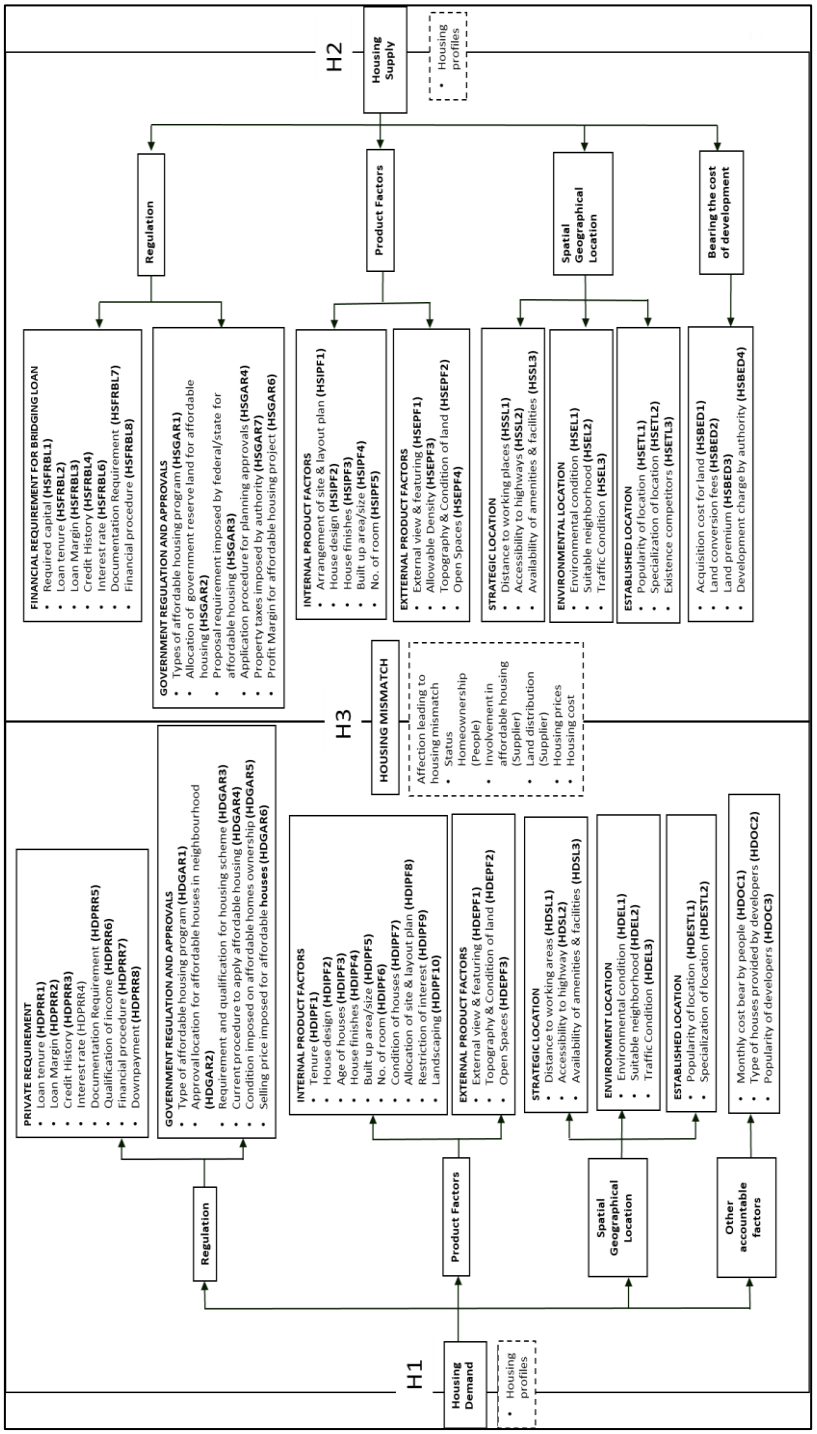


**Figure 1**: Proposed Conceptual Framework *(Author self-compilation)*


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Firstly, a questionnaire survey was distributed to 400 people who rented houses in a few urban areas in Kuala Lumpur and Selangor, Malaysia, to identify the significant effect on housing demand, followed by 120 developers who have been involved with affordable housing projects in Malaysia. Using a five-point Likert scale (1-Strongly disagree, 2- Disagree, 3-Neutral, 4-Agreed, 5-Stongly Agree), They were asked to evaluate every attribute that impacts purchasing (housing demand) and developing (housing supply) affordable housing in Malaysia. Then, the data were analysed using a statistical package for social science (SPSS) and validated through Structural Equation Modelling (PLS-SEM). PLS-SEM will create a connection between the measurement items and their associated construct within the analysis (Hair et al., 2011; Sartsedt et al., 2019). The analysis is made for order construction under the reflective-formative model, as suggested by Sarstedt et al. (2019). The authors suggest reflective model should be analysed using composite reliability for composite validity. Average Variance Extracted (AVE) for convergent validity in order to eliminate and finalise the established of each construct as for measurement model. Then, using formative analysis, the structural model was analysed to interpret their Coefficient of determination (R2), Path coefficient (β), Effect size ($f^2$) and Predictive relevance ($Q^2$).

## RESULT AND DISCUSSION

### a) Evaluation of Measurement Model

**Table 1**: Composite and Convergent Validity

| No. | Indicators | Composite Validity | Convergent Validity |
|---|---|---|---|
| | | **CR** | **AVE** |
| 1 | **PRODUCT FACTORS HD** | 0.945 | 0.657 |
| 2 | **PRIVATE FINANCIAL REQUIREMENT & REGULATION HD** | 0.896 | 0.554 |
| 3 | **GOVERNMENT APPROVAL & REGULATION HD** | 0.923 | 0.751 |
| 4 | **LOCATION FACTORS HD** | 0.834 | 0.511 |
| 5 | **PRODUC FACTOR HS** | 0.907 | 0.583 |
| 6 | **FINANCIAL REQUIREMENT FOR BRIDGING LOAN HS** | 0.920 | 0.659 |
| 7 | **GOVERNMENT APPROVALS & REGULATION HS** | 0.858 | 0.605 |
| 8 | **LOCATION FACTORS HS** | 0.900 | 0.693 |
| 9 | **HIRE REGULATORY COST HS** | 1.000 | 1.000 |
| 10 | **HOUSING DEMAND** | **0.810** | **0.592** |
| 11 | **HOUSING SUPPLY** | **0.815** | **0.688** |
| 12 | **HOUSING MISMATCH** | **0.275** | **0.659** |

**CR: 0.6 ≤ CR & α ≤ 0.7: Acceptable *0.7 ≤ CR & α ≤ 0.9 : Satisfactory*
**AVE: AVE > 0.5: Satisfied * AVE0 ≤ 0.5 : Consider to remove*

Subsequently, after some elimination of attributes, Table 1 shows the final composite and convergent validity. The CR values explain that all the constructs are under a satisfied range of 0.700 except construct factors of housing mismatch (0.275). The analysis then proceeded with determining convergent validity by interpreting the result from the AVE value. From Table 1, all constructs provide AVE values greater than 0.5 accept hire regulatory cost by housing supply since it has only one attribute left after the elimination process. In this context, the construct validity is met and accepted. From here, after the elimination of some attributes to finalise its validity, 25 attributes from housing demand and 22 attributes from housing supply were selected to be analysed for the next level of the structural model.

**b) Evaluation of Structural Model**

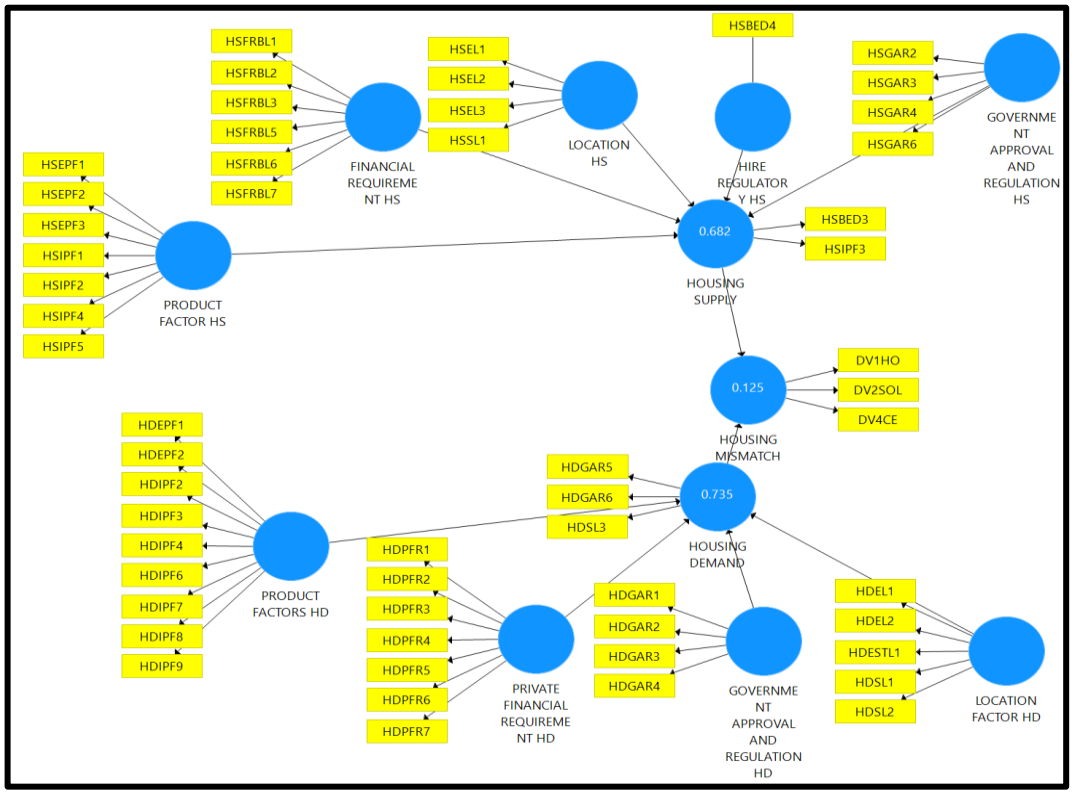


**Figure 2**: Coefficient determination ($R^2$)


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Figure 2 portrays all factors and attributes associated with housing profiles after analysis from convergent validity. The contribution of the Product Factor HD, Private Financial Requirement HD, Government Approval and Regulation HD, and Location Factors HD associated with housing demand and housing profiles as a dependent variable are shown to be $R^2$ of 0.735. Accordingly, this would suggest that 73% of the positive variation for the housing demand component can explain all the features, followed by housing supply responded by housing developers, which recorded $R^2$ of 0.682. However, after grouping both constructs from housing demand and housing supply for measuring the proportion of housing mismatch, it contributed to a low relationship of $R^2$ of 0.125. Thus, 12% of positive variation from housing demand and housing supply contributed to the existence proportion of housing mismatch in such areas. According to Hair et al. (2011), a high number of $R^2$ will indicate a high level of association and accuracy. The significant indicator used to identify the variables was greater than 0.26 (Cohen 1998); 0.33 is regarded as moderate, and 0.19 is weak (Chin 1998).

**Table 2**: Summary of Effect and Path Coefficient

| **Relationship: Exogenous > Endogenous construct** | **Effect size** $f^2$ | **Path coefficient (β)** | ***t*-statistic** | **P-Value** | **Significance** | **Result** |
|---|---|---|---|---|---|---|
| GOVERNMENT APPROVAL & REGULATION HD > HOUSING DEMAND | 1.434 | 0.693 | 9.633 | 0.000 | P < 0.01 | Significant & large effect |
| LOCATION FACTORS HD > HOUSING DEMAND | 0.268 | 0.319 | 3.099 | 0.000 | P < 0.01 | Significant & medium effect |
| PRODUCT FACTORS HD > HOUSING DEMAND | 0.001 | 0.016 | 0.254 | 0.799 | P <0.10 | Not Significant |
| PRIVATE FINANCIAL REQUIREMENT & REGULATION HD > HOUSING DEMAND | 0.000 | -0.009 | 0.150 | 0.881 | P <0.10 | Not Significant |
| PRODUC FACTOR HS > HOUSING SUPPLY | 0.226 | 0.325 | 4.111 | 0.000 | P< 0.01 | Significant & Medium effect |
| FINANCIAL REQUIREMENT FOR BRIDGING LOAN HS > HOUSING SUPPLY | 0.018 | -0.093 | 1.257 | 0.209 | P <0.10 | Not Significant |
| GOVERNMENT APPROVALS & REGULATION HS > HOUSING SUPPLY | 0.000 | -0.008 | 0.086 | 0.932 | P <0.10 | Not Significant |
| LOCATION FACTORS HS > HOUSING SUPPLY | 0.062 | 0.162 | 2.169 | 0.031 | P < 0.01 | Significant & small effect |
| HIRE REGULATORY COST HS > HOUSING SUPPLY | 0.753 | 0.582 | 6.544 | 0.000 | P < 0.01 | Significant & Large effect |

| | | | | | | |
|---|---|---|---|---|---|---|
| HOUSING DEMAND > HOUSING MISMATCH | 0.051 | 0.211 | 1.955 | 0.051 | P < 0.05 | Significant & small effect |
| HOUSING SUPPLY > HOUSING MISMATCH | 0.090 | -0.280 | 2.763 | 0.006 | P < 0.01 | Significant & small effect |

Notes: *$f^2$ = 0.02: Small effect * $f^2$ = 0.15 Medium effect * $f^2$ = 0.35 Large effect: * P ≤ 0.01 and P ≤ 0.05 : Significant * P ≤ 0.10 : Not significance

According to the effect size result in Table 2, Government Approvals and Regulation from the Housing Demand Side ($f^2$ = 1.434) and Hire Regulatory Cost from the Housing Supply Side ($f^2$ = 0.753) have a substantial effect size towards their endogenous construct. Both Location Factor HD ($f^2$ = 0.268) and Product Factor HS ($f^2$ = 0.226) show a medium effect size on their endogenous construct. Other than that, the location factors HS ($f^2$ = 0.062) component has a negligible impact on the availability of homes. Housing supply and demand, for the second-order construct, have negligible effects on housing mismatch ($f^2$ =0.090 and 0.051, respectively). Lastly, the components of Product Factor HD ($f^2$ =0.001), Private Financial Requirement HD ($f^2$ =0.000), Financial Requirement for Bridging Loan HS ($f^2$ =0.018), and Government Approvals and Regulation HS ($f^2$ =0.000) have no impact at all on their endogenous construct of housing demand and housing supply. According to Hair et al. (2011), the route coefficient value needs to be at least 0.1 to consider the effect in a structural model. However, the observation should also be determined using the t-statistic and P-value for deleted non-significant construct variables. T-statistics values under 1.65 are not significant, according to earlier studies, and the road should be discarded. Meanwhile, seven (7) paths have significant relationships toward endogenous variables, while another four (4) do not have significant relationships. The highest relationship indicates a significant association between government approval regulation HD and housing demand, with a path coefficient value larger than 0.1 (= 0.693) and a t-statistic value greater than 1.65 (t-statistic= 9.633). Secondly, the route coefficient value of 0.319 and the t-statistic of 3.099 indicate a substantial correlation between the geographic location parameters HD and housing demand. Thirdly, the path coefficient for housing supply showed a substantial and accepted association between the components of product factors, location factors, and hire regulatory cost, with path coefficient values of 0.325, 0.162, and 0.582 and t-statistic values of 4.111, 2.169, and 6.544. Housing supply and the housing mismatch are accepted with the path coefficient values of 0.211 and -0.280 and t-statistic values of 1.955 and 2.763, respectively. The link between the private financial requirement and regulation HD with housing demand is not significant, as shown by a different route that has a path coefficient value below 0.1 (=0.016 and -0.009) and a t-statistic value below 1.65 (t-statistic= 0.254 and 0.150). Therefore, this route is rejected. The relationship between factors of financial requirement for bridging loans and the government approvals and regulation associated with housing supply are both taken into account as non-


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significant results due to path coefficient values of -0.093 and 0.008, and t-statistic values of 1.257 and 0.086, respectively.

**Table 3**: Summary of Predictive Relevance

| Relationship: Exogenous > Endogenous construct | $Q^2$ | Degree of predictive relevance |
|---|---|---|
| HOUSING DEMAND > HOUSING MISMATCH | 0.405 | Strong |
| HOUSING SUPPLY > HOUSING MISMATCH | 0.433 | Strong |
| HOUSING SUPPLY AND HOUSING DEMAND > HOUSING MISMATCH | 0.064 | Week |

Table 3 shows a substantial correlation between housing demand, housing supply, and endogenous housing mismatch. From housing demand to housing mismatch construct has contributed a strong degree of predictive relevance of $Q^2$ with the value of 0.405. Similarly, with housing supply to housing mismatch construct recorded a strong degree of predictive relevance with $Q^2$ of 0.433. Finally, a combination of both housing demand and housing supply with the constructed variable of housing mismatch has observed a weak effect of predictive relevance with $Q^2$ at 0.064.

Predictive significance was established because the $Q^2$ value for all endogenous constructs overall was greater than 0. The past scholars suggest 0.02 is considered a weak form, 0.15 is moderate, and 0.35 and above have strong degrees of predictive relevance.

## DISCUSSION AND CONCLUSION

The study makes three noteworthy points: (1) the attributes that show a significant impact on the people (housing demand) for purchasing affordable houses; (2) the attributes that show a significant impact on the housing developers in developing affordable houses; and (3) the existence of housing mismatch in sampled areas are low.

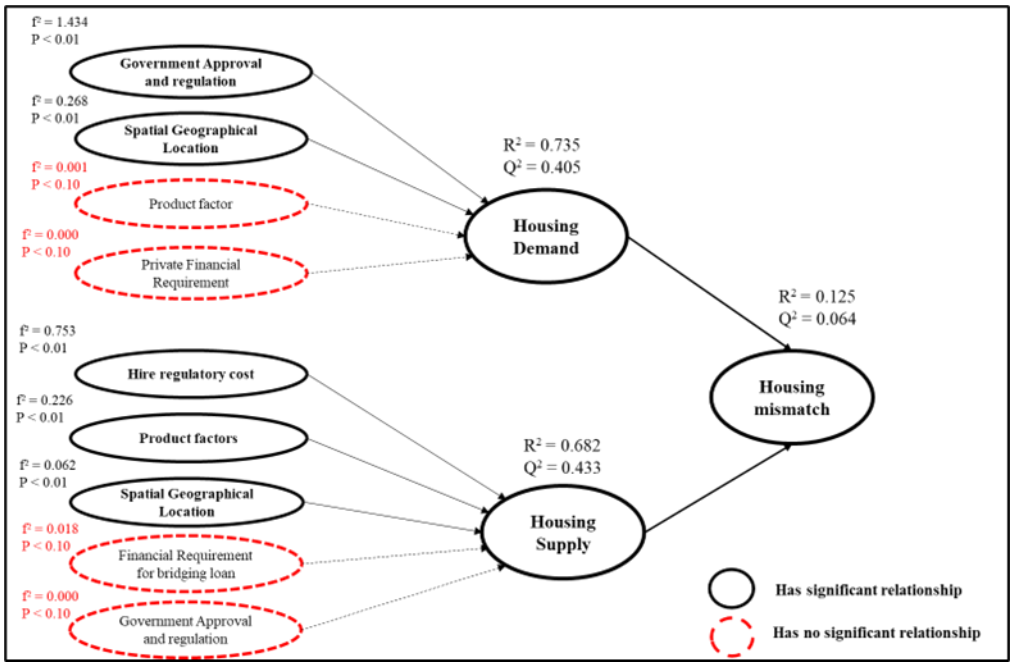


**Figure 3**: Housing Mismatch Model for Affordable Housing

The result from PLS-SEM was summarised using the above figure. After eliminating some constructs and analysing the results from relationship and effect size, the result has shown that two factors out of four factors with an overall of nine attributes were found to be significant with housing demand, three factors with 11 attributes were found to be significant with a structural model in housing supply.

Meanwhile, another factor that shows significance in the current situation is the financial requirement for bridging loans. Nowadays, the COVID-19 pandemic forces housing developers to be careful with any agreement on the short-term bridge loan and their capital expenditure. Zulkarnain et al. (2023), COVID-19 does affect property development and its value. The rational reason for the non-significant result from these factors is probably because financial institutions and the government have already given the faultless process in borrowing bridging loans and a good standard of approval for developing affordable houses; it is just a matter of hire regulatory cost; product factors, and location that affect them.

One can see the existence proportion of housing mismatch in such areas is low. However, the stakeholders cannot ignore the factors that affect housing demand and housing supply.


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Additionally, by explaining the factors that contributed to housing mismatch, it indirectly aids communities in understanding the fundamental problems with sustainable development and their interrelationship. Recognising the elements makes it the ideal path for scaling the solution needed and helps stakeholders define and focus on the attributes that highly affect housing mismatch. The model also helps to influence frameworks relating to housing provisions and eventually supports the condition of lack of homeownership and deficiency of building affordable houses that should be parallel with its qualities. For example, governments are recommended to perform adequate feasibility studies for their intended customers to address this problem, especially in regard to understanding the purchasing power of the populace. The Housing Ownership Campaign (HOC), launched in 2019, was one previous attempt to increase overhang unit sales. According to previous Housing and Local Government Minister Zuraida Kamarrudin, 31,415 housing units worth RM23.3 billion were sold as a result of this campaign (Thean, 2020). The continuation of similar governmental measures this year may boost sales of the remaining overhang units. However, the stakeholders should be aware that numerous things have changed since the pandemic, including the reality of housing demand and housing supply. Models for financing could also need to be changed, especially after the world crisis of COVID-19. This was supported by Khan et al. (2024), who highlighted the significant improvement in handling financial capability during a crisis. For instance, when remote employment becomes more prevalent, potential purchasers might be inclined to purchase affordable houses in suburban areas. The Malaysian housing market could be improved, and more affordable homes could be provided for everyone through government initiatives and more targeted real estate development projects.

All of these factors and attributes increase the likelihood of housing mismatch. Inequality in certain locations and differences in demographic profiles will have a detrimental effect on the housing industry. Most people have personal concerns that prevent them from purchasing a home. Similarly, housing developers also have their limitations, such as labour force and capital, leaving most areas to end up with various housing disparity characteristics due to the differences in people's tastes and developers' profiles. However, the question is not only whether these imbalances exist but rather what factors and to what extent they contribute to the imbalance. From that result, the government can arbitrate which areas are more important to be rescued in order to reduce the gaps.

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This work should pave the way for further investigations in the future, especially when it comes to the specification of each main factor. I hope that the knowledge gathered from this study will open doors for additional research and validate the framework we have developed.

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# "US" VERSUS "THEM": (RE)VISITING THE DAILY LIFE STRUGGLE OF STATELESS COMMUNITY IN SABAH, MALAYSIA

**Peter Aning Tedong[1], Fathin Amelina Fazlie[2], Evelyn Shyamala A/P Paul Devadason[3]**

[1] *Department of Urban and Regional Planning, Faculty of Built Environment*,
UNIVERSITY OF MALAYA
[2]*Institute of Advanced Studies*,
UNIVERSITY OF MALAYA
[3] *Faculty of Economics and Administration,*
UNIVERSITY OF MALAYA

## Abstract

The statelessness issue in Malaysia, particularly in Sabah state, began in the early 1970s due to the influx of Filipino refugees during the Mindanao insurgency and civil war. Scholars have documented that the stateless community in Sabah faces social discrimination and exploitation from various actors that cause them to live in vulnerability. Although previous research has written extensively about the plight of the stateless children in Sabah, there is limited research that talks about living conditions and the daily life struggles of the community itself. Therefore, using a qualitative approach, this study will explore the issues and challenges this community faces regarding their living conditions and access to essential services and amenities. In so doing, we conducted in-depth interviews with 30 stateless individuals living in Kota Kinabalu, Sabah. This study found that the stateless community in Sabah is having difficulty in terms of status registration, limited access to employment, worse housing and living condition, and no access to healthcare and education. Therefore, this study may improve the understanding of the state of statelessness in Sabah and provide input in constructing policy and mechanism frameworks to reduce the statelessness issue.

***Keywords***: Statelessness, Plights, Policy Framework

[1] Peter Aning Tedong, Senior Lecturer, Universiti Malaya. Email: peteraning@um.edu.my

## INTRODUCTION

The international law defines stateless as an individual who is not recognized by any state as a citizen under the operation of its law. Recently, statelessness and forced displacement have become the focus of global agenda as the high widespread of the issue globally (UNHCR, 2019). The stateless individuals can be classified as internally displaced persons (IDPs) because "they have been forced or obliged to flee or to leave their homes or places of *habitual residence*, in particular as a result of or to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognized state border" (UNHCR, 1998). Thus, stateless individuals are separated into two types, namely, *de jure* (people who have no legal nationality) and *de facto* stateless (people who have no "effective" nationality) (Chickera, 2010; Massey, 2010).

Statelessness and forced displacement are interconnected because the stateless individuals encountered a high risk of being forcibly displaced and the forced displacement peoples also faced a high risk of being stateless (Albarazi & Van Waas, 2015). Though the refugees, migrants and stateless have clear differences from each other, Malaysia law categorized all refugees and stateless individuals as an illegal immigrant (Kanapathy, 2008; Petcharamesree, 2016). The issue of stateless people that occurred from the presence of refugees is highly happened in Sabah compared to other states in Malaysia (Jassica et. al., 2020).

Tamara (2016) identified three groups of de facto stateless in Malaysia, including Orang Asli and Indians in Peninsular Malaysia and the children of IMM13 pass holders (the Filipino refugees). Meanwhile, the de jure stateless group in Malaysia are among the Bajau Laut community (Sanen et al.,2019) in Sabah and the Rohingya ethnic (Tamara, 2016) in Peninsular. However, the data on the stateless population captured by UNHCR are highly concentrated on the situation in the Peninsular and there are unavailable data and demographic profiles for the stateless people in Sabah (UNHCR, 2017). The circumstances due to unavailability of documents and evidence of their citizenship for generations and rejection from the local people of any country fit them into the definition of the stateless person by international law (Rodziana, 2017). In 2018, it is estimated that there are 800,000 stateless individuals among were children and living in isolated areas across the Sabah (Jassica et. al, 2020).

The citizenship issue in Sabah was started in early 1970 due to the tremendous influx of Filipino refugees during the Mindanao insurgency in Philippines (Azizah, 2009; Badariah, 2018). The Filipino refugees were provided with basic housing and special permission to reside and work from the state government (Azizah, 2009). However, the vulnerability of Filipino refugees to register the birth of their newborn children to the National Registration Department Sabah (NRDP) led to the birth of a stateless generation (Badariah, 2018). As the consequences, the expanding of their generation led to the rising


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number of this intergenerational case of stateless population in Sabah (Azizah & Ubong, 2005; Allerton, 2017). Since the Malaysia government does not ratified the convention related to refugees and statelessness, all the irregular migrants including the generation of Filipino refugees are seen as "illegal immigrant" (Azizah, 2009).

There are various factors including the internal and external reason that contributes to the statelessness issue in Sabah. The internal factors are including the vulnerability of refugees to register birth of newborn (Kanapathy, 2008), unregistered married (Azizah, 2009), the children status who born out wedlock (Allerton, 2017) and illegal status of the parents. For external reason, Tamara (2016) state that the ad-hoc policies by the government in governing stateless lead to confusion due to the inconsistencies in statements and poor registration system (Rodziana et. al., 2015). Therefore, a systematic framework involving multiple stakeholders are significant to find effective solutions to the statelessness issue (Rodziana, 2017).

## RESEARCH BACKGROUND

The statelessness has wide concepts and perspectives from various scholars and institutions. The 1954 Convention relating to the Status of Stateless Persons and international law defines stateless as an individual who are not recognize by any countries or study under its operation law. Meanwhile, Rodziana et. al (2015) defined statelessness phenomenon as a result of reverse nationality. Groot et. al. (2015) state that the statelessness is related to the deprivation of legal documentation of birth certificate or evidence, that affect to another significant issues where it restricts an individual from proper access to civil, cultural, and social right. The definition by international law is criticized because it is not understandable and difficult to interpret (ISI, 2014). Besides, the interpretation of "stateless person" by international law only applicable by the authority of states on minority cases and unable to consider both citizenship laws and governance practices when determining whether a person is stateless (Thomas, 2006).

Generally, the stateless persons are divided two types which are de jure and de facto stateless. Both de jure and de facto stateless are comes from the Latin words meaning of "legally" and "factually" respectively (Vonk, Vink and de Groot, 2013). de jure statelessness occurred when the individual does not have any nationality from any countries in the world while de facto statelessness happened when the individual nationality in his/her country is ineffective (Chickera, 2010). In fact, the statelessness definition by international law is only referred to the de jure stateless and does not confer to de facto (Achiron, 2005; Guterres and Johnsson, 2005; Rodziana et al, 2015). Besides, many legal scholars also argued that the international law definition is too narrow and insufficient as it does not include those peoples whose citizenship ineffective or inability to prove their nationality (Weissbrodt and Collins, 2006). On the other hands, the

de facto stateless who are born as second generations and above are at the risk and vulnerable in changing their status to de jure stateless (Massey, 2016).

Being stateless also means limited from various access and right such as proper living conditions, education, and healthcare. The stateless are forced to lives in ghetto-like condition without sufficient access to healthcare, education, and job opportunity (Kaveri, 2017; Badariah, 2018). According to Lynch and Teff (2009), the unavailability of birth certificate among the stateless children causes them restricted to received vaccination and education. Many of the stateless population faced chronic poverty, malnutrition, unnecessary detention, denied from the right of education and being the victim of exploitation, which depicted overall of their daily life (Brunt, 2015). In a study by Barua et. al. (2019) had found that the Rohingya stateless peoples are not entitled on birth registration at government hospital, disposed to poor babies and child health, malnutrition, and other multiple illness and some of them lives in dismal condition in the unregistered refugee camp at Bangladesh (Crabtree, 2009). Meanwhile, the displaced Kosovo Roma community in Berane, Montenegro, who resides in impoverished informal settlements at riverside as they have no right on any property and proper dwelling (Arraiza and Ohman, 2009).

Lack of full set of rights accessible to citizens, stateless individuals face a greater discrimination in the justice administration, harassment, and arbitrary detention (Perks and Clifford, 2009). Besides, the stateless individuals are restricted to vote and participate in political affair, restricted to acquire travel documents, and restricted to access multiple ranges of government services and employment (Goris et. al., 2009). Limited information is available on the plight of stateless individuals in detention in the country they reside because they often seen as 'hidden' population and received a lack of attention been paid to stateless populations (Perks and Clifford, 2009).

Meanwhile in Sabah, the Filipino refugee generation who at risk of stateless lives in slum and squatter settlements or workers' housing with no proper piped water and electricity supply is limited (Azizah, 2009; Allerton, 2017; Tedong, 2018). Additionally, the majority of stateless communities in Sabah live in poverty because their income is below the poverty line (Tedong, 2022). The stateless individuals often received public resentment, and risk of exploitation (Allerton, 2017) and are often blamed by the local people in Sabah for the crime rate, security threat, pollution, and unemployment among the local community (Azizah, 2009). This is contradicted with the statement by Commissioners of Enquiry on Immigrants in Sabah (2014) as they mentioned that the refugees in Sabah have more privileges compared to the refugees in Peninsular in terms of their ability to work, to live with their dependents and apply for a Permanent Resident (PR) status.

In fact, they are frequently in the state of fear of arrest by the enforcers that jeopardize their freedom of movement (Tamara, 2016). Furthermore, due to the


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poverty and the absence of birth certificates, stateless children are prevented from receiving Malaysian education (Allerton, 2014). The undocumented and stateless children are considered as marginalized and disadvantages group as they face confinement on access to education, healthcare, birth registration and child protection services (Fahisham, 2012). Past studies finds that the data on stateless persons captured by UNHCR statistics in Sabah is remain unavailable as they are largely concentrated on the stateless situation and population in Peninsular Malaysia (Rodziana, 2017). Also, each government agency and state government also have different definition and perspectives of who constitutes as stateless (Chuah, 2016). The locals add to the lack of focus on this group as they refuse to allow this group to be integrated into the community, by playing a key role in influencing the government to not grant them citizenship or any special pass for the proper documentation purposes. Past researchers finds that the authority encountered several issues and challenges in governing the Filipino immigrants including the stateless individuals, such as unacceptance of locals due to negative perception on them for created social issues in the state (Sabihah, 1992), a threat to the political sector (Suhaili and Kamarulnizam, 2018) and security threat (Institute for Policy analysis of Conflict, 2020). Consequently, the governance of statelessness in the state of Sabah must be examined so as to enhance the governance of stateless individuals. In light of this, this study will investigate the daily struggles faced by stateless communities in Sabah.

## RESEARCH METHODOLOGY

This study derived insights from a mixed method approach which includes semi-structured in-depth interview with various key actors and face-to-face quantitative surveys with stateless communities. For quantitative stage, we employed a non-probability sampling and snowball sampling technique to select the respondents. The reason for using snowball sampling techniques is that the stateless individual is a marginalised group that may be difficult to find. Furthermore, this sampling technique is used because the actual population and sample distributions are unknown. The questionnaire survey took place in Kota Kinabalu, Sabah. This survey included 310 respondents who were either stateless or at risk of becoming stateless in Sabah.

We used the snowball sampling approach for the qualitative stage, interviewing more than 30 stateless people from four settlements near Kota Kinabalu, Sabah, namely Kampung Teluk Luyang, Telipok, Pulau Gaya, and Kampung Numbak. The qualitative interviews were usually recorded and transcribed for thematic analysis and lasted 60 to 90 minutes. The interviews were conducted to demonstrate how they discussed the issues and challenges they faced in their daily lives.


**Figure 1**: Map of Sabah
*Source: https://www.dreamstime.com/illustration/map-sabah.html*

**Figure 2**: Stateless community in Kampung Teluk Luyang (Left) and Kampung Numbak (Right)

Therefore, this study will investigate the implications of statelessness towards the stateless community in Sabah using a qualitative inquiry guided by case study design. We argue that the state of Sabah has unique characteristics for


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studying the phenomenon of statelessness because it has the highest non-citizen population in Malaysia.

## RESULT AND FINDINGS

In order to investigate the living conditions and challenges faced by stateless communities in Kota Kinabalu, Sabah, we asked respondents to rate seven statements on a 5-point scale: strongly agree (1), agree (2), neutral (3), disagree (4), and strongly disagree (5). Table 1 displays the percentage distribution of respondents, mean value, and standard deviation for respondents' perceptions of the settlement. According to the findings, the majority of respondents (92.9 percent) strongly disagree with the statement "my settlement area is clean and well maintained". The majority of respondents (84.7%) strongly disagree with the statement "my settlement area has a good selection of facilities and services that meet my needs." Further investigation revealed that 67.1 percent strongly disagree with the statement "I am satisfied with the current situation in my settlement area," while 50.6 percent strongly disagree with the statement "my settlement area incorporates elements of sustainability and eco-friendliness into daily life." Furthermore, 41.2 percent of respondents strongly disagree with the statements "my settlement area is safe and has a low crime rate" and "my settlement area is rich in landscapes and natural beauty (aquatic and green areas)." Finally, 38 respondents (44.7 percent) strongly disagree with the statement "(e) the location of my settlement area is strategic and easily accessible from other areas."

**Table 1**: Perceptions of statelessness about their living conditions.

| Statement | 1 (%) | 2 (%) | 3 (%) | 4 (%) | 5 (%) | Mean | S.D | Level |
|---|---|---|---|---|---|---|---|---|
| My settlement area has a good selection of facilities and services that meet my needs | 0 | 0 | 15.3 | 0 | 84.7 | 4.69 | .724 | High |
| My settlement area is clean and well maintained | 0 | 0 | 7.1 | 0 | 92.9 | 4.86 | .515 | High |
| My settlement area is safe and has a low crime rate | 28.2 | 0 | 30.6 | 0 | 41.2 | 4.41 | 1.061 | High |
| My settlement area is full of landscapes and natural beauty (aquatic and green areas) | 28.2 | 0 | 30.6 | 0 | 41.2 | 3.25 | 1.656 | Moderate |
| The location of my settlement area is strategic and easily accessible from other areas | 0 | 23.5 | 31.8 | 0 | 44.7 | 3.66 | 1.268 | Moderate |
| My settlement area applies elements of | 9.4 | 0 | 40.0 | 0 | 50.6 | 3.92 | 1.136 | Moderate |

| Statement | 1 (%) | 2 (%) | 3 (%) | 4 (%) | 5 (%) | Mean | S.D | Level |
|---|---|---|---|---|---|---|---|---|
| sustainability and eco-friendliness in daily life | | | | | | | | |
| I am satisfied with the current situation in my settlement area | (12.9) | (0) | (10.6) | (9.4) | (67.1) | 4.31 | 1.102 | High |

According to qualitative data, the state of statelessness has placed the stateless in a miserable situation. Their documentation status presented them with numerous obstacles. Allerton (2017) argued that the second and third generation of Filipino refugees are desperately attempting to escape irregularity by possessing verified documents and being exploited by unauthorized passport or visa agents. The majority of stateless people interviewed faced registration and documentation issues as one participant talked commented:

> "[…] *I do not have any registration card. I was registered with "Kad Burung", but the card is not verified by the government due to invalid serial number. Last time, I was registered the card with third party and I paid some amount of money".*

In addition, Malaysian law requires all children born in Malaysia to be registered and have birth certificates, regardless of their parents' nationality. However, the registration of children may impose a financial burden on stateless communities due to the numerous bureaucratic procedures that result in the lack of birth registration documents. The lack of a birth certificate as evidence impacts other significant issues, limiting the stateless community's access to human rights. This is what a father of stateless children reveals:

> *"[…] it is really difficult to have registration from the government. I have 7 children and all of them do not have birth certificate. How would they have birth certificates if the cost of DNA test for each child is RM2000. This is not including the cost for courts. I also need to pay RM50 to take the registration form. I do not have enough money."*

On the other hand, being stateless also restricts their employment and occupation opportunities. Due to their lack of documentation and formal education, it is evident that they are involved in 4D sectors (dirty, dangerous, difficult, and demeaning), and their income fluctuates based on environmental conditions, health, and job availability. A respondent commented as follows:

> *"[…] currently I only work at the sea to catch fish and sell it at morning market or night market in Kota Kinabalu. I earned RM20 to RM50 per day.*


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> *However, this is not daily based because I could not go to sea during rainy day. It has been 2 weeks I lack money and only eat anything left".*

In fact, Asis (2005) also mentioned that the stateless community has low income and underpaid as one of the participants told that*: "[…] I was working as dish washer in restaurant. The employer pays low salary, but it is still enough to buy food for a day. I was arrested because I do not have any documentation and get released in few days after. I could not work due to lack of document".* In addition, our data analysis revealed a number of problems and obstacles faced by stateless communities, such as a lack of access to clean water. The villagers rely solely on natural sources of well water and clean water purchased by boat from the city centre. The cost of water for a single family can exceed RM200 per month. As a member of a poor family, one of the informants from Kampung Pondo has stated that this cost is burdensome for them. Clean water is an essential requirement for all humans on a daily basis. However, they must pay hundreds of ringgits per month for this clean water. In terms of living conditions, stateless people in Sabah reside in poor, slum-like settlements that lack proper infrastructure such as piped water, electricity, and waste collection. One respondent mentioned the following:

> *"[…] our house is wooden based made by our great-grandparents. I am living here as the third generations. It is terrible. We have no water supply and electricity, and we buy the water from middle person with the price RM1 per gallon."*

Besides that, our fieldwork revealed that the stateless people are lives in a small wood house with their big family. A participant simply said: "[…] *our house has no bedroom, so we just sleep altogether. The small house is sufficient for my ten family members to lives here*". The federal and Sabah state government also must encounter issue related to escalating number of street children especially in Kota Kinabalu city (Ismail, 2008). A stateless parent said:

> […] "*our children are not going to school. Since they were young, we asked them to do any job including catching fish or any other work*".

Apart from living conditions, the stateless community has limited access to healthcare services as they lack proper documentation and their children have no birth certificate (Jassica et al., 2020). A participant said: *"[…] I have never gone to public or private hospital because I heard the cost is expensive. All of my children are born in the house and there is a midwife helping".* This issue is faced by most of the stateless people around the world. For example, Barua et al. (2020) in their study found that the Rohingya stateless people are vulnerable

to poor children health, malnutrition, lack of obstetric care and ineligible on birth registration at government hospital.

Nevertheless, drawing from the empirical data, two conclusions can be summarized: most of the respondents encountered similar issues and challenges as the stateless people and the vicious cycle will continuously happen within their generation due to the vulnerability of the stateless community. These findings are very significant because it is essential to identify the socio-economic characteristics of the stateless community to solve the issue as it is inseparable from the Sabah society, politics, development, and economy.

## CONCLUSION

In conclusion, this paper revealed that stateless people in Sabah faced many barriers and discrimination throughout their livelihood. As seen in other countries, the enclosure and barriers faced stateless discuss Rohingya in Bangladesh (Crabtree, 2009); Kosovo Roma in Montenegro (Arraiza and Ohman, 2009); and Bihari community in Bangladesh (Hussain, 2009). In Malaysia, the statelessness issue may not have signaled the states on effective policing but rather to strengthen and protect the sovereignty and security of the state. Therefore, by this point we believed that the status as stateless person with ineffective nationality also means the absence of various human rights.

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# BEYOND BARRIERS: AN EXPLORATION OF ACCESSIBILITY CHALLENGES AND EMOTIONAL EXPERIENCES IN INCLUSIVE HERITAGE VISITATION AT LALBAGH FORT, DHAKA

**Fariba Samia Omi[1], Zuraini Md Ali[2], Hazreena Hussein[3]**

[1] *Department of Building Surveying, Faculty of Built Environment*
[2] *Centre for Building, Construction & Tropical Architecture,*
[3] *Centre for Sustainable Urban Planning and Real Estate,*
*Faculty of Built Environment,*
UNIVERSITI MALAYA

## Abstract

Heritage sites, as revered repositories of cultural memory, form an integral facet of a nation's cultural and architectural fabric. In Bangladesh, where conventional conservation paradigms have been traditionally embedded, the connection between heritage conservation and outdoor accessibility, especially for physically challenged individuals, remains under-researched and overlooked. This study seeks to bridge the gap between existing research and the limitations of accessibility regulations in Bangladesh by investigating outdoor accessibility challenges faced by physically challenged persons at heritage sites, focusing on the historical Lalbagh fort. This qualitative case study methodology includes surveys with observations through access audit checklists and semi-structured questionnaires to investigate the physical barriers, communication systems, and representative and interpretive resources that could impede accessibility and impact the experience of heritage visitation. This study aims to investigate the challenges that prevent individuals with physical disabilities from having barrier-free access to the heritage site's resources and experiences. While doing this, this research also explores potential solutions to overcome these obstacles and promote inclusive heritage tourism practices. The findings of the study indicate that while there is a genuine intention to enhance accessibility, the barriers of core outdoor accessibility elements remain unattended. The study recommends a multifaceted strategy to improve accessibility, including modifications to the site's physical environment, enhancements to communication systems, and increased staff training and capacity-building. By addressing these barriers and promoting accessible tourism practices, places like Lalbagh Fort can become more inclusive, fostering future generations' cultural heritage preservation.

***Keywords***: Accessible heritage, Accessible tourism, Cultural tourism, Cultural heritage, People with disabilities.

[2] Senior Lecturer at Universiti Malaya. Email: zuraini_mdali@um.edu.my

## INTRODUCTION

Heritage sites are the collective memories of a nation's cultural dimensions developed by its historical and architectural identity. Schaper et al. (2018) defined heritage sites as educational and socio-cultural platforms combined with historical affiliations that captivate many domestic and international visitors. Moreover, people worldwide explore heritage sites due to their unique historical insights and immense educational and emotional value (Zahari et al., 2023). However, despite being globally important tourist places, a constantly overlooked aspect of the narratives of these heritage sites is the accessibility concerns for people with disabilities. As recognized by Article 30 of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD), disabled persons have equal rights as others to actively engage in any recreation, leisure, sports, or cultural activities (United Nations, 2006). For this reason, it is very important to address the issue of incorporating accessibility into heritage sites to accommodate people from diverse backgrounds to experience the cultural legacy without any barriers.

Disabled individuals want to explore various travel destinations as much as abled persons although most of the time they must give up their aspirations due to accessibility issues (Zahari et al., 2023). Particularly, the physically disabled encounter hurdles in terms of navigating places in contrast to other disabled persons (Page & Thorsteinsson, 2018). As a result, they feel discriminated against because they cannot access numerous locations, particularly heritage tourist sites. Accordingly, 15% of the people in the world face challenges in the form of physical disabilities while visiting tourist attractions including heritage sites (UNESCO, 2017). Also, these challenges arise not only from physical and informational barriers but also from societal perceptions and marginalization toward disability (Darcy et al., 2020; Oliver, 2018). However, despite global consideration for inclusivity, making heritage sites accessible continues to be a considerable challenge.

Furthermore, Darcy et al. (2020) discovered that making heritage sites accessible is difficult due to the absence of initial design considerations for people with disabilities along with the adaptive transformations these sites undergo over time. Latip et al. (2018) pointed out that enhancing accessibility often necessitates physical alterations, which may conflict with preservation demands. Moreover, Kosmas et al. (2020) suggested that integrating accessibility must be in harmony with heritage conservation principles. Therefore, these perceptions of different researchers regarding integrating accessibility in heritage sites necessitate the pressing need to maintain the balance between preserving historical authenticity and ensuring inclusivity. Particularly, in countries such as Bangladesh, this interplay between conservation and accessibility has become prominent and critical (Khan, 2020).


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Given the context of Bangladesh's historical Lalbagh Fort, the challenges encountered by disabled people are often neglected like other tourist places. Moreover, Huq et al. (2017) found that in Bangladesh, literature primarily focuses on the financial and socio-economic benefits of accessible tourism rather than accessibility challenges. Moreover, he also pointed out that accessibility laws in Bangladesh have made it compulsory for public buildings and sites to provide disabled access or ramps, but there is a lack of instructions for enhancing accessibility in heritage sites. Whereas countries such as the United Kingdom and Australia have clearly defined accessibility regulations for heritage structures (Huq et al., 2017). It emphasizes that there is a lack of clear guidelines for enhancing accessibility in heritage sites, combined with limitations in the implementation and oversight of local regulations. In addition, previous studies reveal that incorporating accessibility with the conservation process has always been under-researched and overlooked in the context of Bangladesh. Therefore, this research aims to comprehensively investigate and address the outdoor accessibility challenges faced by physically challenged individuals at heritage sites in Bangladesh, with a specific focus on the historical Lalbagh Fort, and bridge the gap between existing research and the limitations of accessibility regulations in Bangladesh. Through a qualitative methodology encompassing e-surveys, and document analysis, this study intends to investigate the physical barriers that hinder accessibility and impact the heritage visitation experience for physically challenged individuals.

The paper begins with an understanding of the concept of outdoor accessibility and disability by incorporating a barrier-environment approach in parallel to the conventional conservation paradigm within heritage sites in Bangladesh. Next, the paper discovers the present condition of accessible heritage tourism in Bangladesh. Then the study investigates the different barriers that could impede accessibility and impact the experience of heritage visitation for disabled people. For this paper, the term persons with disabilities (PwDs) specifically refers to physically challenged persons, including wheelchair users and crutch users.

## LITERATURE REVIEW

### Understanding of Disability & Accessibility

Accessibility and disability are deeply interconnected and an integral part of creating an accessible barrier-free environment. Both the Disability Discrimination Act (1995) and the World Health Organization (WHO, 2008) defined disability in terms of physical and mental well-being that limits an individual to perform their everyday functions independently. Whereas accessibility can be characterized as the notion of providing equal rights to access the barrier-free built environment. Converging these two, it demonstrates that it

is the service provider's responsibility to ensure equal rights for PwDs to utilize public spaces with equal opportunity as others.

Disabilities impact a significant segment of the global population while many view accessibility as an infrastructural issue (Hooi & Yaacob, 2019). Meanwhile, Oliver (2018) found that despite its broad acceptance, the concept of disability encountered an evaluation of how Pwds experience their surrounding environment. This implies that disability is not restricted to being a medical term only, it refers to a complex phenomenon involving the interaction of an individual's physical characteristics and sociocultural factors. It is thus crucial to change social perception towards disability and collective notions around physical capabilities to ensure equitable accessibility.

However, in the discourse of disability, the term 'accessibility' broadly refers to a theoretical investigation into access to the built environment undertaken to establish how the environments and their inherent tangible and intangible properties can be made convenient to all (Darcy et al., 2020). Moreover, Oliver (2018) in his further research about disability found that the contemporary requirements of accessibility focus solely on the physical modifications to the exteriors of heritage sites. For this reason, the evolving dynamics of global society necessitates critical consideration for continuing adaptation particularly around inclusion, even though historical context has a place. So, when coming especially to the heritage sites, this understanding translates to architectural and design alternations. For instance, ancient pathways might need to be reimagined to ensure they are navigable for those with mobility impairments, without compromising the site's historical integrity (Muscarà & Sani, 2019).

**Why it is important to make heritage sites accessible?**

It is not possible to make heritage sites completely accessible until people with disabilities are accepted as contributing parts of a nation's past, present, and future (Sakarneh & Katanani, 2021). He further emphasized that full accessibility goes beyond adding ramps and grab bars; it necessitates a change in societal perspectives about the participation of PwDs in all aspects of life. Moreover, heritage does not exist in isolation rather it is defined by how people collectively acknowledge and assign value to it (Kosmas et al., 2020). This implies that heritage value is not universal but potentially varies depending on who accesses and assesses the site.

Moreover, Hooi & Yaacob (2019) found that visiting heritage sites helps PwDs feel part of larger social narratives and that they prefer historical places over other public spaces due to reduced feelings of isolation. For this reason, alterations to external features like pathways and entrances can enhance their experience. In contrast, Lynch & Proverbs (2020) discovered a startling


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figure that 42% of disabled individuals have not encountered any arts event. This absence might result from barriers such as inaccessible facilities or inadequate communication strategies. Conversely, Muscarà & Sani (2019) argued that when it comes to heritage sites, the entire site does not necessarily require full accessibility. In this regard, Sakarneh & Katanani (2021) pointed out an example such as if a building can be accessed through both a staircase and a ramp, most of the users will use the ramp instead of the stairs, even if they do not have mobility issues. It demonstrates that what is necessary for a person with a disability can still prove useful and make situations easier for others.

**Challenges to Outdoor Accessibility in Heritage Sites**

Disabled travelers undeniably experience distinct travel challenges compared to non-disabled individuals. Sakarneh & Katanani (2021) found that the main challenges extend beyond architectural and infrastructural limitations. Hence, ignoring these barriers declines to address systemic inequity in travel and exploration. Similarly, even within the context of heritage sites, the travel challenges of disabled individuals remain distinct. This highlights a clear oversight in preserving history at the expense of inclusivity. Lynch & Proverbs (2020) pointed out that heritage sites tend to prioritize architectural authenticity and conservation over inclusivity. However, historical preservation should never come at the cost of excluding a significant portion of the population.

According to a report by Global Accessibility News (GAN), many archaeological sites are off-limits to disabled individuals due to the absence of wheelchair ramps and other health utilities. This implies that when planning heritage sites, the concept of accessibility, which fundamentally emphasizes inclusivity, is frequently neglected. On the other hand, Darcy et al. (2020) categorized barriers into three primary types: environmental, interactive, and intrinsic. This implies that the barriers identified not only interrupt travel experiences but also have broader implications for social equality and inclusion.

However, among all the challenges that PwDs encounter in heritage sites, the most prominent identified barrier is the physical one such as uneven surfaces, a lack of tactile guides, and inadequate pathways (Muscarà & Sani, 2019). Although physical obstructions can be removed or modified, reshaping societal attitudes is more profound. In addition, Foster & Nuttgens (2016) found that besides physical barriers, attitudinal challenges also significantly contribute to inaccessibility issues. This finding emphasizes a pressing need for society to address its deep-seated preferences. As suggested by Hooi & Yaacob (2019) and supported by UNESCAP (2016), the duality of the issue implies that a truly inclusive environment can only be achieved when society confronts and adjusts both its physical structures and discriminatory perspectives. In addition, Kosmas et al. (2020) stated that informational barriers, such as inadequate signage, and

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untrained staff, obstruct full accessibility and understanding of a site's context. This implies that the barriers identified not only interrupt travel experiences but also have broader implications for social equality and inclusion.

**Area of Study: Lalbagh Fort, Dhaka**

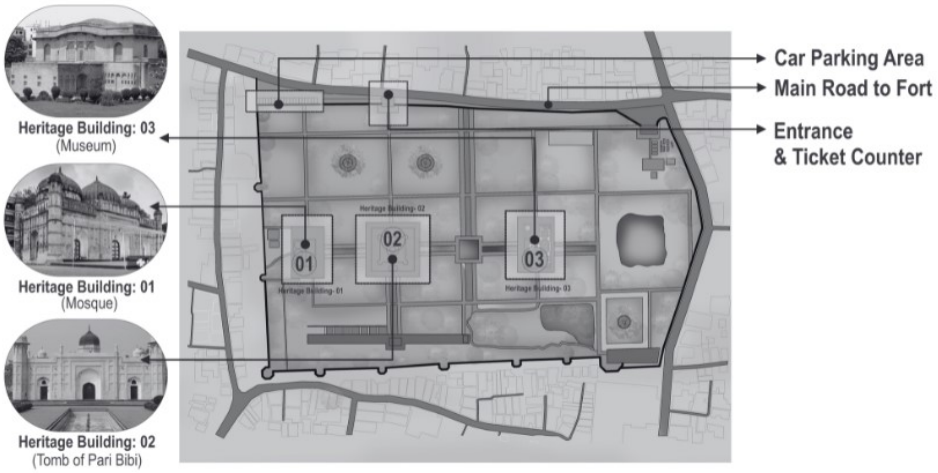


**Figure 1:** Site Plan of Lalbagh Fort
*Source: Author*

Lalbagh is a prominent tourist destination in Dhaka city, renowned for its cultural and historical significance in Bangladesh. Yet, the majestic architectural aesthetics do not diminish the need for adaptive measures to enhance outdoor accessibility. The Fort spans an area of 71,827 square meters. Within this expanse, the fort encompasses three heritage structures complemented by two gateways and remnants of the fortification wall.

## METHODOLOGY

This study aims to investigate and critically analyze outdoor accessibility challenges at Lalbagh Fort for people with physical disabilities, focusing on identifying physical barriers impacting their visitor experience. As a result, a qualitative method was adopted for this study to identify the obstacles and evaluate the experiences of PwDs. For this study, data was collected through two sources.

1. The first source is the survey that was conducted among 31 disabled individuals from the site Lalbagh Fort. A semi-structured interview was conducted to gather detailed information about their experiences and challenges in accessing heritage sites like Lalbagh Fort, along with suggestions for improvements. The researcher


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visited the site to observe and interview these individuals to capture their direct interactions with the site's facilities and services.

2. The second source is the access audit checklist which was designed based on the ADA Standards for Accessible Design (2010) and ADA Standards for Accessible Design (1991). This checklist, used to assess accessibility and investigate barriers at Lalbagh Fort, was also used by Yaacob & Hashim (2005) for evaluating heritage sites in Malaysia. The checklist identified accessibility issues using available documents and reports on the study areas.

**Table 1**: Accessible Checklist

| | **Access Feature** |
|---|---|
| Public Transport | Transport Arrival and Departure (Bus stop) |
| Accessible Car Parking | a) Car Parking b) Passenger Loading Zone |
| Approach & Entry | a) Accessible footpath b) Ticket Counter |
| Entrance | Entrances and Doors |
| Accessible Toilet | Public Toilet |
| Wayfinding | Wayfinding or sign |
| Services | Café, Information centre |
| Public Transport | Transport Arrival and Departure (Bus stop) |

*Source: (Hooi & Yaacob, 2019)*

Based on previous studies, eight core elements were identified to determine outdoor accessibility barriers at heritage sites. These were derived from checklists based on the ADA Standards for Accessible Design (2010 and 1991).

**Table 2**: Core elements of outdoor accessible provisions in heritage sites

| **Outdoor Accessibility Elements** | **Access Audit Inventory for Heritage sites** |
|---|---|
| 1. Accessible Footpath | i) Surface material, ii) Width of footpath,<br>iii) Clear markings, iv) Obstruction |
| 2. Entrances and exits | i) Total number of entrances/Exits, ii) Entrance width,<br>iii) Presence of ramps, iv) Signage for accessibility features |
| 3. Accessible Car Parking & Passenger Loading zone | i) Distance from the main entrance,<br>ii) Number of accessible parking spots,<br>iii) Width of parking spots,<br>iv) Clear signage for parking & loading zone,<br>v) Ease of transition from parking to footpath |
| 4. Entry & Ticket Counter | i) Distance from the main Gate,<br>ii) Counter Height,<br>iii) Space for Queue, iv) Obstructions |
| 5. Internal Pathways and Routes | i) Total Length of Internal Pathways,<br>ii) Width Consistency & Turning Radius,<br>iii) Elevation Changes & Ramp Inclinations, |

| Outdoor Accessibility Elements | Access Audit Inventory for Heritage sites |
|---|---|
| | iv) Obstructions |
| 6. Seating and Rest Areas | i) Number of Seating Areas, ii) Types of Seating,<br>iii) Distance Between Seating Areas,<br>iv) Accessibility for Disabled |
| 7. Wayfinding | i) Entrance Signage,<br>ii) Directional Signage to Key Attractions,<br>iii) Informational Signage,<br>iv) Map Availability |
| 8. Services | i) Information Desk, ii) Accessible Toilet, iii) Café |

*Source: (Hooi & Yaacob, 2019)*

## FINDINGS AND DISCUSSIONS

### Semi-Structured Interview Analysis: Disabled Visitor's Experience

a) Visitor's demography and patterns of visitation: According to the checklist, Lalbagh Fort attracts a diverse group of disabled visitors, including both male and female children. The fort has a significant proportion of local participants, with nearly 75% being locals. Approximately 450 to 500 individuals visit Lalbagh Fort daily, but only 4 to 5 people with disabilities visit every 3 to 4 days. This rate increases during national holidays. Most disabled visitors are locals who use the fort as a primary leisure and recreational space due to the lack of accessibility in more conventional places like parks, which are often overcrowded and incompatible with their needs.

b) Impact of socio-cultural factor: The access audit checklist revealed that at Lalbagh Fort, 31 disabled visitors consistently reported a strong sense of belonging and appreciation, enhancing their visit. This positive experience extended beyond physical features to include the way people interacted with them. Visitors felt that their disability did not define their experience; instead, they were treated as integral members of the visitor community, particularly by the staff at the entrance. One visitor emotionally stated, "Here, I am not just 'the disabled one' but a true part of the crowd, enjoying stories of our heritage." Another shared, "The way I'm welcomed and assisted here makes me feel valued; it's not just about being able to access everything physically but feeling genuinely included."

c) Visitor Satisfaction and Feedback: According to the report, disabled visitors generally appreciated the accessibility of pathways at Lalbagh Fort, and the efforts made to make the site navigable. However, despite these positive aspects, the absence of enough benches often made their visits less enjoyable and physically exhausting. A respondent mentioned, "The paths are easy to travel, but


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the absence of enough benches and accessible restrooms sometimes cuts my visit short."

d) Impact of Accessibility on Repeat Visitation Patterns: The checklist revealed that accessibility measures significantly enhance the visitor experience at Lalbagh Fort, encouraging frequent repeat visits. Among the 31 disabled visitors surveyed, the majority expressed high satisfaction with the site's infrastructure. One respondent stated, "Lalbagh is a place I can easily navigate, and every visit feels welcoming here. Moving around freely without help makes me want to come back often."

e) Relationship with the Heritage site: At Lalbagh Fort, the analysis of 31 disabled participants revealed that the initial attraction for many visitors was the availability of open space for leisure and recreation. Of the 31 interviewees, 21 highlighted that their first visits were motivated by a desire to find an accessible place to breathe freely and enjoy the outdoors. For instance, one participant stated, “I first came here because it was one of the few places I could easily navigate in my wheelchair.” However, repeated visits sparked curiosity, with many becoming increasingly interested in the historical structures and their significance. One visitor shared, “I wanted to know why this fort was built, who built it, and what happened here.” This continued engagement reflects a growing emotional connection with the site, transitioning from practical needs to cultural exploration.

f) Experience with the Heritage site: According to the data, accessibility experiences for disabled visitors vary significantly between locals and non-locals, and by mode of transport at Lalbagh Fort. Locals often rely on family assistance due to poor roads and footpaths. One local visitor shared, "My brother helps me navigate the broken pavements, which are impossible alone in a wheelchair. It is exhausting for both of us before we even reach the fort." Non-local visitors faced challenges with public transportation, "The buses here are not equipped for wheelchairs, which makes me dependent on costly private transport to visit this place I love," a non-local visitor said. However, the data revealed that those who could afford private transportation found sufficient parking facilities. One visitor who drove to Lalbagh Fort expressed moderate satisfaction: "While the parking facilities were sufficient, the journey was still stressful. However, getting down at the entrance with the help of others made it manageable and slightly more pleasant."

Based on the data, the ticketing experience was poor for all respondents. A local visitor stated, "Reaching over a high counter to get a ticket is not just

inconvenient; it is humiliating." One non-local mentioned, "The ticket counter was highly inaccessible. It caught me off guard and started my visit on a sour note." As the data revealed, upon reaching the main entrance, the welcoming attitude of the staff somewhat alleviated the initial discomfort. Moreover, the internal pathways were appreciated for their width, but the lack of accessible resting spaces and toilets was a significant drawback. "I can navigate the paths but cannot rest when needed. Why there are no accessible benches or toilets?" asked another, highlighting a critical oversight. At the end of the survey, the data revealed that local visitors have developed a strong sense of adaptability, fostering place attachment to Lalbagh Fort, which acts as a social hub for leisure, recreation, and spiritual activities. In contrast, non-local visitors, lacking place attachment, face heightened challenges and connect more with the site's cultural and historical significance.

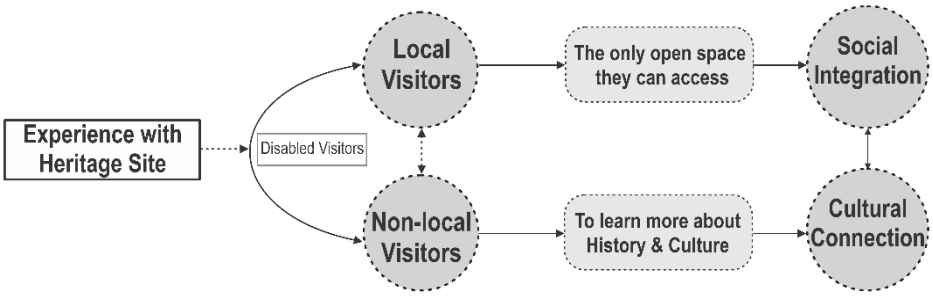


**Figure 2:** Developed narratives from the experiences of disabled visitors at Lalbagh Fort
*Source: Author*

**Table 3:** Summary of participants' perspectives and experiences from Lalbagh Fort

| **Narratives** | **Lalbagh Fort** |
|---|---|
| Terminology outlined | Semi-Inclusive<br>Multicultural<br>Cohesion<br>Interconnectedness<br>Collectiveness |
| Opinions regarding experiences | Relatively accessible – 21<br>Physically tiring - 19<br>Enhanced social interaction - 23<br>Cultural engagement despite barriers - 17<br>Valued community space- 20 |

*Source: Author*


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## Findings From the Access Audit Checklist

A. External Pathway and Entrance: The nearest public transport stops lack direct routes and suitable pathways, making access difficult for disabled visitors. Additionally, the fort's main entrance and ticket counter are not wheelchair-friendly, lacking essential accessibility features, clear signage, and adequate space for independent use by persons with disabilities.

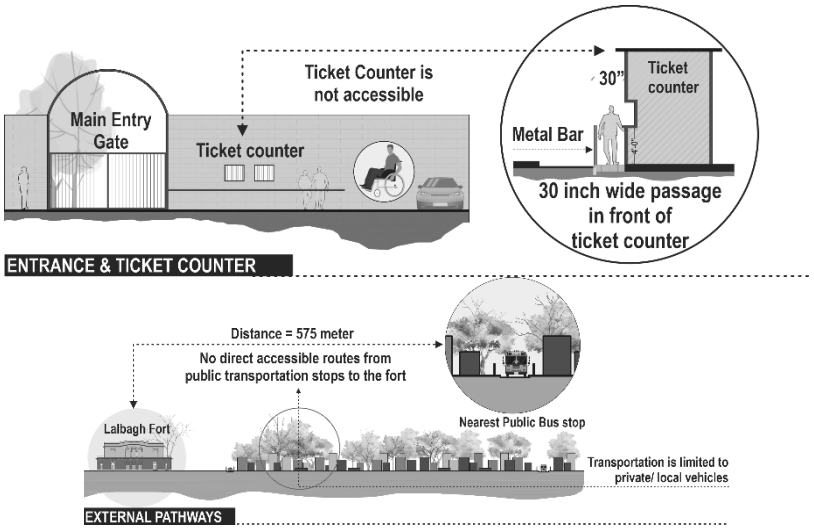


**Figure 3:** External Pathway and Entrance
*Source: Author*

B. Internal Pathways: The internal pathways at Lalbagh Fort have mixed accessibility results. While they are wide and connect main areas, the brick paving creates an uneven, challenging surface for wheelchair users. The lack of consistent smoothness and seating arrangements, along with difficult transitions between surfaces, further impacts accessibility.

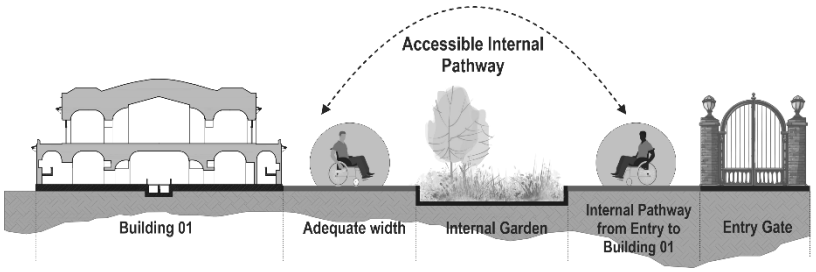


**Figure 4:** Internal Pathway
*Source: Author*

C. Accessible Car Parking: The parking space at Lalbagh Fort, encompassing 1027 square meters, is located near the entrance and ticket counter to accommodate all visitors, including Pwds. However, the availability of designated spaces for PwDs may fluctuate based on visitor volume and time. The passenger loading zone ensures convenient disembarkation for individuals with disabilities, while its proximity to the ticket counter facilitates ease of access.

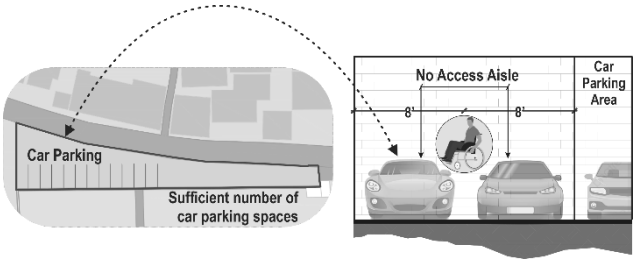


**Figure 5:** Accessible Car Parking
*Source: Author*

D. Accessible Toilet: Accessibility criteria were unmet, with only one male-only accessible toilet 75 meters from the entrance, requiring wheelchair assistance due to stairs. The toilet near Hammam Khana lacks proper dimensions, and signage, and has narrow doorways

E. Wayfinding: While the complex attracts a considerable number of visitors, it has been noted that there is a lack of wayfinding systems within the site. This poses a significant challenge for PwDs, as the absence of clear directions can make navigating the complex difficult.

F. Services (Café, Information Counter, seating areas): The present study reveals that the Fort does not have a cafe situated within its premises and instead has several cafes located near it. Additionally, the Fort also appears to lack an individual information counter, as the information services are likely provided at the ticket counter. Also. there are no seating or rest areas for disabled or elderly people within the fort

This summary of findings has been derived from detailed observations conducted using the access audit checklist at Lalbagh Fort. These observations provide a comprehensive assessment of the site's accessibility, identifying key areas where improvements are needed to ensure inclusivity for all visitors, particularly those with disabilities.


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**Table 4**: Summary of Findings from Access Audit Checklist for Lalbagh Fort

| Category | Evaluation Criteria | Critical Analysis and Details |
|---|---|---|
| 1. External Pathways (Arriving at the site) | a) Nearby public transportation stops<br>b) Accessible routes from public bus stops to the fort<br>c) Dependence on private or local Transport<br>d) Pathway stability and slip-resistance of walkways<br>e) Shelter and seating at public transport stops | a) The nearest public transportation (Bus stoppage) is available within 575 meters of the Fort.<br>b) There is no direct public transportation route to the Fort.<br>c) Visitors need to rely on the private or local transport (rickshaw, CNG)<br>d) There is no proper footpath from the bus stop. The pathway is extremely narrow, lacks curb ramps, and has improper grading<br>e) There is no shelter and seating arrangement |
| 2. Car Parking | a) Number of accessible parking spaces<br>b) Accessible parking space width (8 feet)<br>c) Parking signage | a) The number of accessible parking spaces meets the required standards.<br>b) The accessible parking space meets the standard<br>c) There is no signage for accessible car parking |
| 3. Approach and Entrance | a) Main entrance accessibility<br>b) Availability and usability of alternative entrances<br>c) Signage at entrances<br>d) Ticket counter | a) The collapsible gate at the entrance is not suitable for disabled individuals.<br>b) The main entrance does not have any ramps or any steps, but the entry point is very narrow.<br>c) There are no accessible alternative entrances.<br>d) There is no clear signage at entrances to direct visitors to accessible routes.<br>e) There is no accessible ticket counter |
| 4. Accessible toilet | a) Accessibility of toilet facilities. | a) There is no accessible toilet available |
| 5. Internal Pathway | a) Width and condition of internal pathways<br>b) Level changes and obstructions | a) The internal walkway has sufficient width but lacks smooth, firm, slip-resistant surfaces.<br>b) Internal pathways have abrupt level changes and obstructions.<br>c) There is a lack of ramps or navigational aids. |
| 6. Signage and Other Services | a) Visibility and information of signage<br>b) Staff training on disability awareness<br>c) Accessibility in cafes, shops, and service areas | a) The signage inside the site is inadequate in visibility and lacks critical information.<br>b) The Staff members are trained to assist individuals with physical disabilities.<br>c) The absence of amenities like cafes and souvenir shops reduces the overall visitor experience |

*Source: Author*

## CONCLUSION

This study focused on Lalbagh Fort, reveals a glaring inconsistency between the need for accessibility in heritage sites and the current reality faced by Pwds. The access audit checklists and e-surveys point out significant areas for improvement, such as inaccessible car parking, pathways, and toilets, which severely limit the visitation experience for physically challenged individuals. The findings show

that these challenges are not only physical barriers but also symbolic of the broader neglect of inclusivity within heritage conservation practices. Moreover, it highlighted that the traditional conservation paradigms in Bangladesh have neglected mainly accessibility considerations. This oversight not only disregards international norms, such as the United Nations Convention on the Rights of Persons with Disabilities but also limits the socio-cultural engagement opportunities for a considerable population segment. Moreover, the research highlights the urgent need for a reimagined approach towards heritage conservation that goes beyond mere compliance with regulations and adopts a more holistic view. This approach should harmoniously integrate accessibility with preservation efforts, ensuring that heritage sites like Lalbagh Fort are not just preserved in their historical authenticity but are also made available and accessible to all.

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## DISCLOSURE STATEMENT / ETHICAL STATEMENT

All participants involved in this study provided informed consent for their interviews, all of them are adults, and all procedures were conducted following ethical standards.

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# A CONCEPTUAL PAPER ON STIGMATISED DIMENSION TOWARDS RESIDENTIAL OVERHANG

**Norulelin Huri[1], Zarita Ahmad @ Baharum[2], Ting Kien Hwa[3], Yasmin Mohd Adnan[4], Noor Farhana Akrisha Ishak[5]**

[1,2,5]*College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA, MALAYSIA
[3]*Departmemt of Real Estate Faculty of Built Environment,*
UNIVERSITI PENGURUSAN DAN TEKNOLOGI TUNKU ABDUL RAHMAN, MALAYSIA
[4]*Departmemt of Real Estate, Faculty of Built Environment,*
UNIVERSITI MALAYA, MALAYSIA

## Abstract

Property stigma refers to some characteristics, features, social values, or an event relating to land and buildings that can create a negative perception of a building, land, project, or neighbourhood area. It was identified as a significant factor contributing to the number of overhang residential units in Malaysia. This paper aims to develop a Conceptual Framework of a stigmatized dimension model for residential overhang properties that can assist the decision-making of the property market players (developers, planners, and property consultants). This study utilizes a desktop analysis that reviews previous scholars' conceptual frameworks. The conceptual paper develops four (4) stigma-related variables: Environmental stigma, phenomena stigma, neighbourhood stigma, and structural stigma. However, it is not an empirical investigation of property overhang since this paper needs to review in detail all the factors that influence the property overhang. The proposed conceptual framework will provide valuable insights into the stigmatized dimension of property overhang from the buyer's perspective. This paper provides an essential conceptual framework that will assist the property market players enhance their housing development and sales strategy, thereby increasing the bottom line. Subsequently, this will improve the property market efficiency and meet the demand and supply requirements.

***Keywords*:** Property Stigma, Property Overhang, Residential

[1] Student at Universiti Teknologi MARA. Email: norulelin@uitm.edu.my

## INTRODUCTION

A good housing development project should be designed to help households develop a safe and secure neighbourhood (Osman et al., 2017; Teck-Hong, 2011). The environmental condition that reduces the value and marketability of the property and sometimes those adjacent to it is known as stigmatization (Ogban & Akujuru, 2016). Stigmatized property is real estate burdened with an external negative effect (Hajnal, 2017). Furthermore, stigma is also known as a phenomenon when there are physiological impacts by bad circumstances, and the value or reputation of the property is affected. For example, the existence of high-voltage power transmission lines (HVPL) and contaminated land might expose the neighbourhood to health risks (Ibrahim & Maimun, 2022; Ogban & Akujuru, 2016). Notably, this perception will influence the decision of the homebuyers when purchasing the property (Said et al., 2016). They might refuse to buy a house close to the area. According to Leiss (2013), stigma refers to some mark that could be placed on a person to signify shame, disgrace, and disapproval. Stigma is also defined as fearful behaviour that cannot be quantified and may or may not be substantiated (Callanan & Eves, 2015). In real estate, the stigmatized property can cause the buyer or tenant to be shunned for reasons unrelated to its tangible conditions or features. A property may be deemed stigmatized based on the occurrence of certain events. This term is sometimes used to describe a property affected by negative events. However, it does not impact the property's appearance or function, such as murder, crime, or harassment (Nallathiga et al., 2018). Hence, it can be concluded that variables related to stigma cannot be quantified or measured. It does not relate to the physical property, yet it tends to relate to external factors like environmentally friendly and events that have happened before. In addition, stigma does not necessarily refer to the whole area. In some cases, it might refer to the individual unit of property. For example, while the region has no record of environmental issues, the individual unit has a haunted house history. That stigma is difficult to eradicate and may be temporary or permanent. Stigma was identified by Rahim et al. (2019), causing property overhang in Johor Bahru. However, before this paper, no previous research had been conducted on the stigmatized aspect of property overhang. Hence, this study attempts to form a framework demonstrating their relationship to identify the stigmatized dimensions in the case study area.

## PROBLEM STATEMENT

Failing to match consumers' dynamic requirements will eventually result in accumulating unsold properties labelled as overhang properties (Sivadasan et al., 2020). Property overhang and oversupply are terms used to describe a gap between supply and demand in the property market. The definition of property overhang includes the completed housing units that obtained the Certificate of Completion and Compliance (CCC) from local authorities and remained unsold

for more than nine months after it was launched on or after 1st January 1997 (NAPIC, 2022). Table 1 defines overhang and unsold property by the National Property Information Center (NAPIC). Any remaining units left unsold after the issuance of a Certificate of Completion and Compliance (CCC)will be deemed as overhang (NAPIC, 2022).

**Table 1**: Definition of Property Overhang

| Sales Status | Development Stage | Units | Period in The Market | Start Date |
|---|---|---|---|---|
| Overhang | Completed with CCC | Unsold more than 5 units | More than 9 months from the launch date | Launch date at or after 1st January 1997 |
| Unsold Under Construction | Under Construction | | | |
| Unsold Not Constructed | Not Constructed | | | |

*Source: NAPIC (2023)*

According to the NAPIC, up to the third quarter of 2023, there will be 25,311 residential units classified into overhang buckets. Selangor was the main contributor of the central region state with the highest number of overhangs with 4,995 unit. Note that Selangor was the state with the most active industrial activity and the highest population among the states in Malaysia.

**Table 2**: Percentage of Residential Overhang in Selangor as of 2023

| Segment | First 3 years | % | More than 3 years | % | Total Overhang |
|---|---|---|---|---|---|
| Total number of Unit | 3,393 | 67.9 | 1,602 | 32 | 4,995 |
| Total number of Housing Scheme | 49 | 48 | 53 | 51.9 | 102 |
| Total value of overhang (RM/ bil) | 2.93 | 65.5 | 1.54 | 34.4 | 4.47 |

*Source: NAPIC (2023)*

Table 2 exhibits the percentage period of residential overhangs in Selangor as of Q3 2023. The data revealed, that about 32% of residential overhang units in Selangor have not been sold even after 3 years of obtaining the CCC. It indicates the slow performance of sales by developers will lead to the property overhang. There are many actions taken by responsible agencies to mitigate the issue, but the effort is focusing on reducing the number of overhangs but not the property stigma. Despite the number of property overhangs trend reducing, the stigma remains (Rahim et al., 219). Therefore, it is an issue that should be resolved as to why the buyer refuses to buy the house in Selangor. According to Said et al. (2016), property that has been determined to have a stigma will affect housing prices. Housing prices will reduce by 10% to 20% from similar comparable properties. Thus, properties with a stigma are not the choice of investors or potential buyers. This indicates that any property with a stigma


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will have a lower take-up rate since the value is different from a property without a stigma. This aligns with the definition of property overhang. Once the house has been completed and not taken up by potential buyers or investors, it will be counted in the property overhang statistics released by NAPIC nine months after the launch date (NAPIC, 2023). According to Hajnal (2017) and Ogban and Akujuru (2016), stigma is significant to house prices. Does this stigma have a direct effect on the occurrence of property overhang?

Table 3 provides several conceptual frameworks that have been developed by previous scholars.

**Table 3:** Conceptual Framework

| Author | Independent Variable | Dependent Variable |
|---|---|---|
| Hajnal (2017) | Nearby Airport<br>Groundwater contaminations<br>High Voltage Power Line Cables<br>Waste Dump<br>Haunted house | Property Value |
| Said et al. (2016) | Type of stigma<br>Implication of stigma | Housing Price |
| Rahim et al (2019) | Unattractive location<br>Price<br>Imbalance property market<br>Unethical speculation<br>End financing and unreleased Bumiputra units<br>Design consideration<br>Mismatch supply and demand<br>Accessibility<br>Poor Integrated Planning Provision<br>Social stigma<br>Feasibility Study<br>Affordability<br>Economic activities<br>Neighbourhood<br>Connectivity | Property Overhang |
| Kassim & Tey (2022) | Price<br>Location<br>Housing loan<br>Building condition<br>Feasibility Study | Property Overhang |

*Source: Author (2024)*

There is a lack of previous research specifically addressing the issue of stigma associated with the property overhang. The latest study of the property overhang was conducted by Kassim and Tey (2022) and Rahim et al. (2019), which discovered that they only focused on the overall factor that may affect the property overhang in the selected case study. Consequently, Kasim and Tey

(2022) examined the factors contributing to the property overhang towards a double-story semi-detached residential. However, the scope of their research was limited to a specific type of property, and it considered general aspects that could influence the overhang issue without explicitly addressing studies related to social stigma. Moreover, their study did not touch on the stigma element, which may be why the number of overhang units keeps increasing. In their finding, the factors that caused the overhang scenario were also one of the stigmas. However, they have yet to be studied in depth, such as the physical condition of the building. The conceptual framework highlighted by Kassim and Tey (2022) and Rahim et al. (2019) was trying to solve the property overhang issue within the region of their case study. They were using the general factors that may potentially affect the property overhang as their independent variable without any specific focusing element. In contrast to Hajnal (2017), he examined stigma but was more concerned with determining the market value of properties in Central Europe. It is similar to the findings of Said et al. (2016), whose study has focused on all types of property stigma in-depth and the implications of stigma towards housing prices. Whereas, according to Rahim et al. (2019), property stigma is also one of the factors that may affect the property overhang. The conceptual framework developed by Said et al. (2016), is more focused and concentrated on specific elements like property stigma and limited to other factors that may affect the property value, however, the focus is on housing prices and determining the market value of the stigmatized property. Said et al. (2016), revealed that the property attached to stigma would influence house price, yet it did not impact the implications of stigma variable towards housing price. However, the conceptual framework was applicable towards the housing price and not to property overhang. Therefore, the recent research relating to property stigma and property overhang has not yet been studied. Housing is a basic need for humans, which involves a procedure of transactions and, of course, a large amount of money. Therefore, deciding to acquire a house is something crucial that needs to be determined since they need to study the history of the property and the area in which the property is located prior to proceeding with the transaction (Said et al., 2016). This is attributed to the fact that investors will put abundant money into properties in good locations; however, if the property is discovered to have a bad reputation, its value will be affected.

## RESEARCH AIM

This paper aims to develop a conceptual framework of stigmatised dimension towards residential property overhang from buyers' perspective. Thus, this study aims to identify all types of stigmas associated with the properties.


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## METHODOLOGY

This paper was a desktop research analysis. It is secondary research that analyses available data sources. The desktop study was an analysis involved in collecting data from existing resources. Hence, it is often a low-cost technique (Gandhi et al., 2018). This research relies on data from the previous literature and conceptual framework. The data was then collected and organized into a literature matrix to represent the components and structure of the variables visually. Subsequently, a conceptual framework was constructed based on the literature matrix. The layout of the concept matrix is straightforward. The references to be reviewed are listed in abbreviated APA style. The head of each column displays concepts that have been derived from the problem statement of the research project (refer Table 4). If a concept is discussed in a particular reference a tick is placed in the appropriate cell. This approach enables the researcher to conduct a critical comparative literature review of all references listed under each concept (Klopper et., 2007).

## CONCEPTUAL FRAMEWORK

Property values are affected by "location, location, location," which is an old and oversimplified saying, however, it might be more true to say that "perception, perception, perception" determines the value of a property." (Bell, 2016). According to his statement, other significant factors need to be closely examined rather than location. Said et al. (2016) said that properties that have been found to have a stigma are not the choice of investors or potential buyers. Therefore, it might take a long period to sell. This situation will lead to a property overhang scenario, once the units are not able to sell within 9 months it being launched, it will be categorised as property overhang. Does this stigma have a direct effect on the occurrence of property overhang? The conceptual framework is focused on external stigma. External stigma is a negative connotation that may exist outside of the property (Horgan, 2020). Meanwhile, external stigma categories refer to attributes distinct from individual properties. It consists of several subcategories, namely environmental stigma, neighbourhood stigma, phenomenon stigma, and structural stigma.

### Environmental Stigma

Environmental stigma is assumed to be attached to contaminated places or sites. Its connotations include a high perception of risk, inequitable risk distribution, and consequences from the damage to severe and long-lasting areas for the local communities near such places (Leiss, 2013). This recognition is seen in the adverse effect of environmental pollution on the worth of properties (Mccluskey & Rausser, 2003). For example, the neighbourhood property adjacent to the dumping site (Ogban & Akujuru, 2016), groundwater contaminated by chemicals (Zhuang et al.,2016; Hajnal, 2017), nuclear power stations (Leiss, 2013), high voltage power lines cables (Bell, 2016), airport and railway lines (Hajnal, 2017).

These stigmas are thought to contribute to scent pollution, noise pollution, and health concerns. Apart from that, neighbourhood stigma also harms property value. It is the negative public perception of living in a community that has experienced a degraded quality of life.

**Neighbourhood Stigma**

Neighbourhood stigma pertains to social matters and distance from one area to another (Ibrahim & Maimun, 2022). It is related to the residential location, whether urban, suburban, or rural. Therefore, it is vital since it impacts those who rely heavily on public transport services and travelling periods, thus involving high costs if the travel distance is far (Lin & Long, 2008). Several scholars mentioned that people refuse to buy a house due to the distance and location. This includes access to public transport (Cheng & Ling, 2023) and distance to public healthcare and educational facilities (Olanrewaju & Woon, 2017). According to the previous scholar, this type of stigma is a highly significant sign as it has been identified that if a stigma is associated with a property or community, it would be less attractive to investors or potential buyers, for example, the housing scheme is located within the crime area (Ibrahim & Maimun, 2022). Hence, many students are rented in the family neighbourhood (Horgan, 2020) as it tends to create a moral issue, and the housing scheme makes no sense of security (Teck-Hong, 2010). All of these factors pose a potential risk to personal and familial safety. Naturally, if potential buyers know these issues, they will decide not to purchase a property in such an area. Regarding the distance, it is determined to have higher significance from the previous scholars as it will be more costly if they decide to house far from the working area, especially government or private departments (Olanrewaju & Woon, 2017), hospitals (Rahim et al., 2019) and retail area (Kasim, & Tey 2022). All of these factors are priorities when deciding on buying a property. Accordingly, it can be concluded that if the distance variables are far from their housing scheme, it becomes a property that gets less attention due to negative connotations and, therefore, can cause the property to overhang.

**Phenomena Stigma**

Phenomena or hunting stigma is associated with a residence believed to be haunted or similar phenomena, such as an extant ghost, death experience (Nallathiga et al., 2018), and former abandoned housing projects (Ibrahim & Maimun, 2022). They also defined phenomena stigma as psychological stigma due to the property having an awful history. According to Nallathiga et al. (2018), this stigma will mainly impact the property value. Hence, this will affect the demand in certain areas, too. It is supported by Said et al. (2016) that property involved in a murder or suicide case will reduce the value of the property by about 10 to 20% from the comparable properties. Meanwhile, Chang and Li (2018)


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discovered that, in Hong Kong, the property value that has experienced unnatural death will drop by about 25%, and the nearby property will drop by about 4.5%. The drop in value will affect not only the individual property but also the neighbourhood and surrounding area. Therefore, if the prospective buyer becomes aware of such stigmas, they will certainly decline to purchase a property in the residential area.

**Structural Stigma**

Institutional stigma is more systemic, involving policies of government and private organizations. There are two institutions involved that are responsible for the existence of stigma on a residential scheme. Firstly, developer reputations play a vital role in attracting buyers (Rahim et al., 2019), and local authorities are responsible for the planning permission approval on an area of development (Said et al., 2017). According to Mohammad et al. (2022), people refuse to buy houses at a higher price. With the high cost of living nowadays, the higher commitment will burden the buyer. Kassim and Tey (2022) supported the idea that price is the main factor contributing to Johor Bahru's property overhang. Usually, branding developer will have their marketing strategy to portray their business. Indirectly, they are using the high cost for marketing strategy, which leads to the high price due to the selling quality. In addition, the local authority also plays a vital role in approving planning permission. If planning approval is granted to a development zoned as a flood zone, it will put potential buyers at risk. Thus, it can cause a negative perspective on the property due to the potential risk that may be faced towards potential homebuyers (Bell, 2016). This situation relates to the town and country planning department, which permits the development of housing schemes in flood zones. This kind of stigma will give a negative perception and bad reputation towards housing development due to the lack of policies implementation by specific agencies. When the property's value drops and it becomes challenging to sell, it becomes more difficult to attract buyers. Apart from that, the housing site also increases the probability of property stigma, whereby the housing site is near an area affected by landslides (Said et al., 2016). The uncertain condition will make potential homebuyers uneasy about buying a property in the affected area. Meanwhile, according to research by Zhuang et al. (2016), housing development adjacent to an industrial zoning area is believed to experience rapid building obsolescence and, after that, will cause physical defects, amongst others. This stigma will result from the approval of planning permission.

Table 4 displays the stigma factors associated with properties. The factors will be used to ascertain the relationship with the property overhang.

**Table 4:** Stigma Variables

| STIGMA VARIABLES | | SOURCES |
|---|---|---|
| | **ENVIRONMENTAL STIGMA** | |
| 1 | Nearby airport | (Hajnal, 2017; Ibrahim & Maimun, 2022) |
| 2 | nearby railway | (Hajnal, 2017; Ibrahim & Maimun, 2022) |
| 3 | HPVL | (Elliot & Wadley, 2022; Callanan & Eves, 2015; Bell, 2016;Hajnal, 2017; Ibrahim & Maimun, 2022) |
| 4 | Waste dump | (Leiss, 2013; Ogban & Akujuru, 2016; Hajnal, 2017; Ishak et al., 2019; Ibrahim & Maimun, 2022) |
| 5 | Water contaminated | (Ogban & Akujuru, 2016; Zhunag et al, 2016; Hajnal, 2017; Ibrahim & Maimun, 2022) |
| 6 | Odour Nuisance | (Ogban & Akujuru, 2016) |
| | **NEIGHBOURHOOD STIGMA** | |
| 7 | Crime | (Zhuang et al, 2016; Said et al., 2016; Olanrewaju & Woon et al., 2017; Brian, 2018; Hew et al., 2019; Ishak et al., 2019; Ibrahim & Maimun, 2022) |
| 8 | Students rental | (Horgan, 2020; Nallathiga et al., 2017) |
| 9 | Morally loaded | (Horgan et al., 2020 |
| 10 | Retail area/ Shopping | (Mc Cluskey & Rausser, 2003; Teck-Hong, 2020; Olanrewaju & woon, 2017; Rahim et al. 2019; Ishak et al, 2019; Cheng & Ling, 2023; Kassim & Tey, 2023) |
| 11 | Hospital | (Tech-Hong, 2010; Olanrewaju & Woon, 2017; Rahim et al., 2019; Ishak et al., 2019;Cheng & Ling, 2023) |
| 12 | Sport Centre | (Teck-Hong, 2010; Olanrewaju & Woon, 2017; Rahim et al., 2019; Cheng & Ling, 2023 |
| 13 | Airport | (Mc Cluskey & Rausser, 2003) |
| 14 | CBD | (Mc Cluskey & Rausser, 2003; Rahim et al. 2019; Cradduck & Warren,2019; Cheng & Ling, 2023; Mohammad, 2022) |
| 15 | Public Transport | (Olanrewaju & Woon, 2017; Cheng & Ling, 2023) |
| 16 | Government Office | (Olanrewaju & Woon, 2017) |
| | **STRUCTURAL STIGMA** | |
| 17 | Reputation | (Rahim et al., 2019) |
| 18 | Price | (Mc Cluskey & Rausser, 2003; Teck-Hong, 2020; Olanrewaju & woon, 2017;Mohammad, 2022; Kassim & Tey, 2023) |
| 19 | Landslide | (Said et al., 2016) |
| 20 | Mining land | (Bell, 2016) |
| 21 | Flood prone | (Bell, 2016) |
| 22 | Industrial zoning | (Zhuang et al, 2016) |
| | **PHENOMENA STIGMA** | |
| 23 | Hunting | (Alias et al., 2014; Zhuang et al., 2016; Said et al., 2016: Chang et al., 2018; Nallathiga et al., 2017; Ibrahim & Maimun, 2022) |
| 24 | Abondend project | (Ibrahim & Maimun, 2022) |
| 25 | Death/ murder | (Alias et al., 2014; Said et al., 2016: Chang et al., 2018; Nallathiga et al., 2017; Ibrahim & Maimun, 2022) |

*Source: Author (2024)*

## Impact From Property Overhang

Poor sales performance will impact developers' ability to cover their bridging loans, which may raise the possibility of project abandonment. This situation usually results in a price reduction or more rebates will be provided. Furthermore, an overhang scenario causes purchasers to expect more price decreases and hold off on buying the property later (Utusan Malaysia, 2023). From financial institutions' perspectives, when the economy, particularly the housing industry, is hurting, lenders will be more cautious in approving loans, resulting in the


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tightening of consumer credit. All these will further exacerbate the drop in housing demand. This may lead to severe consequences on housing prices and develop into a housing bubble that unavoidably leads to the collapse of the financial system (Yip et al., 2021; Yiu et al., 2013). Not only that, property overhang is also related to property transactions. If there is no transaction, it will affect the primary source of government revenue, which is involved in tax collection for stamp duty, real property gain tax, and rating and assessment tax (Utusan Malaysia, 2023). Apart from that, it also impacts most professional firms involved in real estate transactions, whereas each transaction brings income opportunities to the lawyer, valuers, estate agents, and contractors. Consequently, this cycle contributes to economic growth (Utusan Malaysia, 2023). It will also lead to other side effects, such as pre-occupancy obsolescence, high maintenance costs, high energy costs, the abandonment of properties and houses, and others (Liew, 2023). Most people viewed the high overhang data as a negative indicator for the real estate industry. Sheldon Fernandez, country manager (Malaysia) of Property Guru, stated that the overhang units in the high-end segment took up the largest market share, and targeting wealthy foreign purchasers could further help decrease the volume of unsold units in Malaysia (Sharen Kaur, 2022). If the country allows it to happen, there will be more foreign purchasers than locals owning property in this country.

**Implication of Stigmatized Property**

When a property is labeled as stigmatized, the demand for the property decreases, leading to a decline in its market value. Potential homebuyers typically hesitate to acquire the property, especially when additional remedial costs are necessary due to phenomena such as stigma or environmental concerns. They feel insecure when they do not understand the defects and are afraid they have no adequate control over the property (Muldowney & Harrisons, 1995). Therefore, it is crucial to understand that the effect of stigma arose from the risk perception which concerned the homebuyer. Every risk encountered or perceived by them will influence their decision, whether it is from the environmental, safety, or financial. However, when homebuyers react negatively toward the risk or stigma, the demand for the stigmatized property will reduce (Said et al., 2016). The impact of the stigmatized dimension would vary according to the beliefs of homebuyers and their needs. According to Said et al. (2016), stigmatized properties significantly impact property prices. However, it was discovered that the implications of these stigmas do not have a significant impact on property prices. Some people might think that having a property attached to stigma will create a chance to generate profit in the future otherwise since they can have it below market value. Nevertheless, the earlier statement by the previous scholar mostly agreed that stigmatized property can lower the demand for the property. According to Callanan and Eves (2015), their preliminary studies suggested that when HVPL cables are in place, the value

of residential property in the surrounding area will decrease. Nevertheless, 60% of the property owners in New Zealand believe that if the HVPL is removed, the whole neighbourhood will improve by 10%, with the stigma remaining for three to four years. This is because some potential buyers may believe in the health effects of the electromagnetic field, and the valuers have to expect the buyer's attitude to value the impact (Ibrahim & Maimun, 2022). Moreover, most residential properties located close to the dump sites will also face a diminution of market value. In addition, it will affect the demand for residential property. The dump site will cause air pollution, odour nuisance, and groundwater contamination in the proximity area (Ogban & Akujuru, 2016). In conclusion, properties close to environmental problems will likely affect people's decisions about whether or not to buy them since an unsettling environmental issue will risk the buyer's health (Hajnal, 2017). This implies that any property associated with a stigma will receive less favour from investors or potential buyers due to its diminished value than a property without a stigma. This is consistent with the definition of property overhang. Nine months after the launch date (NAPIC, 2023), if the house has been completed but not taken up by potential buyers or investors, it will be included in the property overhang data reported by NAPIC. Hence, stigma is significant in house prices, as indicated by Hajnal (2017) and Ogban and Akujuru (2016). Therefore, this study aims whether the same variables have a direct impact on the occurrence of property overhang. Some conceptual frameworks propose a blueprint for this research (Said et al., 2016), which uses the same variables by previous scholars toward the market value price of the property. Consequently, this study will adopt the variables toward property overhang to fill the gap.

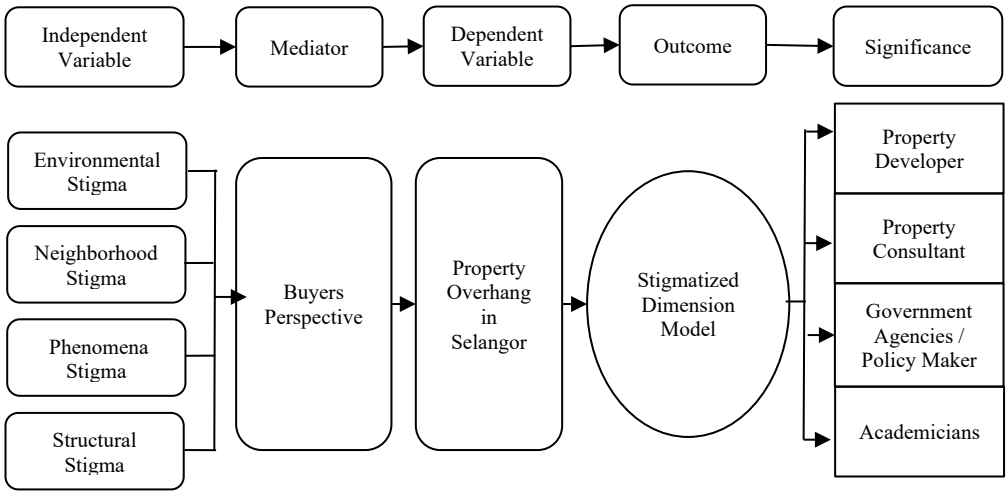


**Figure 1:** Conceptual Framework
*Source: Author (2024)*


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Figure 1 proposes the conceptual framework which will use external stigma as an independent variable and property overhang as the dependent variable, with the buyer's perspective as a mediator variable.

## SIGNIFICANCE OF THE STUDY

This paper provides an essential conceptual framework that will assist the property market players in enhancing their housing development and sales strategy, thereby increasing the bottom line. Subsequently, this will perfect the property market efficiency and meet the demand and supply requirements. The property developer will consider all the stigma categories to tackle potential buyers to get the best sales performance once they launch the product. Note that it is also necessary for them to examine several issues from the buyers' perspective when making such a development.

## CONCLUSION

This paper concludes that the stigma towards property can affect the value of property involved. Once the property's market value is concerned, the property will have less demand compared to similar properties, leading to property overhang. Therefore, the proposed conceptual model fills the gap from the previous study by adopting all the variables toward the property overhang. Since the property overhang is related to the property with no demand, using the variables will demonstrate the relationship between the stigmatized dimension and property overhang. As the property overhang has continued to persist and increase over the past two decades, it is pertinent to examine the overhang issue from other perspectives. Researchers have neglected stigmas as a contributory factor towards residential property overhang. Moreover, stigmas are expected to negatively influence the decision-making of house buyers in house purchases in terms of location, neighborhood, housing scheme features, floor design, and unit characteristics. Therefore, the developer, government agencies, or any other relevant entities can be guided to reduce stigmas associated with property overhang by considering this stigmatized aspect from the beginning of the design phase.

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# SECULAR TRENDS IN PROPERTY OVERHANG IN MALAYSIAN RESIDENTIAL AND SERVICED APARTMENTS

**Noor Farhana Akrisha Ishak[1], Zarita Ahmad@Baharum[2], Ting Kien Hwa[3], Yasmin Mohd Adnan[4], Norulelin Huri[5]**

[1,2,5] *College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA, MALAYSIA
[3] *Faculty of Built Environment,*
TUNKU ABDUL RAHMAN UNIVERSITY OF MANAGEMENT AND TECHNOLOGY, MALAYSIA
[4] *Faculty of Built Environment,*
UNIVERSITI MALAYA, MALAYSIA

## Abstract

In 2022, property overhang residential and serviced apartments recorded 51, 724 units valued at RM38.6 billion. Property overhang occurred when the excessive supply of property stocks in 2017 caused a drastic increase of overhangs, which is 31,102 units then carried forward to 2018, continuing to rise in the housing market. This scenario cannot be taken lightly by the government. Hence, this study aims to explore the secular trend in property overhang in Malaysian residential and serviced apartments over the past ten years. Data property overhang in the years 2013 to 2022 was obtained from the National Property Information Centre (NAPIC). The data property overhang will be analysed using time series analysis based on (1) state, (2) type of property, and (3) price range. Then, this study reveals that the top three (3) overhang residential and serviced apartment properties are in Johor (19,390 units), Federal Territory Kuala Lumpur (9,441 units), and Selangor (6,624 units). Condominiums/Apartments and serviced apartments are the highest type of overhang properties with a price range of RM500,001 – RM1,000,000. Thus, this study provides insight into the market performance of overhang residential and serviced apartment properties in Malaysia. This data will be used to examine the factors that influence the overhang of these properties.

***Keywords***: Secular trends, Property Overhang, Residential, Serviced Apartment, Malaysia

[1] Student. Email: farhanaakrisha@gmail.com

## INTRODUCTION

Property is defined as the physical land and those human-made items that attach to the land (IVSC, 2003). It is one of the most significant economic sectors because the demand to own property for living houses and income-generating sources increases along with socio-economic development (Thrinh, 2022). Hence, close monitoring of this sector is vital as it influences land use activities, the industry, and the economy. For good measure, the National Property Information Centre (NAPIC) was established as a property centre with the role of monitoring the performance of the property market in the country. NAPIC provides accurate, comprehensive, and timely information on the demand and supply of property in the country to government agencies, property developers, and other parties involved in the property industry.

Data NAPIC 2022, property market activity continued to grow with more than 389,107 transactions worth RM179.07 billion. It shows an increase of 29.5% in volume and 23.6% in value compared to last year. The residential property recorded 243,190 transactions worth RM94.28 billion, increased by 22.3% in volume and 22.6% in value as compared with 2021. For serviced apartments recorded 6,821 transactions worth RM4.50 billion. It shows an increase of 56.5% in volume and 59.4% in value of transactions (2021: 4,359 transactions worth RM2.82 billion). The property market activity is driven mainly by the residential property which contributes 62.5% to the overall market. This explains the similarity in transaction volume and value patterns, which indicates the significance of the residential market performance to the overall property sector.

Property overhang comprises residential units, commercial units, and industrial units that are completed with a Certificate of Completion and Compliance/ Temporary Certificate of Fitness for Occupation in the review period. These units remained unsold for more than nine months from the date of launching or after 1st January 1997 (NAPIC). The serviced apartment units were reclassified from residential to commercial as of 2016 because of land titles. However, buyers still purchased serviced apartment units as residential units for them to live in (Marzukhi et al., 2019).

By looking up trend property overhang arising in Malaysia, mostly previous research stated the overhang is mostly due to a lack of research which resulted in a poor understanding of supply and demand and a mismatch in the property price range that purchasers are looking for in specific places (Chan, 2022). The types of houses built by developers differed on what the market needed, for example, the people expected property developers to provide affordable terrace houses (landed) but most of the properties built were condominiums/apartments (Noor Rosly, 2023). Besides that, evidence showed that the reason for the high number of overhang residential properties is the mismatch between demand and supply (Chan Wai Seen, 2023). Furthermore, the


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overhang or unsold properties will affect the economy because the unproductive capital locked up in unsold units has no rolling economic effect and indirectly affects nearly 150 industries related to the property sector (Ng, 2019).

Accordingly, this study was conducted with the aim to explore the secular trend in property overhang in Malaysian residential and serviced apartments and identify the top three state residential and serviced apartment properties overhang, the highest types of property overhang, and the most price range of property overhang using time series analysis. The secular trend describes the movement over the long term of a time series that globally can be increasing, decreasing, or stable (Secular Trend, 2008). These secular trends provide insights in helping to understand trend property overhang and will be used in the upcoming research.

## LITERATURE REVIEW

### Definition of Overhang

Property overhang is a term that is taboo in the real estate industry, where some believe that it gives the impression of a sector that is in dire straits. Simply put, a property overhang occurs when the rate of building exceeds that of take-up, culminating in a property supply-demand gap (Yee, 2023). Overhang occurs when there is an oversupply of houses that are not built based on demand, or a lack of demand for those units (Suraya & Gregory, 2021). Moreover, the property overhang came about from the frenzy of building among developers during the property market boom, which was buoyed by Malaysia's strong economic growth. Unfortunately, average salary increases and household income were not at par with the rise in property prices, particularly housing (Bernama, 2023).

According to NAPIC, there are three categories of market status: overhang, unsold under-construction property, and unsold not-constructed property. Table 1 shows the different definitions of the property status. The similarity between these property statuses is that the sales status has been unsold for more than nine months from the launch date. This study highlights the definition of property overhang as residential units completed with CCC and remain unsold for more than nine months from the launching date.

**Table 1**: Definition of overhang status in property market report

| No | Property Status | Definition | | | |
|---|---|---|---|---|---|
| | | **Development stage** | **Sales status** | **The period in the market** | **Start date** |
| 1 | Property overhang | Completed with CCC | Unsold | More than 9 months from the launching date | Launching date at or after 1st January 1997 |
| 2 | Unsold, under-construction property | Under construction | Unsold | | |

| No | Property Status | Definition | | | |
|---|---|---|---|---|---|
| | | **Development stage** | **Sales status** | **The period in the market** | **Start date** |
| 3 | Unsold, not constructed property | Not constructed | Unsold | | |

*Source: NAPIC*

**Definition of Residential**

Craighead (2009) defined a residential building as a building containing separate residences where a person may live or regularly stay. Meanwhile, NAPIC stated residential property is housing accommodation to include any building, which is wholly or principally constructed, adapted, or intended for human habitation or partly for human habitation and partly for business premises. The term human habitation would include buildings constructed for humans to live with their families. For this report, shop houses, which are partially used as retail and partially for human habitation are excluded as a residential property but reported as shops, under Section 3, The Housing Development Act 1966 (Control and Licensing) and (as amended 2002). The type of residential property consists of single-storey terrace, 2-3 storey terrace, single storey semi-detached, 2-3 storey semi-detached, detached, townhouse, cluster, low-cost house, low cost flat, flat, and condominium/apartment.

**Definition of Serviced Apartment**

In Malaysia, the serviced apartment is one of the terms for 'apartment' but is located in the 'commercial' land use zoning. In the *Manual Garis Panduan dan Piawaian Perancangan Negeri Selangor*, the Serviced Apartment is defined as a concept of commercial development that embodies features of residential furnished with designated facilities packages for each unit.

Other than that, a serviced apartment can be defined similarly to a condominium, a multiple-unit structure in which the units and pro rata shares of the common areas are owned individually, a unit in a condominium property. Also, the absolute ownership of an apartment or unit, generally in a multi-unit building, is defined by a legal description of the air space the unit occupies plus an undivided interest in the common elements that are owned jointly with the other condominium unit owners (Craighead, 2009). In Malaysia, NAPIC stated that as of 2016, serviced apartment units were reclassified from residential to commercial.

**Overview Property Overhang in Malaysia**

Malaysia’s housing needs are very much influenced by population growth and household size formation (Alom, 2020). To ensure the optimum resources used for any housing programs, it is appropriate if housing need and demand could be


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measured. The basic demand factors among households that generally relate to demographic characteristics such as monthly income, consumer preferences, and household size as the most influential performance in housing sales that developers have always neglected (Desmond & Shollenberger, 2015).

In addition, Yin et al. (2019) stated that the housing glut is caused by developers moving into the housing market without first conducting precise housing market demand and supply research to determine the saleability of their projects. The mismatch between supply and demand requirements creates more and more units of unsold houses. Another reason contributing to the mismatch could be traced to the fact that the normal lead period between submission of an application for a development project and official approval is quite long, about two years. Within these two years, the state of the economy may have changed due to uncontrollable external and internal factors.

It is worth noting that as of Quarter 3 (Q3) of 2023, the number of residential and serviced apartment units in overhang stands at 47,463 units, with a combined value of RM35.64 billion. For the year 2022, the volume of the residential and serviced apartment overhang is 51,724 units, with a value of RM38.6 billion. The residential and serviced apartments overhang problem that is currently occurring originated from the excessive supply in 2016 (18,704 units), which is the highest since 2003. At that time, the states that contributed the most overhang units were located at Johor (5,435 units), Federal Territory Kuala Lumpur (2,354 units), and Selangor (2,071 units). The excessive supply of property stocks in 2017 caused a drastic increase of overhangs, which is 31,102 units and then carried forward to 2018, continuing to rise in the housing market.

Since then, the imbalance of demand and supply has increased in the residential, commercial, and industrial properties. However, the 130,6903 units of the residential property remained unsold for more than a decade. As a result, the cost of new housing is raising difficulties to low-income people (Alom, 2020). Mohd et al. (2022) mentioned that since house prices in the city are escalating, more housing projects are now being constructed further from the city. Despite being sold at a lower starting price; these house projects are still less affordable. Supported by Dr. Hassanudin Mohd Thas Thaker, an Associate Professor at the Department of Economics and Management Sciences of International Islamic University Malaysia (2023), that the imbalance between supply and demand, the increasing costs of construction-related raw materials, and the location are factors contributing to Malaysia's continued issues overhang.

## METHODOLOGY

The data were mainly based on secondary data of property overhang from the year 2013 to 2022. The data was collected on residential and serviced apartment properties and was sorted by state, type of property, and price range. The main source of data from the government's official publication was NAPIC.

The data were analysed by time series analysis using Microsoft Excel 2019. A graphical representation of time series data revealed changes over time. By secular trend, long-term changes in the series were observed over ten years. Some series exhibited an upward trend, some series a downward trend, while others remained more or less constant over time. This method is used as an analysis due to its effectiveness in identifying long-term changes or trends within a dataset over a significant period of time. Since the data spanned from 2013 to 2022 and involved property overhang, which is subject to long-term factors such as economic conditions, demographic shifts, and policy changes, secular trend analysis was deemed appropriate.

## RESULTS AND DISCUSSION

For this time series analysis, data has been collected and analysed for all 13 states of Malaysia from 2013 to 2022. States in Malaysia consist of Johor, Melaka, Kelantan, Pulau Pinang, Kedah, Perlis, Perak, Pahang, Sabah, Selangor, Negeri Sembilan, Terengganu, and Sarawak, with three (3) federal territories which are Federal Territory Kuala Lumpur, Federal Territory Putrajaya, and Federal Territory Labuan.

Figure 1 below illustrates the trends in the overhang of residential and serviced apartment properties by state from 2013 to 2022. There is an uptrend for all states, especially WP Kuala Lumpur, Johor, and Selangor, with the figures for Johor (19,390 units), Federal Territory Kuala Lumpur (9,441 units), and Selangor (6,624 units). The only exceptions to this are Perlis (29 units), Federal Territory Labuan (47 units), and Federal Territory Putrajaya (231 units), which remained comparatively low.


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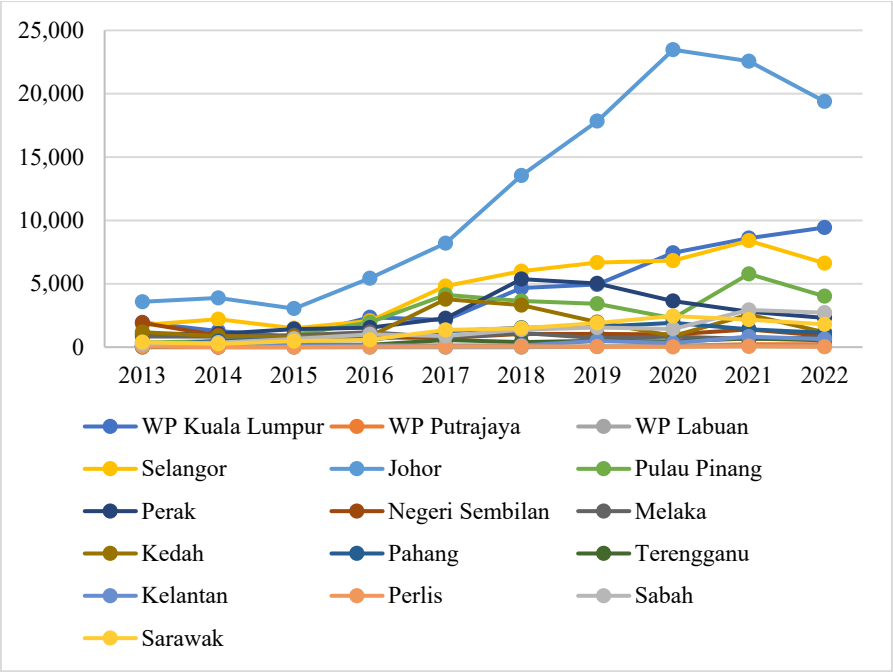


**Figure 1**: Volume of Overhang Residential and Serviced Apartment Properties Trend by State
*Source: NAPIC, various years*

**Table 2**: Volume of Overhang Residential and Serviced Apartment Properties Trend by State

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|
| WP Kuala Lumpur | 1944 | 1270 | 823 | 2354 | 2140 | 4664 | 4941 | 7444 | 8603 | 9441 |
| WP Putrajaya | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 114 | 230 | 231 |
| WP Labuan | 0 | 0 | 0 | 0 | 0 | 0 | 70 | 69 | 65 | 47 |
| Selangor | 1750 | 2200 | 1488 | 2071 | 4818 | 5990 | 6672 | 6828 | 8397 | 6624 |
| Johor | 3578 | 3883 | 3041 | 5435 | 8205 | 13544 | 17834 | 23472 | 22565 | 19390 |
| Pulau Pinang | 366 | 477 | 992 | 1953 | 4125 | 3643 | 3422 | 2287 | 5778 | 4012 |
| Perak | 1045 | 1055 | 1426 | 1542 | 2276 | 5367 | 5024 | 3637 | 2802 | 2312 |
| Negeri Sembilan | 1914 | 932 | 709 | 770 | 728 | 1046 | 1048 | 1008 | 1401 | 886 |
| Melaka | 836 | 835 | 929 | 1181 | 753 | 1121 | 710 | 823 | 651 | 755 |
| Kedah | 1184 | 865 | 813 | 860 | 3783 | 3311 | 1974 | 877 | 2569 | 1174 |
| Pahang | 1222 | 484 | 612 | 576 | 1262 | 1524 | 1607 | 1917 | 1409 | 1135 |
| Terengganu | 32 | 11 | 226 | 185 | 566 | 402 | 498 | 455 | 686 | 541 |
| Kelantan | 88 | 113 | 161 | 152 | 132 | 139 | 488 | 327 | 830 | 630 |
| Perlis | 49 | 0 | 0 | 44 | 67 | 65 | 33 | 18 | 67 | 29 |
| Sabah | 251 | 357 | 652 | 1011 | 879 | 1377 | 1544 | 1437 | 2933 | 2718 |
| Sarawak | 388 | 253 | 475 | 570 | 1358 | 1491 | 1907 | 2458 | 2172 | 1799 |

*Source: NAPIC, various years*

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Over time, there is a downward trend. For example, Johor volume started to drop from 2020 (23,472 units) to 2022 (19,390 units), and Perak decreased from 2019 by 5,024 units to 2022 (2,312 units). However, for Federal Territory Kuala Lumpur, the graph shows that growth slowed down in 2017 to 2,140 units and shot up to 9,441 units in 2022. In contrast, the overhang situation in Pulau Pinang, Sabah, and Perak showed no sign of levelling off and was consistent through the years. In Federal Territory Kuala Lumpur and Selangor, the overhang is dispersed across the states and not focused on one area. The overhang in Johor is focusing on Johor Bahru only. Hence, the increasing trend of property overhang especially in main urban areas such as Johor, WP Kuala Lumpur, and Selangor could have implications such as declining property values and reduced investor confidence which may challenge policymakers to implement effective measures to address the issues.

Figure 2 depicts the trends on the overhang of residential and serviced apartment properties by type of property. In Malaysia, there are landed and high-rise residential properties. The landed residential property includes a single-storey terrace, 2-3-storey terrace, single-storey semi-detached, detached, townhouse, cluster, and low-cost house. Meanwhile, high-rise residential consists of low-cost flats, medium-cost flats, condominiums or apartments, and serviced apartments.

The volume of overhang residential and serviced apartment properties by type of property over ten years from 2013 to 2022 is illustrated in Figure 2. It shows that from 2015, the overhang units for serviced apartments were 1,031 units, and condominium/apartment (1,805 units) increased in 2022, with 23,978 units for serviced apartments and 17,162 units for condominium/apartment. In contrast, 2-3 storey terraces are decreasing from 2018 (9,273 units) to 4,475 units in 2022, and other properties show slightly undulated. The overhang in landed property is less volatile compared to high-rise property. The trends reveal that serviced apartments have 23,978 units and condominium/apartments with 17,162 units were the most common types of property overhang units.

Hence, an increase in overhang units for serviced apartments and condominiums/apartments highlights a potential shift in demand towards landed properties, which the government needs to reassess existing policies related to preferences buyers or population growth in the areas to mitigate the issue of overhang.


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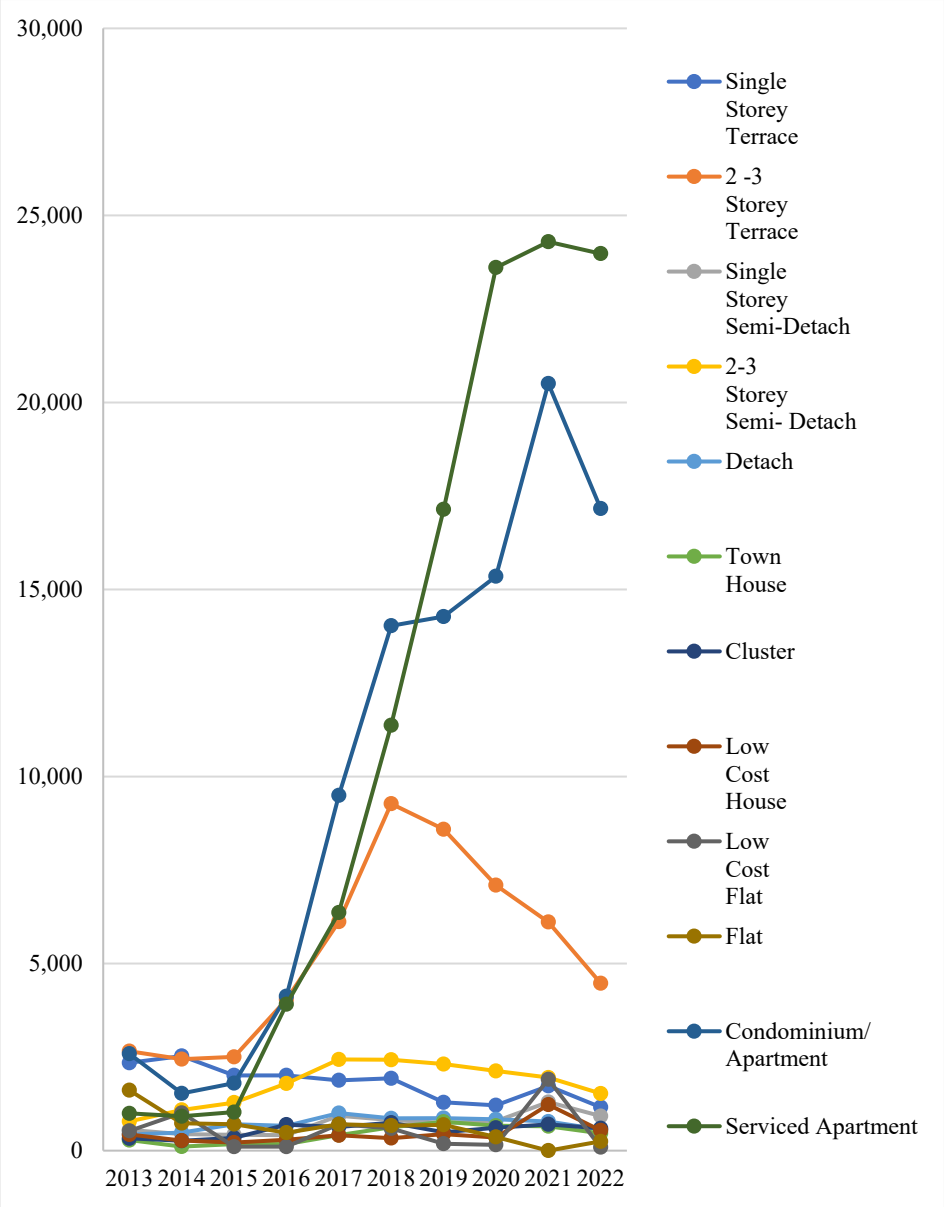


**Figure 2**: Volume of Overhang Residential and Serviced Apartments Properties Trend by Type of Property
*Source: NAPIC, various years*

**Table 3**: Volume of Overhang Residential and Serviced Apartments Properties Trend by Type of Property

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|
| Single storey terrace | 2348 | 2529 | 2012 | 2011 | 1879 | 1933 | 1290 | 1212 | 1729 | 1161 |
| 2-3 storey terrace | 2657 | 2445 | 2507 | 4039 | 6120 | 9273 | 8591 | 7094 | 6110 | 4475 |
| Single storey semi-detach | 558 | 442 | 425 | 414 | 932 | 819 | 744 | 789 | 1300 | 922 |
| 2-3 storey semi-detach | 782 | 1087 | 1284 | 1796 | 2438 | 2429 | 2313 | 2130 | 1954 | 1527 |
| Detach | 432 | 483 | 705 | 661 | 1004 | 863 | 869 | 837 | 777 | 563 |
| Town house | 282 | 108 | 176 | 174 | 415 | 624 | 771 | 666 | 652 | 463 |
| Cluster | 329 | 264 | 341 | 695 | 635 | 746 | 494 | 611 | 702 | 596 |
| Low cost house | 432 | 269 | 217 | 289 | 409 | 334 | 441 | 352 | 1229 | 539 |
| Low cost flat | 527 | 1008 | 105 | 105 | 706 | 593 | 186 | 156 | 1905 | 90 |
| Flat | 1614 | 732 | 708 | 481 | 704 | 668 | 689 | 364 | 0 | 248 |
| Condominium | 2590 | 1530 | 1805 | 4127 | 9496 | 14031 | 14276 | 15354 | 20505 | 17162 |
| Serviced apartment | 996 | 919 | 1031 | 3912 | 6364 | 11371 | 17142 | 23606 | 24295 | 23978 |

*Source: NAPIC, various years*

Figure 3 illustrates the trends in the overhang of residential and serviced apartment properties by price range. NAPIC uses three price ranges for easier data representation. The price range is (1) below RM500,000, (2) RM500,000 – RM1,000,000, and (3) above RM1,000,000.

As illustrated in Figure 3, the properties with a price range below RM500,000 show volatile movement for over one decade. For properties with the price range of RM500,000 – RM1,000,000, the overhang was 700 units in 2013 and increased to 26,717 units in 2021 before declining to 25,160 units in 2022. The properties above RM1,000,000 show a steady uptrend growth year on year, with more than 11,000 units within one decade.


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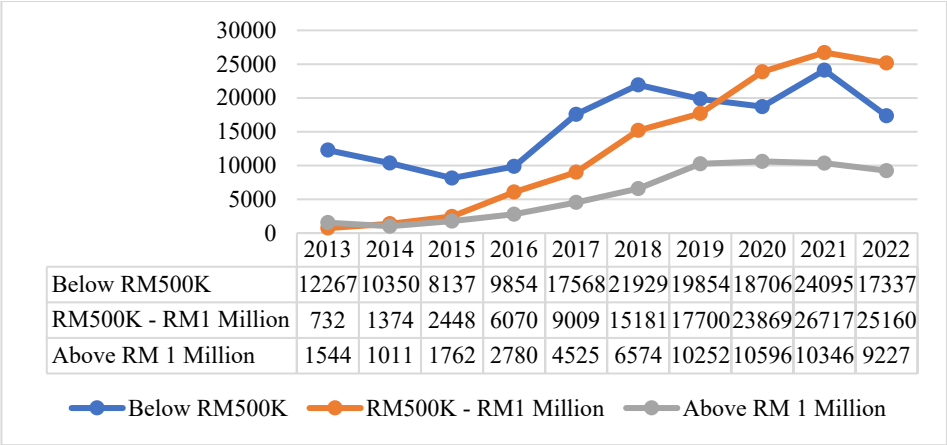


| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|
| Below RM500K | 12267 | 10350 | 8137 | 9854 | 17568 | 21929 | 19854 | 18706 | 24095 | 17337 |
| RM500K - RM1 Million | 732 | 1374 | 2448 | 6070 | 9009 | 15181 | 17700 | 23869 | 26717 | 25160 |
| Above RM 1 Million | 1544 | 1011 | 1762 | 2780 | 4525 | 6574 | 10252 | 10596 | 10346 | 9227 |

**Figure 3**: Volume of Overhang Residential and Serviced Apartment Properties Trend by Price Range
*Source: NAPIC, various years*

For the previous five years (2018-2022), a total overhang unit is 108,627 for the price range RM500,000 – RM1,000,000. Compared to the price range below RM500,000 with a total of 101,921 units and above RM1,000,000 with a total of 46,995 units. The price range of RM500,000 – RM1,000,000 revealed that the price is not affordable, thus influencing the demand for the property. Implement effective housing policies to address affordability issues such as giving incentives to developers to build more affordable housing units.

Figure 4 and Table 4 illustrate the year-over-year (YoY) percentage change in volume and value of overhang residential and serviced apartment properties. Based on YoY percentage change, the overhang residential and serviced apartments gradually increase and steadily decrease. The highest percentage increase for volume is 66.3% (2017), and the value is 74.4% (2017). In 2022, the residential and serviced apartment overhang numbers were reduced to 51,724 units with a value of RM38,608.88 billion. This shows a decrease in the YoY percentage change of 15.4% in volume and 10.7% in value, respectively.

Furthermore, the reduction in overhang numbers by 2022 both in volume and value is a positive progress for the real estate market. It indicates efforts to address the issue of overhang properties which could have implications for market stability and economic growth. However, it's essential to look into the reasons behind the reduction to assess its sustainability and long-term impact.

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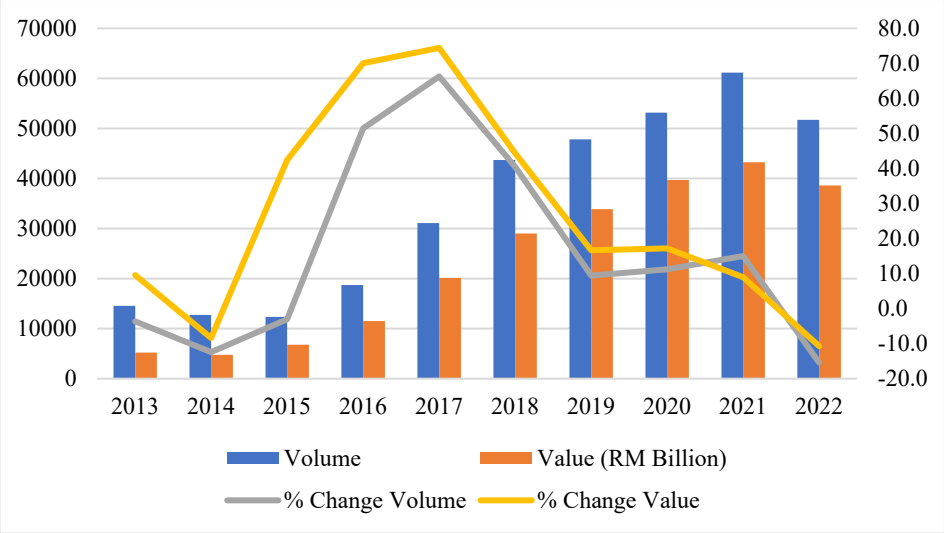


**Figure 4**: Year-over-Year (YoY) Percentage Change in Volume and Value of Overhang Residential and Serviced Apartment Properties in Malaysia
*Source: NAPIC, various years*

**Table 4**: Year-over-Year (YoY) Percentage Change in Volume and Value of Overhang Residential and Serviced Apartment Properties in Malaysia

| Year | Volume | Value (RM billion) | Volume (% change) | Value (% change) |
|---|---|---|---|---|
| 2013 | 14,543 | 5,197.46 | -3.6 | 9.5 |
| 2014 | 12,735 | 4,760.09 | -12.4 | -8.4 |
| 2015 | 12,347 | 6,779.36 | -3.0 | 42.4 |
| 2016 | 18,704 | 11,527.75 | 51.5 | 70.0 |
| 2017 | 31,102 | 20,107.31 | 66.3 | 74.4 |
| 2018 | 43,684 | 29,023.52 | 40.5 | 44.3 |
| 2019 | 47,806 | 33,858.58 | 9.4 | 16.7 |
| 2020 | 53,171 | 39,677.89 | 11.2 | 17.2 |
| 2021 | 61,158 | 43,243.24 | 15.0 | 9.0 |
| 2022 | 51,724 | 38,608.88 | -15.4 | -10.7 |

*Source: NAPIC, various years*

In Table 5, the findings from this research can be observed as the top 3 state overhangs, the most overhangs of property types, the highest overhang price ranges, and the high and low YoY % changes of volume and value.


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**Table 5**: Summary of Findings on Secular Trend in Property Overhang in Malaysian Residential and Serviced Apartments

| | |
|---|---|
| Top 3 State | Johor, Federal Territory Kuala Lumpur and Selangor |
| Type (most overhang) | Serviced apartment and Condominium/Apartment |
| Price range | RM500,000 – RM1,000,000 |
| Volume (% change) | 66.3% (2017) – high<br>-15.4% (2022) – low |
| Value (% change) | 74.4% (2017) – high<br>-10.7% (2022) – low |

*Source: Author, 2024*

## CONCLUSION

Property overhangs happen all over the world, including Malaysia. Many factors influence this phenomenon, including house prices not matching buyers' monthly income (Nor, 2021); homebuyers' preferences (Cheng & Ling, 2022); indiscriminate approvals by various local authorities (Adzhar et al., 2021; Ab Rahim et al., 2019) and many more. Evidence also showed that these overhang factors differ from country to country, and every country has its own approaches to overcoming them. It is important to look at the imbalance between supply and demand because the overhang in Malaysia started from excessive supply in 2016 and the continuing rise in the housing market (Hung, 2020).

The findings from this analysis reveal that the top three (3) states with overhang residential and serviced apartment properties are Johor (19,390 units), Federal Territory Kuala Lumpur (9,441 units), and Selangor (6,624 units). Condominiums/Apartments and serviced apartments are the highest type of overhang properties with a price range of RM500,001 – RM1,000,000. The highest percentage change for volume is 66.3% (2017), and the lowest is -15.4% (2022). The highest percentage change for value is 74.4% (2017), and the lowest is -10.7% (2022).

The overhang of residential and serviced apartment properties in Malaysia should not be taken lightly. The one-decade data on overhang indicates that the overhang will not go away soon. Hence, a solution must be considered to help reduce this phenomenon, especially for the agencies and stakeholders such as the state and local authorities and developers to work together. This study provides insight into the performance of overhang residential and serviced apartment properties in Malaysia. This data will be used in the upcoming research to examine the factors that influence the overhang of these properties.

## ACKNOWLEDGEMENTS

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# FOSTERING PERCEIVED SAFETY IN NEIGHBOURHOOD PARKS: EXPLORING THE INFLUENCE OF PLANTING DESIGN, SCENIC VISTAS AND MAINTENANCE FACTORS

**Nurfadilah Saadul Kurzi[1], Olaf Schroth[2], Wan Azlina Wan Ismail[3], Syahidah Amni Mohamed[4]**

[1,3,4] *Department of Landscape Architecture,*
*Faculty of Architecture and Ekistics,*
UNIVERSITI MALAYSIA KELANTAN
[2]*Faculty of Landscape Architecture,*
WEIHENSTEPHAN-TRIESDORF UNIVERSITY OF APPLIED SCIENCES (HSWT)

## Abstract

Neighbourhood parks serve as essential recreational infrastructure, offering opportunities for captivating natural experiences near residential zones, thereby delivering social, physical, and cultural amenities that enhance the well-being of the community. Nevertheless, numerous studies have shown that a decrease in perceived safety significantly impacts individuals' ability to derive enjoyment and comfort from their outdoor green spaces. This, in turn, influence the perceived quality of life among Malaysians, as documented by the Malaysian Economic Planning Unit (EPU). There is a lack of research investigating the relationship between well-maintained landscape and the perception of personal safety, with the majority of existing studies originating from foreign sources. Therefore, this study was undertaken to collect evidence addressing these gaps within the context of Malaysia. This endeavour is vital to assimilating valuable knowledge to enhance the ongoing processes of both place-making as well as place-keeping within Malaysian park management.

***Keywords***: Neighbourhood Park, personal safety, perception of personal safety, community engagement.

[1] Lecturer at Universiti Malaysia Kelantan. Email: nurfadilah.sk@umk.edu.my

## INTRODUCTION

The neighborhood park serves as essential green space infrastructure, located in close proximity to residential areas, significantly contributing to the enhancement of community quality of life through diverse nature experiences (Kimic & Polko, 2021; Moulay et al., 2017). In contemporary society, public safety has become a crucial factor for achieving an improved quality of life, with growing attention to heightened security levels, particularly in urban green spaces (Abdul Rahman and Abdul Razak, 2021). Despite a decrease in the crime index, the perceived quality of life in Malaysia remains a serious concern (Ros Mahadi et al., 2023; Mulok et al., 2018). The fears and threats resulting from crime news and incidents impact the perception of green spaces and personal security (Kimic & Polko, 2021). In fact, crime itself is a serious social problem that directly impacts overall quality of life (Abdul Rahman and Abdul Razak, 2021).

Studies on the perception of personal safety concluded that fear of crime can have more complex reasons beyond the occurrence of crime incidences (Khan, 2015; P. Sundramoorthy, 2014). Consequently, a perceived lack of safety can restrict the use of outdoor spaces (Banchiero et al., 2020; Jenks & Dempsey, 2007; Nam & Dempsey, 2020). Public outdoor spaces must meet three criteria—protection, comfort, and enjoyment—to ensure their optimal utilization (Suhaila et al., 2017; Soholt, 2004). These criteria contribute significantly to the sense of feeling safe (Suhaila et al., 2017). Nevertheless, numerous studies have shown that a decrease in perceived safety significantly impacts individuals' ability to derive enjoyment and comfort from their outdoor green spaces. Previous studies have emphasized the importance of a well-maintained, high-quality environment in influencing positive perceptions of outdoor surroundings. This finding aligns with prior research conducted in Malaysia (Suhaila et al., 2017; Aldrin et al., 2012; Maruthaveeran & Van den Bosh, 2015; Siti Rasidah & Aldrin, 2012; Sreetheran & van den Bosch, 2014). However, these studies have primarily focused on the general environmental aspects and have not delved into the specific elements of physical recreation and their associated maintenance cues, which are integral components contributing to the overall quality of a park.

Bedimo-Rung et al. (2005) categorized park landscapes into two states: those amenable to change over time and those that remain fixed based on their initial planning. This dual state nature implies that maintenance processes must accommodate both conditions, and this duality has long-term implications for their appearance, in line with similar findings from various parts of the world (Bedimo-Rung et al., 2005; CABE Space, 2007). Given that maintenance processes are continuous and routine work, they are considered integral components of the urban environment. Ultimately, these processes play a crucial role in ensuring the sustainability and quality of life in urban areas (Paramita, 2019).

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Physical disorder serves as an indicator of deficient or insufficient maintenance and simultaneously signifies neglect, which can potentially evoke feelings of vulnerability to crime (Sreetheran & van den Bosch, 2014). This feeling of vulnerability according to Paramita (2019) suggests that the process of maintenance reveals hidden issues that causes discomfort and deterioration of a space. Therefore, this study delves into the physical factors associated with maintenance that serve as cues influencing individuals' perceptions of personal safety. Notably, the research gap underscores the scarcity of literature addressing perceived safety in Malaysia in this present moment.

## METHODOLOGY

The national concern regarding quality of life has included crime and public safety as major issues since 2000. It began with the national report on the Malaysian Quality of Life Index (MQLI 2004-2011), followed by the Malaysian Well-being Index (MWI) in 2013, and currently, the Malaysian Liveability Index (iDAM), introduced in 2021. These initiatives aim to assess the community's quality of life, well-being, and liveability to provide a high standard of living environment.

The government has undertaken various initiatives to address the issue of crime incidences, implementing measures to enhance the public safety component and target crime prevention at the national, local, and community levels. The National Key Result Area (NKRA), initiated in 2009, focused on reducing crime as a key developmental goal, beginning with the four states leading in crime statistics. According to the latest data from 2022, Selangor is ranked fourth highest in recorded crimes among these identified hotspots, compared to being second highest between 2010 and 2017 (Economic Planning Unit, 2023; Dass & Ananthan, 2019; P. Sundramoorthy, 2014).

Former Minister of Home Affairs, Dato' Seri Dr. Ahmad Zahid Hamidi, emphasized the importance of addressing crime incidences with consideration for the perception of crime and fear as well. He stressed, *"It is now about tackling perception, sentiments, and the reality. As long as the rakyat feel unsafe, we will continue to look at crimes which were not given much attention before, such as break-ins and crimes at shopping malls,"* (The Editor, 2021).

Nevertheless, further exploration is required to address the conceptual uncertainties surrounding 'fear of crime' and 'fear of becoming a victim' (Abdul Rahman and Abdul Razak, 2021). To fill these gaps, this paper focuses on distinguishing physical cues of fear and safety perception in community green spaces in dwelling areas.


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**Table 1:** Malaysian Crime Index Ratio by States

| **State** | **Crime index ratio** | | |
|---|---|---|---|
| | 2022 | 2021 | 2020 |
| **Malaysia** | **146** | **153** | **194** |
| W.P. Kuala Lumpur | 241 | 303 | 414 |
| Kedah | 200 | 163 | 182 |
| Pulau Pinang | 188 | 208 | 213 |
| Selangor | 188 | 216 | 257 |
| Negeri Sembilan | 151 | 155 | 209 |
| Perlis | 149 | 161 | 186 |
| Melaka | 132 | 133 | 187 |
| Sarawak | 130 | 144 | 201 |
| Perak | 123 | 110 | 130 |
| Johor | 111 | 108 | 187 |
| Terengganu | 110 | 119 | 162 |
| Kelantan | 108 | 99 | 129 |
| Pahang | 105 | 114 | 133 |
| Sabah | 96 | 80 | 92 |

*Source: Economic Planning Unit (2023)*

When discussing feelings unsafe and the fear of crime, one significant outdoor environment that encourages a misperception of safety is public green spaces. This misperception leads to discomfort and, consequently, causes a deterioration of these spaces (Dempsey and Burton, 2012). In Malaysia, a neighborhood park is a recreational area that provides activities such as sports and social events for the local community (PLANMalaysia, 2013), managed by the local authority. Neighborhood parks significantly contribute to the mental health and well-being of surrounding communities by offering social, physical, and cultural services derived from the nature experience within the residential areas.

In the district under the jurisdiction of Majlis Bandaraya Subang Jaya, there are only four public neighborhood parks under their supervision. However, for this study, only three parks were selected due to their location in built-up urban areas. The chosen parks are Taman Tasik Seri Serdang, Taman Puchong Perdana, and Taman Wawasan Recreational Park (Figure 1). Additionally, this study focuses on only one local government without comparing it with any other authorities.

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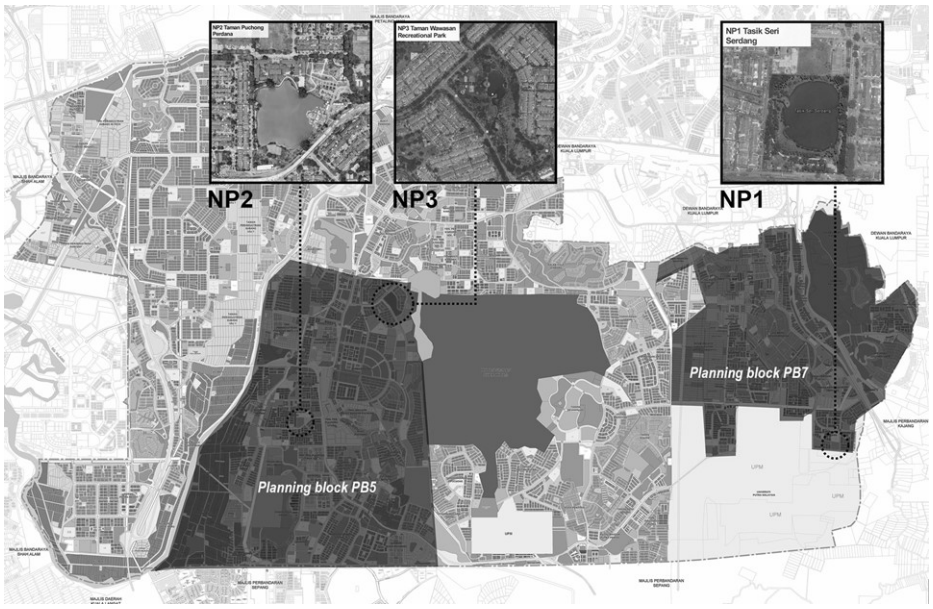


**Figure 1**: The three selected neighbourhood parks - Taman Tasik Seri Serdang (NP1), Taman Tasik Puchong Perdana (NP2), and Taman Wawasan Recreational Park (NP3)
*Source: Rancangan Tempatan Majlis Bandaraya Subang Jaya*

## Survey Questionnaire Methods

**1. Layers of planting and view distance *(Jenis-jenis tanaman dan jarak pemandangan)***

1. A layer of trees with long-distance view *(Satu lapisan tanaman dengan jarak penglihatan yang jauh)*

| | | LOW ◄ | | | | | | | | | ► HIGH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| a) | Practice | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| b) | Preference | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| c) | Perceived safe | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

**Figure 2**: The place's image-based questions with 1 to 10 scores of Likert-scale
*Source: Author*


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Statistical analysis methods were used to identify the effect of maintenance on users' acceptance of park design and conditions, and how they impact their perception of personal safety. To obtain more accurate answers, 10-point Likert scale questions on twelve (12) items based on images of the actual site conditions, plus two questions on general perceptions and perceived care were used (refer Figure 2). The images were taken during an earlier site verification process in order to obtain likely similar responses to the respondents actually being at the park, especially among the residents of the surrounding neighbourhood.

The twelve (12) items that are measured are divided into four main attributes that were generated through the literature studies. The attributes and items measured are as follows (Table 2).

**Table 2:** Twelve (12) measures on users' acceptance and perception of personal safety

| Attributes | Items |
|---|---|
| Types of planting and views | 1. Single layer planting with long-distance view<br>2. Multi-layer planting with wide view<br>3. Multi-layer and overlaid with limited visibility |
| Planting structure | 4. Organised planting<br>5. Naturalistic planting effect |
| Facilities and maintenance | 6. Trees and plant maintenance/presence of bushes<br>7. Defective and faulty equipment<br>8. Broken walkway/track |
| Cleanliness and waste management | 9. Near the building and structures<br>10. General waste and trash<br>11. Standing water<br>12. Tipping and illegal waste dump |

*Source: Author*

## One-way ANOVA

One-way ANOVA was carried out to analyse the statistical significance of these maintenance variables to perception of safety. Initial exploration found an association between physical factors and conditions and perception of safety.

Assuming the probability that the correlation alone would be insufficient to indicate that the perceptual judgment can be predicted by measuring the place conditions and/or from the independent effects of individual measures, further analysis was undertaken, such as regressions for predictive relationship tests or ANOVA to compare more than two groups of safety factors, i.e., gender, age, location, and time.

## Exploratory Factor Analysis (EFA)

An exploratory factor analysis (EFA) was conducted to specify the potential correlation between 12 measures of landscape design and views, and maintenance

factors. EFA has been used in the past to classify factors in smaller sets especially for a large set of variables by testing it in a different context (Hur & Nasar, 2014). Principal component analysis (PCA) was utilized, and for the purposes of rotation, it was assumed that the factors were correlated, employing Oblimin with Kaiser Normalization (Hinton et al., 2014). The recommended sample size for EFA in this study was 187 (N = 187).

The results indicated the KMO value was .877, exceeding the recommended value of .6, which suggested an adequate sampling for factor analysis. The PCM revealed the presence of three components with eigenvalues exceeding 1, explaining 44.7%, 15.7% and 11.2% of the variance, respectively. The two-component solution explained a total of 71.6% of the variance, with Component 1 contributing 44.7%, Component 2 contributing 15.7% and 11.2% contributed by Component 3.

## RESULTS AND DISCUSSION

The study analysed the physical factors that affected users' perception of personal safety and caused them to perceive those cues as threats. To the author's knowledge, this study is the first to examine people's perception of personal safety, particularly in terms of maintenance factors in Malaysia, specifically in Subang Jaya, Selangor.

### Acceptance of and preferences for park design and maintenance: demographic characteristics

The initial findings from the descriptive analysis illustrate the similarities and differences between the background and character of each demographic grouping in relation to each of the three neighbourhood parks.

The gender balance of all respondents in the survey is fairly even at 50.8% male and 49.2% female. However, when broken down to individual parks, there are differences in gender percentages for the three neighbourhood parks. Two parks recorded a majority of male respondents, NP1 (52.5%), and NP3 (60.7%), while NP2 only has 39.3% male respondents.

No neighbourhood park shows any significant differences in ethnic composition. There is a higher proportion of respondents from a Malay ethnic background in Taman Tasik Seri Serdang, (NP1, 55.9%) and Taman Tasik Puchong Perdana (NP2, 69.4%), while Taman Wawasan Recreational Park, NP3, recorded the least number of Malays (20%).


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**Table 3:** Respondent demographics for the three neighbourhood parks

| **Respondent's characteristics** | **Percentage** | | |
|---|---|---|---|
| | **Taman Tasik Seri Serdang (NP1)** | **Taman Tasik Puchong Perdana (NP2)** | **Taman Wawasan Recreational Park (NP3)** |
| **Sex** | | | |
| Male | 53% | 40% | 60% |
| Female | 47% | 60% | 40% |
| **Ethnicity** | | | |
| Malay | 56% | 69% | 20 |
| Chinese | 10% | 11% | 20 |
| Indian | 25% | 16% | 5 |
| Other *Bumiputera** | 3% | 2% | 4 |
| Others | 5% | 2% | 11 |
| **Age** | | | |
| 18-29 yo | 33% | 47% | 28% |
| 30-39 yo | 41% | 23% | 26% |
| 40-49 yo | 17% | 13% | 30% |
| 50-59 yo | 7% | 11% | 5% |
| 60-69 yo | 2% | 4% | 10% |
| 70 and above | - | 2% | 2% |
| **Education** | | | |
| Primary school | 4% | 3% | 12% |
| Secondary school | 22% | 53% | 35% |
| Certificate & equivalent | 10% | 10% | 10% |
| Diploma & equivalent | 24% | 23% | 17% |
| Degree holder | 34% | 8% | 25% |
| Master & PhD | 7% | 3% | 2% |

* *Bumiputera* stands for ethnicity groups including Malays, aboriginal, and the indigenous people of Sabah and Sarawak states.

Results for respondents' acceptance of the twelve (12) practices of planting design, views and maintenance show that the most favoured planting compositions are those that offer long-distance and wide views, either in single layer (m=7.45) or multi-layer planting (m = 7.14). The least accepted planting design and views is the design that offers limited visibility (m = 7.14).

The significant differences in acceptance are illustrated across gender and ethnic backgrounds. The mean rating among the Indian respondents range from 8 (moderately preferred) to 9 (very preferred), except for multi-layer planting with closed visibility and organised and structured planting with ratings lower than 7 (slightly preferred). Chinese and respondents of other ethnic backgrounds rate the multi-layer planting design differently (refer to Figure 1). It is believed that the respondents do not have a significant concern about the

planting design itself; rather, their views are of great importance to them. In this regard respondents generally show a significant lack of comfort in enclosed spaces

Interestingly, naturalistic planting is liked the most by a majority of respondents (m = 7.28) compared to an organised and structured planting in all three neighbourhood parks (refer Table 3).

**Table 4:** Mean rating for acceptance of and preferences for 12 practices in planting design, views, and maintenance conditions

| | **NP1** | **NP2** | **NP3** |
|---|---|---|---|
| | **Mean** | **Mean** | **Mean** |
| **Planting design & views** | | | |
| Single layer of trees with long distance view | 7.96 | 6.85 | 7.64 |
| Multi-layer planting with wide view | 7.78 | 6.43 | 7.19 |
| Multi-layer planting and overlaid with closed/limited visibility | 7.79 | 5.90 | 6.09 |
| Organised and structured planting | 6.75 | 5.08 | 5.36 |
| Naturalistic planting | 7.72 | 6.64 | 7.53 |
| **Maintenance variables** | | | |
| Tree and plant maintenance | 6.96 | 5.05 | 6.03 |
| Defective and faulty equipment | 7.34 | 5.72 | 6.20 |
| Broken path and track | 5.65 | 4.72 | 4.05 |
| Cleanliness near building and structures | 6.16 | 4.62 | 5.16 |
| General waste and trash | 5.26 | 4.20 | 5.00 |
| Standing water with waste | 4.74 | 3.82 | 3.92 |
| Tipping and illegal waste dump | 4.54 | 3.66 | 4.15 |


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**Table 5:** Acceptance of 12 practices in planting design, views and maintenance conditions

| **Result between subjects** | **Significant to demographic background** | | |
|---|---|---|---|
| | **Neighbourhood parks** | **Gender** | **Ethnic group** |
| **12 awareness of practices** | | | |
| F(11, 1881) = 76.8, p<.001 | F(22,1859) = 1.7, p = .01 | F(11,1859) = 2.5, p = .004 | F(44,1837) = 1.8, p = .001 |
| **Planting design & views** | | | |
| F(4,688) = 35.7, p<.001 | n/r | F(4,680) = 2.51, p = .04 | F(16,672) = 1.93, p = .02 |
| **Maintenance variables** | | | |
| F(6,1044) = 43.8, p<.001 | F)12,1032) = 2.05, p = .02 | n/r | F(24,1020) = 2.1. p = .001 |
| **Neighbourhood parks** | | | |
| F(11,1859) = 77.6, p<.001 | | | |

*The results use the Greenhouse-Geisser correction for the significant results.*
**there are significant differences between subjects, p< .005*
***there is significance relationship within subjects for p < .05*

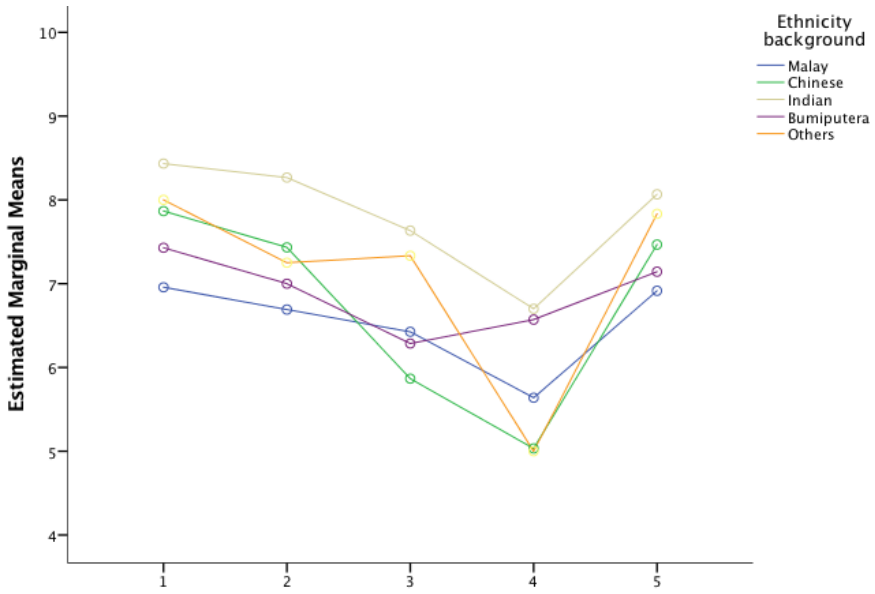


**Figure 3:** Preference scores between ethnic backgrounds

Regarding maintenance, two specific concerns are raised by the respondents: the presence of standing water with waste (mean = 4.08) and incidents of fly-tipping and illegal dumping of waste (mean = 4.06), especially in Neighbourhood Park 2 (mean = 3.66). These findings imply that a significant number of respondents are dissatisfied with the visible aspects of the park's appearance. In contrast, many respondents express moderate satisfaction with the presence of defective and faulty equipment (mean = 6.37).

**Influential Determinants: Maintenance Cues and Perceptions of Personal Safety**

Following the analysis of general feelings and overall park perceptions, the study further explored these findings using simple regression to predict the strength of the feeling of safety influenced by preference for and acceptance of 12 specific measures related to the physical environment and maintenance issues.

The largest Beta (β) coefficient indicating the strongest contribution in explaining the feeling of safety, is observed with regard to standing water with waste (0.944). This is followed by general waste and trash (0.922) and tree and plant maintenance (0.907). The proximity of the β values suggests that preferences for these three factors contribute similarly to the overall feeling of safety. This suggests that the higher the preference for the waste and trees-related measures in the neighbourhood park, the safer people feel within these specific contexts.

Further analysis was carried out through exploratory factor analysis (EFA) and led to the identification of new physical factors influencing the perception of personal safety, assuming that the factors are correlated. As a result, three factors were identified, collectively explaining 72% of the variance. The pattern matrix of the final solution is presented in Table 5.


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**Table 6:** Development of physical Indicators of perception of safety

| New Physical Factors | Item | Factor loading | E | % |
|---|---|---|---|---|
| ***Maintenance and appearance*** | | | | |
| | Standing water with trapped waste | .883 | 6.701 | 44.67 |
| | Fly-tipping and illegal waste dump | .832 | | |
| | Cleanliness near building and structures | .734 | | |
| | General waste and trash | .727 | | |
| | Tree and plant maintenance | .726 | | |
| | Broken path and track | .592 | | |
| | Organised and structured planting | .543 | | |
| ***Planting design and organisation*** | | | | |
| | Multi-layer planting with wide view | -.939 | 2.356 | 15.71 |
| | Naturalistic planting | -.850 | | |
| | Single layer of trees with long distance view | -.802 | | |
| | Defective and faulty equipment | -.534 | | |
| | Multi-layer planting and overlaid planting with closed visibility | -.500 | | |
| ***Environmental satisfaction*** | | | | |
| | Feeling safe to have company (friends/ family) in the park | .991 | 1.684 | 11.23 |
| | Feeling safe to be alone in the park | .892 | | |
| | Feeling comfortable in the park | .881 | | |

The most significant factor, 'maintenance and appearance', contributes to 44.67% of the total variance, making it the primary influence on perceptions of personal safety. All indicators within this category pertain to the physical upkeep and aesthetic qualities of the landscape. The peak values pinpoint the factors exerting the most significant influence on individual perceptions of safety—specifically, standing water with trapped waste, tipping, and illegal waste dump. These findings imply that indicators of inadequate waste disposal practices in the parks significantly influence the perception of personal safety. The results illustrate that cues from poor maintenance and ineffective waste management in the neighbourhood park significantly shape individuals' perceptions of personal safety.

The second factor, explaining 15.71% of the total variance, is described as 'planting design and organisation'. This factor encompasses visual elements such as multi-layer planting with a wide view, naturalistic planting, single-layer trees with a distant view, defective and faulty furniture, and overlaid planting with closed visibility. Nevertheless, negative loadings indicate an inverse relationship with perceptions of personal safety. It is crucial to note that negative

loadings do not signify the strength of the factors (Asnawi et al., 2012). Therefore, this study suggests that these components are less prevalent in the park, yet the preference for and acceptance of wide and distant views and naturalistic elements are the highest.

The third factor, representing 11.23% of the variance, is 'environmental satisfaction'. This factor sums up the common feeling towards the outdoor environment. Despite being a less influential factor on the perception of safety in the park, it is noteworthy that a majority of park users report feeling safer in the company of others in the park.

**Mediating Factors Impacting Perception of Personal Safety**

Previous studies have suggested connections between demographic factors, experience of crime, and personal experience as mediating factors influencing perceptions of personal safety. Gender, age group, and ethnic minority status have been consistently identified as strong factors associated with personal safety perceptions (CABE, 2004; Mak & Jim, 2018; Siti Rasidah & Aldrin, 2012; Sreetheran, 2017; Sreetheran & van den Bosch, 2014; CABE Space, 2007). Beyond demographic factors, it has also been found that personal experiences of crime impact perceptions of safety (Mak & Jim, 2018).

The findings suggest that the first factor, 'maintenance and appearance' is less likely to be affected by the three measures: demographic factors, familiarity with the park, and experience of crime. The only relationships found were age ($p = .006$), and satisfaction with the facilities and recreational resources provided ($p < .001$), and preference for an overall design with big trees and shade ($p = .022$). Further analysis of the age indicator suggested that respondents aged between 60 and 69 years old are more likely to report dissatisfaction with the environmental condition and maintenance.

In contrast, the third factor, 'environmental satisfaction' was found to be affected by most of the measures. Socio-demographic background showed a strong association with perception of personal safety. Upon a more in-depth analysis of the data, it becomes evident that males, individuals of Indian descent, and other ethnic groups tend to report higher levels of comfort and safety when in the park alone. The Indian community exhibits a greater sense of safety in relation to the park's planting design and organisation, whereas the minority ethnic group, Bumiputera, conversely reports a diminished sense of safety concerning these aspects. Socioeconomic status and educational attainment also exert an impact on individuals' perceptions of personal safety.


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**Table 6:** Mediating factors on perception of personal safety

| | **Environmental Satisfaction** | **Planting design and organisation** | **Maintenance and appearance** |
|---|---|---|---|
| **Demographic factors** | | | |
| Sex | P = .001 | X | X |
| Age | P< .001 | P = .003 | P = .006 |
| Ethnic background | P< .001 | P = .003 | X |
| Homeownership status | X | X | X |
| Household composition | P = .025 | X | X |
| Periods of dwelling | X | X | X |
| Length of residency | X | X | X |
| Working background | P< .001 | P = .044 | X |
| Level of education | P = .002 | X | X |
| Frequency of visit to the park | P< .001 | P = .006 | X |
| Accompany during the visits to the park | P = .024 | X | X |
| Location of the park from home | P = .036 | X | X |
| Satisfied with the facilities provided and recreational resources | P < .001 | P < .001 | P < .001 |
| Like the overall atmosphere with big trees and shades | P < .001 | P < .001 | P = .022 |
| Enjoying the good scenery of the lake | P < .001 | P < .001 | X |
| Aware of any presence of patrol (park staff, police, guards) | P = .037 | P = .036 | X |
| Experience of crime anywhere/or witnessed a crime | X | X | X |
| Experience of crime/ or witnessed a crime in the neighbourhood park | X | P = .019 | X |

*X= no relationship*

## CONCLUSIONS

One of the interesting findings concludes that the presence of water bodies such as a lake that was found in each of the three neighbourhood parks, play a crucial role in contributing to maintenance issues. Additionally, the location of the lake close to the residential areas (e.g. housing facing lake) contributing to the issues of fly-tipping and illegal dumping of waste. A noteworthy observation is that the sense of safety experiences a significant decline in areas plagued by this

maintenance problems. Users of the park tend to avoid spaces or designs that pose a physical security risk, threatening their well-being and diminishing the overall appeal of the park.

On the other hands, visual accessibility emerges as a pivotal factor influencing the perception of personal safety. The design and arrangement of plants play a vital role in determining visual accessibility, encompassing factors such as openness, closed visibility, or limited visibility, and spatial enclosure. The research underscores a heightened preference for open spaces, indicating that the concept of openness fosters comfort and a sense of safety in the outdoor environment, irrespective of the specific planting design (whether single or multi-layered).

The findings suggest that most park users experience a reduced sense of safety when alone in their neighborhood park. Interestingly, this study concluded the differences appeal and comfort in the park when alone between ethnic group. The ethnic minority tends to feel more unsafe in disorganised design and spaces. This finding supported the claimed that and minority groups from certain ethnic backgrounds can tend to feels more insecure and vulnerable (CABE Space, 2007). This underscores the importance of addressing maintenance issues and optimizing visual accessibility to enhance overall feelings of safety among park users.

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# URBAN VOIDS: NATURE-BASED SOLUTIONS (NBS) TO REVITALISE KUALA LUMPUR

**Kayelvili Krishnamoorthy[1], Yasmin Mohd Adnan [1,2], Azlina Md Yassin[3]**

[1]*Centre for Sustainable Urban Planning and Real Estate (SUPRE),*
*Faculty of Built Environment,*
UNIVERSITI MALAYA
[2]*Department of Real Estate, Faculty of Built Environment,*
UNIVERSITI MALAYA
[3] *Faculty of Technology Management and Business,*
UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## Abstract

Leftover spaces caused by disparate developments have been identified as key factors in the formation of urban voids within Kuala Lumpur. This paper, therefore, attempts to determine the counter measures that can be taken to remedy the issue of urban voids at a more granular level while coherently revitalising the city in a sustainable manner with the aid of nature-based solutions (NBS). To achieve this aim, this paper examines the implementation of nature-based solutions in urban voids through a qualitative approach. This includes reviewing NBS undertaken to revitalise lacklustre regions via urban green spaces (UGS) and gathering focused insights on the issue from urban experts via semi-structured interviews. It has been understood that the lack of comprehensive planning guidelines and a framework to monitor these urban voids has led to the formation of these urban voids. In relation to this, data transparency, bottom-up approach and human-centric planning have been found critical to effectively revitalise these urban voids for a well-rounded resilient solution for the community and city.

***Keywords***: Framework, Revitalisation, Urban Green Spaces (UGS), Urban Void

[2] Professor at Universiti Malaya, Email: yasmin_alambina@um.edu.my

## INTRODUCTION

The urban model of a city plays a central role in shaping the forms, spaces, bodies, and voids of a city. However, despite their significance, the aspects of typology and spatial cohesion have often been overlooked in many of these developments during their formative stages. As a result, many of these cities experienced significant depletion of green spaces and the emergence of unstructured anti-spaces, commonly referred to as "urban voids''.

The prolonged existence of urban voids can unfortunately result in discriminatory practices such as redlining, which can lead to the segregation of neighbourhoods and communities, exacerbating societal gaps and cultural decline. While many factors are behind the rupture of urban voids, the boom and bust of the real estate cycle is largely believed to be at the crux of this phenomenon. These urban voids, however, present cities with the infinite probability of adopting sustainably conscious nature or biophilic-based solutions through the reinforcement and integration of spaces within their natural setting in a holistic manner (Kellert, 2015).

While urban renewal remains a key approach to tackling the issue of urban voids, the track record of its successes and failures remains varied and uncertain to this day. It is therefore critical for a comprehensive revitalization framework so that complex cross-sectoral efforts of rescuing distressed cities to improve the local community, environment, and economy can be carried out efficiently and effectively.

The study explores the hidden opportunities and values of urban voids in Kuala Lumpur from a sustainable perspective. This is particularly critical during the recovery phase of Kuala Lumpur following the COVID-19 pandemic. The following are the objectives of this paper, i) To identify the variables of urban voids within the context of cities, ii) To compare selected urban revitalization initiatives within other Asian cities and iii) To propose a viable framework that can be adopted by Kuala Lumpur

## LITERATURE REVIEW

### Urban Voids

The term ‘urban void’ is an almost illusive concept associated with the dichotomies of anti-spaces and buffer zones, and are terminologies used to label the oblivion of leftover spaces as a by-product of urban abandonment arising from a kind of obsolescence or loss in the form of economic value, spatial integrity, and urban connectivity (Lopez-Pineiro, 2020). These spaces are typically associated with the lack of lighting, security and waste management, the latter being a prominent cause of flooding problems in Asian cities. However, despite the various extent of studies, the notion of urban void remains ambiguous and unquantifiable, primarily due to its non-scale and non-discipline specific qualities (Lee, 2015).

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The long-term consequences of these forlorn spaces, however, can account for more pressing social issues such as dysconnectivity between the social fabric and these places, depletion in local culture due to perceived segregation of neighbourhoods, and eventually resulting in societal gaps. In addition to that, it can also result in a loss in favourability as a tourist destination and have a detrimental influence on cities that rely significantly on tourism for revenue.

**Urban Revitalisation**

Urban revitalisation is a process by which a part of the city in social, urban or economic crisis undergoes a rehabilitation process in order to reverse its declining trend (Gonçalves, 2016.). That is to say, it is a comprehensive intervention effort to redevelop neglected areas that are lacklustre and in the process of decay. As such, urban revitalisation is often seen as the answer to address urban voids. Concerns however always arise as to whether or not these revitalisation efforts are worth pursuing due to the impending costs involved. It is therefore essential to understand the inherent challenges and opportunities these urban voids present to discover the potential they hold (Lee, Hwang, & Lee, 2015).

Additionally, it is essential that these efforts are carried out in an ethically sustainable manner, and what this means is to achieve the aims of the initiatives without subsequently leading to additional larger problems, especially for future generations (IGI Global, n.d.). NBS entails addressing these concerns with nature in a sustainable manner while also providing socio-economic and environmental benefits (IUCN, n.d.). Case studies from across the world have demonstrated that NBS have the ability to boost a city's resiliency and liveability not only in a sustainable but also cost-effective manner.

***Urban Green Spaces (UGS)***

The perceived benefits make it additionally quintessential to revitalise the aforementioned leftover spaces by implementing NBS such as green roofs, pocket parks, and community gardens, and implementing additional measures such as re-routing traffic, and replacing them with green spaces instead (Nieuwenhuijsen, 2021). One of the methods to adopt NBS to tackle urban voids is by implementing urban green spaces (UGS). The World Health Organization (WHO) recommends that everyone have access to green space with no less than 0.5 ha and no more than 300 m in linear distance from every home.

The efficacy of this approach is however dependent on interventions that are complementary and integrated into the total environment, as opposed to isolated or temporary interventions that appear to be more of an afterthought. To implement these initiatives into a designated site context, it is hence crucial to understand the key factors that contribute to the success of its functionality. Some of the criteria used to evaluate the quality of green areas include walkability,


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inclusivity, infrastructure, vegetation, accessibility, security, location, and distribution (Herzele & Wiedeman, 2003).

On the other hand, while it can be difficult to precisely quantify the economic and fiscal benefits of these urban parks and open spaces, there has been growing awareness and acceptance towards the value they hold (Aliyu, Bello, Adamu & Singhry, 2016). It has been found that individuals are prepared to spend more on a home that is adjacent to green spaces and parks rather than one that is not. Property values primarily residential properties have also been found to rise by as much as 20% after a redevelopment or new UGS is completed (Aliyu et al., 2016).

## RESEARCH METHODOLOGY

Following the significant market slowdown brought upon by the pandemic breakout in early 2020, the real estate market in Malaysia still struggles to see improvement due to reduced property take-up rate as well as unfavourable purchasing conditions (Delmendo, 2023). The consequences brought upon by reduced demand and dampened economic conditions have also subsequently resulted in a critically evident property overhang and a significant decline in property values within the city of Kuala Lumpur (Delmendo, 2023).

Given all these factors, there has been a pressing need for the government to stimulate its real estate sector and economy once again, which makes it all the more compelling as a case study for this study purpose. A qualitative approach was adopted to study the revitalisation efforts that can be implemented to revitalise and harness leftover spaces within the city context of the primary case study. This methodology was appropriate for this study, as it required obtaining descriptive data to comprehend how the municipality has addressed voids in the city of Kuala Lumpur thus far.

### Case Study Approach

For the purpose of achieving the primary aim of this study, three (3) secondary Asian cities were chosen to serve as a benchmark in developing a viable revitalisation framework for the primary case study. The cities of Shanghai, Seoul and Singapore were selected in particular, for their innovation and cultural proximity to the primary case study, as well as their success in having undertaken specially tailored NBS to revitalise the lacklustre regions of its respective city. To understand the performance and design criteria that took precedence in the aspects of planning and implementing the precedent studies, performance profile wheels (PPW) were used to compare the data that was obtained.

### Administration of Interviews

In furtherance to understand how professionals in Kuala Lumpur perceive underutilised spaces, semi-structured interviews were conducted to gather

primary data with key informants who had strong affiliations with the built environment practice as shown in Table 1. The interviews were conducted via Google Meet and the four interviewees participated in the interview.

**Table 1:** Detail of Interviewees

| Interviewee | Position | Area of Expertise |
|---|---|---|
| 1 | Principal Architect & Head Planner at an International Architectural Firm | Architectural design, town planning, and land optimization |
| 2 | Academician & Panel of the Federal Territory of Kuala Lumpur Planning Appeal Board | Urban planning and management, planning law and local governance |
| 3 | Head of Design at a leading Real Estate Developer Firm in Kuala Lumpur | Real estate development and interior architecture |
| 4 | Director at an Architectural Firm in Kuala Lumpur | Architectural and urban issues |

## ANALYSIS AND DISCUSSION

### Primary Case Study: Kuala Lumpur

The rapid urbanisation in Kuala Lumpur today poses a critical problem for urban management, particularly with regard to the comprehension and administration of the spatial and social repercussions of planning policies. Additionally, the transport and land use planning strategies have brought long-term effects on the urban form, in particular on the street network as the city's backbone that affects the flow and pattern of movement. This has affected how individuals navigate and traverse the street network (Bertolini, 2017). The car-centric mobility pattern in KL has led to the subsequent poor integration and inadequacy of other public infrastructures such as walking paths and bicycle lanes, as well as the interconnection of different public transport modes.

Apart from that, the new hype over transit-oriented developments (TOD) in the Klang Valley region has led to a substantially large roll-out of properties to be constructed along highways and transit lines. The lack of cap limit over property developments within the city displays poor adherence to the land use zoning plan and building plot ratio in the city of Kuala Lumpur, without tackling the core problems.

Like many other Southeast Asian cities, Kuala Lumpur today primarily struggles to attain a balanced equilibrium between economic growth and the preservation of its lush natural environment. Instead of preserving the natural reserves, it has instead been making way for unrestrained residential, commercial, and industrial developments within its urban fabric (Mohd Noor, Abdullah, & Manzahani, 2013). Following the decline of green spaces in Kuala Lumpur over the decades, the city has also been experiencing detrimental climate problems such as increased land surface temperatures, and a severe decline in natural rain


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catchment areas which have led to the rampant occurrence of floods and landslides over the recent years (Noordin, Abdullah, & Shahbudin, 2007).

As a result of the latter, many residential areas have been experiencing a steep decline in value due to the risks it poses and the high number of abandoned properties along with the displacement of a high number of residents which have also accounted for the formation of urban voids. Apart from these instances, the common sight of underutilised rooftops, deteriorated parks, vacant old buildings, as well as the large excess of concrete riverbanks observed in Kuala Lumpur are all equally forlorn spaces that have lost their essence over the course of time, and can be defined as urban voids in this context. The rapid development has left the city lacking in visual and physical coherence (Khalid, Hilal, Nasrudin, & Marzukhi, 2018). Consequently, there has been a decrease in the legibility of the city structure together with a certain loss of historical continuum and sense of identity.

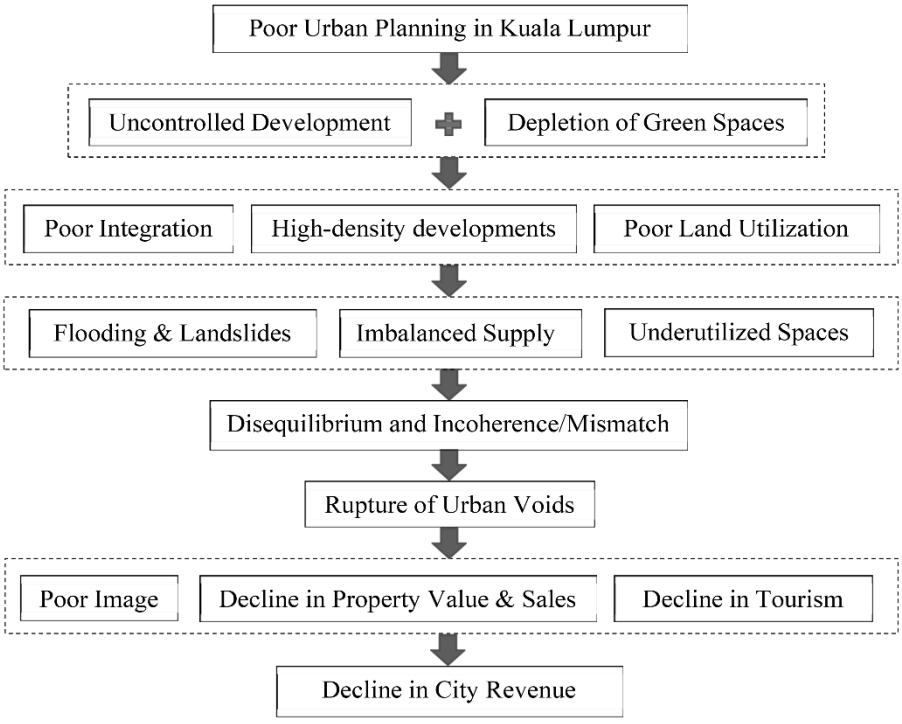


**Figure 1:** The root problem and consequential issues from inadequate urban planning in Kuala Lumpur

## Benchmarking: Shanghai, Seoul, and Singapore

The three cities that were selected for this benchmarking exercise are (i) Houtan Park in Shanghai, (ii) Cheonggyecheon Stream in Seoul, and (iii) Bishan-Ang Mo Kio Park in Singapore.

**Table 2:** Summary of Secondary Case Study Findings

| Case Study | Houtan Park | Cheonggyecheon Stream | Bishan-Ang Mo Kio Park |
|---|---|---|---|
| Type of Land | Brownfield with natural bank | Stream with artificial bank | Artificial canal with natural bank |
| Total Area in Acres | 35-acres (14 hectares) | 100-acres (40 hectares) | 153-acres (62 hectares) |
| Initiated By | Shanghai World Expo (Semi-gov.) | Seoul Metropolitan Government | PUB & NParks (Semi-gov.) |
| Approach | Top-Down | Bottom-Up | Bottom-up |
| Scale of Impact | City & Regional | Neighbourhood & City | Neighbourhood & City |
| Financing Cost | CNY 105 mil. (MYR 70 mil.) | KRW 384 bil.(MYR 1.28 bil.) | SGD 76 mil. (MYR243 mil.) |
| Long-term Cost | - | KRW 200 mil. (MYR 670 500) | SGD 4.45 mil. (MYR 14 mil) |
| Concept | Agriculture (tradition)<br>Industrialization (modernity)<br>Ecology (future) | History (tradition)<br>Culture + Urban (modernity)<br>Nature (future) | Blue (water)<br>Green (plants and trees) |
| Issues | Degraded environment<br>Flood control inadequacy<br>Site topography | Safety issue of the elevated highway<br>Air and water pollution<br>Slums within the area<br>Decline of surroundings and old CBD | Flash floods<br>Inadequacy and decline of concrete canals |
| Design Features | Regenerative wetland<br>Productive and educational landscape<br>Using recycled materials<br>Increasing the capacity of the park<br>Integration of cultural and natural layers | Urban natural stream<br>Integrating with surrounding environment<br>Ecological education<br>Recycling waste materials<br>Improving water irrigation and quality | Purifying and recycling rainwater<br>Recycling waste materials<br>Designing by trial and error<br>Integrating with surrounding environment<br>Strengthening community participation<br>Design inclusivity |
| Value | Immersive learning experience<br>Tranquil city getaway<br>Increase in rental rates<br>Increased site's biodiversity<br>Sequesters 242 t. of $CO_2$ annually<br>A tribute to city's history<br>Revitalized neighbourhood real estate market | Appreciation in property value<br>Stimulated nearby businesses<br>Increased employment rates<br>Reduced surrounding temperature<br>Increased fauna in the area<br>Reduced car traffic<br>Platform for cultural events | Enjoyable outdoor gathering place<br>Foster community participation<br>Increased nearby F&B revenues<br>Influx of tourists<br>Natural flood mitigation<br>Ecological education<br>Bolster water supply |
| Significance | Eight (8) patents with 20-30 new projects of similar strategies | Set precedence which led to the demolishment of 15 other expressways | Set precedence for similar concrete canals in Singapore to be demolished |


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In order to understand the performance and design criteria that took precedence in the aspects of planning and implementing the selected cities, this study utilised performance profile wheels (PPW) to compare the efficacy of its implementation based on four respective categories namely, accessibility, design quality, facilities, and health and well-being. While the key scores varied relatively between the three cities from the performance profile wheels, a distinct pattern was observed in their performances. The general key scores that were observed to have been of higher priority among the cities were accessibility and walkability, lighting and shade, genius loci, sensory stimulation, circulation, site visibility, recreational activities, cultural and heritage value, nature integration, design inclusivity and security. Apart from these, a bottom-up approach was preferred, with the importance put forth on human-centric planning as well as data transparency between the planners and the public. There was also increased emphasis placed on the subject of adaptability and resiliency in mitigating climate change effects and maintaining economic robustness.

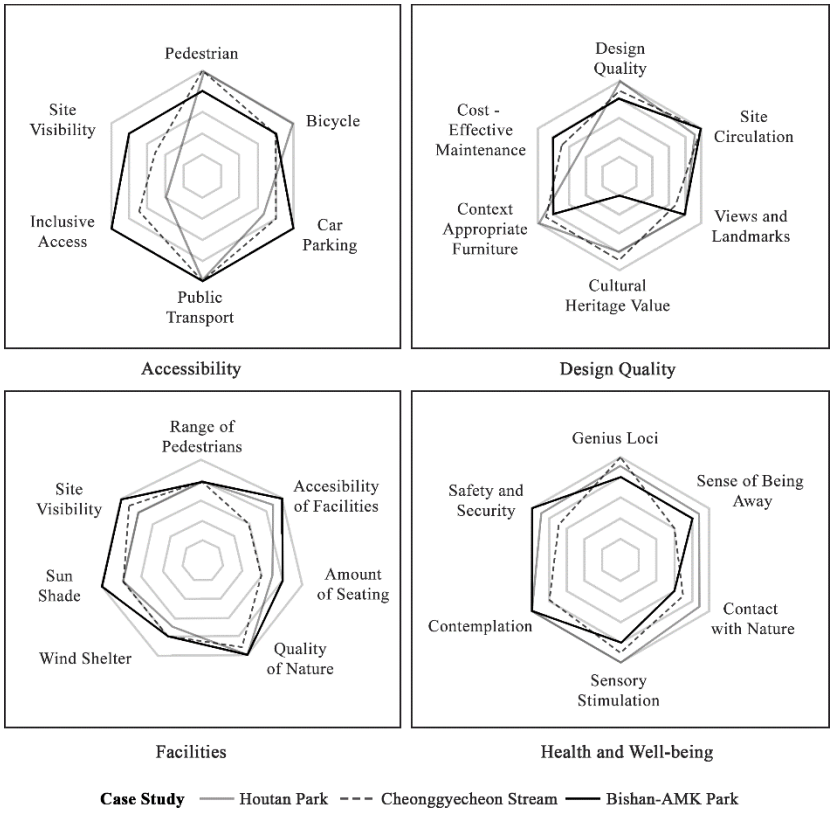


**Figure 2:** Performance Profile Wheels (PPW) of Secondary Case Studies
*Source: BlueHealth*

## Qualitative Analysis: Interview

### *Real Estate Market Outlook*

The global spread of COVID-19 had numerous consequences on the real estate sector in Malaysia and critically in Kuala Lumpur. One of the key issues has been the considerably slow recovery of the real estate market following its shift towards recovery where substantial depreciation in value, low take-up rates and overhang have been observed.

> *"The pandemic has indeed created a lot of artificial values about the actual market value of properties due to speculations. The real estate market in Kuala Lumpur is on a free-market basis where there is no significant board to control the real estate pricing such as the likes of Singapore."* - Interviewee 1

> *"It is hard to predict at the moment but there is a great need for comprehensive study on this subject matter to be carried out by government to freeze developments in areas that have a visibly high overhang or particular types of properties."* - Interviewee 1

Due to the unexpected outbreak of COVID-19, it is presently not possible to quantify and forecast future consequences and implications on the market. It is however critical to ensure market studies are conducted at shorter intervals, and that government authorities employ stringent controls to monitor and curb post-pandemic induced market oversupply. During this substantial period of recovery, it is additionally important that city councils and developers alike, examine and understand the restorative efforts that can instead be implemented to revive the economy and create value for the community in a sustainable manner.

### *City Planning*

The problem of urban voids within the city of Kuala Lumpur however, eventually trickles down to the lack of comprehensive planning and framework to address the problem. As it was observed, in comparison to cities like Shanghai and Singapore, Kuala Lumpur falls short in its up-to-date policy planning and guidelines, which leaves room for a lot of uncertainties, and subsequently makes it harder to enforce them due to the very malleable nature of it.

> *"The guidelines in KL are notably very far behind its Asian peers, in regard to addressing sustainable developments in a comprehensive manner…* - Interviewee 1


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> *"The system is not adaptive and receptive to changes that occur periodically and plans become quickly obsolete. There is also a predominant resistance to change that is not accepting of new strategies and planning systems."* - Interviewee 2

Despite sharing similar historical origins to Singapore, Kuala Lumpur is still very much influenced by the Old British planning system which has its pros and cons. The pro is that the system has a long historical tradition that has been brought forth from the 1920s. The difference however is that while the British system itself has evolved and undergone multiple significant changes to its system since, the city of Kuala Lumpur on the other hand still very much maintains the pre-dated old system that is no longer as relevant as it used to be due to the considerable shifts the city and country has underwent across the past decades due to urbanization.

> *"There needs to be higher public involvement in the decision-making process and less emphasis on bureaucracy within the city council. The current system is also still very much traditional and does not put precedence on scientifically based data and factors them into their planning."* - Interviewee 2

Apart from that, while the City Council of Kuala Lumpur may have made initiatives to listen to the opinions of the public, the bottom-down approach still lacks effective implementation, unlike its Asian peers.

> *"The city planning guidelines in KL are subject to higher abuse by stakeholders such as developers and even politicians. There is a high political interference as well as businessmen who have deep pockets that result in poor adherence to the initial guidelines."* - Interviewee 1

This is particularly due to the lack of data transparency and mutual trust between the public and authorities. The absence of real-time data is also a pre-dominant factor that influences this.

> *"For instance, in cities like Singapore, anyone can easily access data from the city council website in regard to land suitability for specific developments, duration and submission requirements… Our planning and data gaps are too wide and data reliability is extremely low, which is approximately only 30 to 40%."* – Interviewee 2

There is also a strong resistance to change that is not accepting of new strategies and planning systems. Hence, there is a strong need for real-time data

made accessible to the public as data should be public domain. Doing so will not only aid in increasing the efficacy of planning especially by non-governmental sectors but also curb the problem of power abuse and dishonesty.

Additionally, very poor emphasis has been put forth on green open spaces. While there are still large parks in KL, most of them are not immediately accessible and are quite a travel distance. There has also been an increase in motorised transport dependency to get to these places due to the overall poor walkability and accessibility around the city.

> *"There is no significant order in regard to planning development where you will at times find random structures and disconnected buildings scattered across the city. There is also incoherence within certain policies. But above all, the land use plan does not seem to be respected thus far and the city council appears to bend easily."* - Interviewee 4

> *"There is an issue of walkability, the lack of trees in the city and other multidimensional problems. Then there is also the increased frequency of environmental issues that have been inadequately addressed over the years, and as a result have become more severe."* - Interviewee 3

The disconnection of these spaces has additionally given rise to the occurrence of urban voids. Cities like Seoul and Singapore on the other hand have been making rigorous efforts to reduce motor traffic and bridge city gaps. This was evident in the revitalisation projects of Cheonggyecheon Stream in Seoul, and the Bishan-Ang Mo Kio Park in Singapore whereby concrete structures were torn down to instead make way for green spaces and improve city-wide pedestrian connectivity.

***Urban Voids***

There is generally a strong mindset among developers in Malaysia, that the product they offer will be unique, without the forethought on the displacement aftereffect of their property supply and attaining an equilibrium.

> *"There has been an unfortunate number of large development activities in an unsustainable manner without taking into account the project's long-term feasibility."* - Interviewee 4

This is largely due to the lack of comprehensive planning guidelines and monitoring by the city council in managing the cap limit on the type of developments depending on the area, density, and population. As a result, we have a high concentration of similar developments that do not integrate due to jarring design languages with the intention of being exclusively unique. These


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products, such as shopping malls and luxurious residential developments also tend to be concentrated only in particular nodes, solely based on the assumption that there will be a market for them, subsequently resulting in an imbalance in the urban fabric and the coherent rupture of urban voids.

> *"There needs to be a holistic platform to document data on urban voids, ownerships, geographical information as well as identify the potential of these sites..."* - Interviewee 2

In Singapore, authorities utilize dynamic data to not only manage the supply of properties but also actively monitor the status of vacant lands and their revitalisation processes in efforts to green their city. It is hence imperative that local city councils follow the lead of their Asian counterparts in exercising authority as a critical call for action especially in cities experiencing land scarcity, by addressing the urban voids and their notorious impacts in a holistic manner.

> *"Everything eventually boils down to the city council as they are the ones who are responsible and have the authority over the shifts that occur within a city."*- Interviewee 3

City councils therefore need to exercise their authority to address these cracks within the city given its notorious impact on the city. This is because, these urban voids are a critical call for action especially in cities experiencing land scarcity. To date, most of the initiatives that have been taken and implemented in KL have largely been initiated by private sectors or non-governmental organisations.

***Revitalisation***

Urban voids are hence valuable key connections that can help bridge the city in a sustainable manner. In the face of rapid urbanization and the rapid decline of green spaces within the city of Kuala Lumpur, the implementation of NBS such as UGS has thus been regarded as a holistic solution to tackling these urban voids as they open up a myriad of possibilities. This is because, these spaces hold the potential to create value for the community and city, boost the growth of the real estate market sector within the city and subsequently increase the chances for business revenue.

> *"... it will add value to the properties within its immediate effect and benefit the city on the long run ... opportunity for business revenue such as food carts, cafes, event venues and even alternative meeting spots for friends and clients."- Interviewee 3*

Efforts of revitalising the lacklustre voids within the city is however a multi-faceted approach that requires the effort of many to make it a success and is therefore equally important that no parties or groups work in isolation. Without the government's initiative on the matter, projects can only be taken on small scales and in a piece-meal manner, rather than in a comprehensive and cohesive manner.

> *"The city council should form a coalition body of multiple disciplines with private sectors such as architects, town planners, infrastructure & traffic engineers, property development consultants, land surveyors, social scientists, and financial consultants."* - Interviewee 1

However, while a comprehensive framework is critical to the effective implementation of revitalisation projects, this alone does not ensure its success. There are other critical factors that are equally crucial for a proposed framework to work effectively and coherently unlock its full capacity. For example, in the case of the Cheonggyecheon Stream's restoration, the idea to tear down the concrete structures covering the stream was largely made possible thanks to the broad visions of the then Mayor of Seoul. Had the highway restoration happened as per initial plans, it would have come at the cost of compromising the socio-economic and environmental qualities of the stream's immediate vicinity which was already in a deplorable condition at that time.

> *"While the proposed framework is sufficient, good political leadership and vision is important to determine the success… Strict adherence and monitoring over, as well as benchmarking the right projects are extremely important as well."* - Interviewee 1

**Revitalisation Strategy Framework**

While cities like Singapore and Seoul may be at the forefront of urban revitalisation projects in Asia, many other Asian cities to date have also excelled in implementing world-class standard urban green spaces (UGS) as part of their revitalisation efforts such as the likes of Bangkok, Taipei and Hong Kong. As for Kuala Lumpur, although there have been some attempts made in the matter of restorations and adaptive reuse of historical structures, there have been no specific attempts by the government sector on the matter of urban green spaces let alone a customizable strategized framework to aid in the process.

As the formation of urban voids synonymously proved to be an inevitable phenomenon as cities continue to be developed, the ability and foresight to see beyond conventional solutions are therefore imperative to stimulating innovational growth and promoting social cohesion and inter-cultural dialogue in a holistic and sustainable manner. A five-phased revitalisation


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strategy framework that was developed during the course of this study with reference to existing case studies and frameworks, has been proposed to help the city council and respective stakeholders in addressing the rupture of urban voids and coherently harness them to be of value both on the short and long term.

However, to ensure the efficacy and inclusivity of the revitalisation strategies implemented, it is crucial that the framework adopts a bottom-up approach and streamlines the plans and strategies in a horizontal rather than a vertical engagement with stakeholders to devise more well-rounded solutions for the community and city. As such, this method does not centre on a single overarching concept and does not presume anything about the requirements or capabilities of underdeveloped regions. To effectively take into account the human factors when designing a solution, the design-thinking process involves empathising, listening, and understanding experiences through research, behavioural observations and repeated efficacy testing before implementation.

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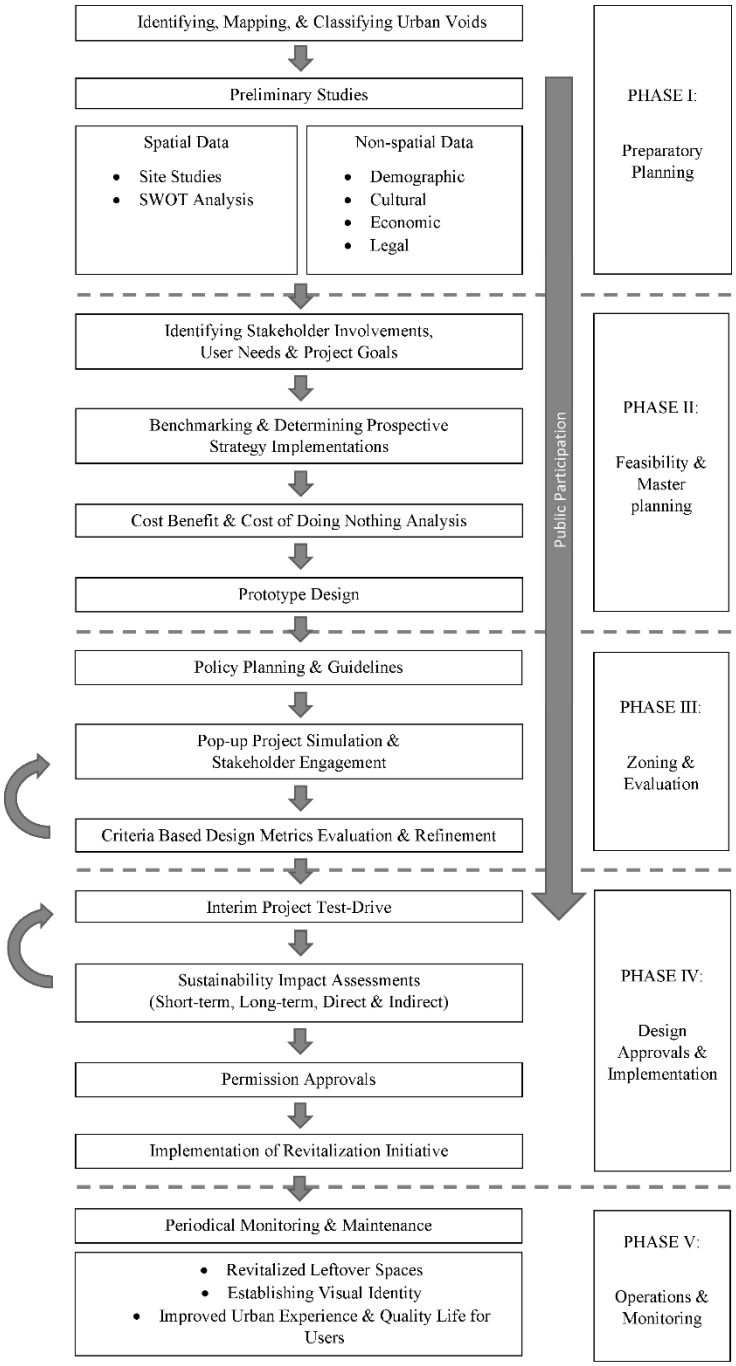


**Figure 3:** Proposed revitalisation strategy framework


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## CONCLUSION

This paper examined the implementation of urban green spaces to revitalise lacklustre regions within the context of other Asian cities, and the pathway to drafting a strategic revitalisation framework for its prospective implementation within the primary case study of Kuala Lumpur. The study proposes a five-phase structured framework in order to rehabilitate and revitalise these lost spaces methodically and holistically with the aid of nature-based solutions.

While the presence of urban green spaces may be viewed as a luxury rather than a necessity, these spaces are in fact of critical essence to building resilient cities and communities. The city of Kuala Lumpur, however, is in dire need of revolutionary mindsets and ideas to transform and revitalise the city in a sustainable manner so that the many deep-rooted problems and effects of urban voids do not further aggravate the equilibrium of the city. To subsequently implement effective solutions within the primary case study of Kuala Lumpur, it is however equally critical to understand the historical junctures and thoughts that have led to the implementation of successful revitalisation projects by other Asian cities to devise tailor-made strategies that befit the condition and environment of the city.

Although the formation of urban voids is an inevitable phenomenon of industrialisation, the contribution of this study is hoped to shed light on the possibilities of harnessing these urban voids, and the importance of undertaking NBS, as well as a more time and culturally relevant approach in its urban initiatives pertaining Kuala Lumpur. Early adopters of sustainably conscious real estate development practises are now reaping the rewards of what has become fiscal gains in recent years. The addressing of the urban void problem is therefore hoped to benefit the city both on the short-term and long-term perspective by not only generating revenue for the city but also creating value for its users, as well as helping the city establish an identity and legacy for the future.

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# A CASE STUDY ON THE SPATIAL PRACTICES OF CONSTRUCTION SITE WORKERS' QUARTERS IN KLANG VALLEY, MALAYSIA

**Veronica Ng[1], Lok Mei Liang[2], TamilSalvi Mari[3], Sucharita Srirangam[4], Anindita Dasgupta[5]**

[1,2,3,4] *School of Architecture, Building and Design & Liveable Urban Communities Impact Lab,*
[5]*School of Liberal Arts and Sciences,*
TAYLOR'S UNIVERSITY, MALAYSIA

## Abstract

This paper examines the spatial practices of construction worker housing in construction sites. In recent years, several standards and guidelines, such as MS 2593:2015 and Act 446, were implemented to improve the living environment of workers' temporary accommodation. Despite that, there is a lack of focus on the sociality of spaces as the design of these accommodations adhered to only basic spatial requirements. This resulted in prolonged issues of workers' poor living environment being unresolved. A qualitative study using physical trace observation was conducted in a construction workers' accommodation located within an urban construction site in Klang Valley, Malaysia. Spatial observations were conducted in private areas, such as the bedrooms and the common areas, including the kitchen and dining spaces. This study reinforces the spatial practices of negotiation within the contested spaces of the temporary accommodation through the dynamic and fluid functional re-appropriation of spaces in the common and private spaces and the expansion of personal territory at both macro and micro levels.

***Keywords***: Construction centralised labour quarters, migrant workers, socio-spatial qualities, spatial practices

[1] Associate Professor at Taylor's University. Email: foongpeng.ng@taylors.edu.my

## INTRODUCTION

The Malaysian government has embarked on a multifaceted approach to enhance the living conditions of migrant workers, with a particular emphasis on addressing challenges within the construction sector. In recent years, concerted efforts have been made to regulate and improve the quality of accommodation provided to workers in this industry. Notably, the introduction of MS 2593:2015 - the Code of Practice for Temporary Construction Site Workers' Amenities and Accommodation in 2016 - marked a pivotal milestone, although its enforcement remained voluntary. Despite its specific focus on construction site workers, MS 2593:2015 set a precedent by establishing the first comprehensive standard for workers' accommodation in Malaysia, laying the groundwork for subsequent legislative measures, such as the amendment to the Workers' Minimum Standards of Housing and Amenities Act 2019 (Act 446).

The revision of Act 446 in 2019 introduced legally binding minimum accommodation standards applicable to all worker housing throughout Malaysia. Simultaneously, the inauguration of Malaysia's pioneering Centralised Labour Quarters (CLQ) in 2018 exemplified purpose-built collective accommodations for workers designed following the provisions outlined in MS 2593:2015. Furthermore, the issuance of guidelines by the Kuala Lumpur City Council (DBKL) in 2020 regarding temporary quarters within high-rise construction sites reflects ongoing efforts to address accommodation challenges. These guidelines, primarily aimed at curbing the use of basement levels for temporary site accommodations and offering spatial planning directives, highlight the evolving regulatory landscape aimed at improving the living conditions of migrant workers.

Despite the implementation of various regulatory guidelines by authorities, the persistent challenges surrounding migrant workers' accommodations continued to feature prominently in news reports (Bernama, 2022; Govindarajan, 2022). The prolonged existence of substandard living conditions among migrant workers catalyses social issues (Uddin & Mohammed, 2020) and detrimentally impacts their work performance (Rahman & Albaity, 2014). Concurrently, the approach to designing construction workers' quarters remained predominantly top-down, often adhering solely to the minimum requirements stipulated by regulatory authorities, thus neglecting the nuanced living experiences and socio-spatial needs of migrant workers, given the transient nature of such accommodations. Contrary to the prevailing notion that migrant workers passively accept unsatisfactory conditions in temporary accommodations, recent accounts from these workers challenge this perception (Dutta, 2020).

The ease of meeting the key human needs increases life satisfaction significantly (Abu Bakar & Osman, 2021; Abu Bakar & Osman, 2022). To improve migrant workers' living environment, investigations of the actual socio-


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spatial qualities within the context of temporariness are critical when discussions of human-centred design are on the rise. This paper examines the spatial practices in a selected Central Labour Quarter (CLQ) in Klang Valley and analyses how the spatial practices produce and shape its living environment.

## RESEARCH BACKGROUND

Recent studies have focused on the link between socio-spatial qualities and migrant's living environment, highlighting its poor social conditions. For example, the study on migrant dormitories in the UAE revealed that cramped and crowded conditions affected workers' sense of belonging and enhanced feelings of exclusion (Reber, 2021); studies that highlighted social problems that arise from built environment qualities such as the lack of space, poor housing facilities, deteriorating conditions and unsuitable building materials (Beckford, 2016; Saldanha, 2022; Wang et al., 2016); and the case study and prototype workers' dormitory unit in Singapore by Agency Design (n.d.).

Local studies on construction site migrant workers' accommodations are limited and mostly focused on compliance with authority guidelines. There is a lack of detailed observations and analysis of socio-spatial qualities, with a few exceptions. Zubir and Rahim (2021) observed three locations of temporary construction workers' accommodations to study construction workers' living environment quality. This included an off-site CLQ, an on-site accommodation in a multi-storey structure and an on-site "rumah kongsi", representing typical accommodation typologies in the construction industry. Although few details of these accommodations are disclosed in the study, the lack of facilities, poor cleanliness and unsuitable building materials were observed in the "rumah kongsi" (Zubir & Rahim, 2021).

Also, scholarly investigations have been conducted to scrutinise the intricacies of public-private partnerships at micro-spatial scales, focussing on spatial practices and their implications for enhancing liveability through spatial appropriation. "Spatial violation" as a form of spatial practice in Palestinian refugee camps (Maqusi, 2021), homemaking experiences in the everyday living environments of migrants and refugees (Beeckmans et al., 2022), re-appropriation of public space such as car parks into private spaces shown in Chua's study on migrant workers in Geylang (2017), Singapore. In a Qatar labour camp, spatial practices of migrant workers include small gestures such as decorating and customising the sleeping room, adding extensions to beds, or hanging a piece of fabric due to the lack of privacy (Bruslé, 2012). Spatial practices were also investigated in refugee camps to understand refugees' spatial negotiation strategies (Misselwitz & Stegeman, 2021). Annisa (2020), in her work on Oman's labour camps, also discussed makeshift mosques, informal vending stalls, vegetable farming patches and the self-funded television as spatial practices or spatial appropriations.

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## THE SOCIAL PRODUCTION OF SPACE

The study of spatial practices is underpinned by Henri Lefebvre's 'The Production of Space' seminal work, which theorised space as a social product. Lefebvre argued that the relations between conceived-perceived-lived spaces are not fixed and are constantly changing, correlating to his preposition on the trialectics between spatial practice, representation of space, and spaces of representation. Lefebvre emphasised the gap between "designed space" and "used space", which rendered the inevitable differences between the planners/architects and the users. Spatial practice was seen as a bridge to the "mediate" between the "conceived" and "lived" space (Merrifield, 2006).

With his book "The Practice of Everyday Life", Michel De Certeau extended Lefebvre's spatial production theory by highlighting spatial practices as tactics employed to negotiate the power structures inherent in the everyday. Spatial appropriation is related to the users transforming their space to produce "different spaces" according to their purpose (Stanek, 2011). Stanek (2011) continued by positing that appropriation of space is a form of spatial practice performed by individuals or collectives, marking, modelling, and shaping space on various scales. This was further adopted by Misselwitz and Steigemann (2021) in their theoretical framework for investigating refugees' communicative construction of spaces in shelter camps. Using the term "concrete spatial practices", Misselwitz and Steigemann (2021) described that these spatial appropriation processes are the result of conflictual spatial negotiations with the authorities/ technocrats/ planning regimes which regulate the daily routines and dismiss the manifestations of identity and sense of social belonging.

This corresponds to migrant workers' accommodations, where the residents are to settle down in a living space adhering to the regulatory spatial standards and design planning. In the context of this research, the representations of space (referred to here as authority regulations and spatial requirements) are prioritised in the production of migrant workers' accommodations, thus affecting the everyday practices of the resident workers. From another point of view, investigating spatial practices provides important clues about the compatibility of the implemented spatial standards.

## METHODS

Lefebvre described spatial practices as "empirically observable" and "readable and visible" practices of material transformation of space that mobilise productive forces within a given economic and social system. (Lefebvre, 1991). Thus, building upon this notion, this research adopted a physical trace observation and architectural drawing methods to investigate the spatial usage and appropriation of the construction workers' accommodation. According to Zeisel (2006), observing physical traces is a systematic search for reflections of previous activities in physical surroundings to examine the relationship between


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the environment and its users. It is less obtrusive and will minimise the influence of the participant's behaviour compared to direct human observations (Zeisel, 2006).

This approach has been used in related studies on migrant workers' living environments. For example, in Lucas's (2020) case study on the Namdaemun market in Seoul, architectural ethnographic representations of existing spatial context (Yaneva, 2018), Tayob's (2018) discussion on the potentials of architectural drawings to illustrate the narratives of spaces used by marginalised populations and Hall et al.'s (2015) social research which used architectural plans to illustrate migrant-shaped infrastructure on Stapleton Road, Bristol.

This approach is further exemplified by a detailed case study of Bangladeshi migrant workers in Oman, which includes illustrations of sleeping cabins and public spaces of labour camps presented through annotated plans (Annisa, 2020). Similarly, spatial layouts of sleeping and public spaces in migrant workers' quarters were also examined in another study (Bruslé, 2012). Besides architectural layout plans, Misselwitz & Stegeman (2021) documented refugees' "adaptation of space" in axonometric illustrations, including soft furnishings and loose furniture. Although not all these studies are architecturally based, they presented a variety of possibilities for illustrating observation in temporary accommodations, indicating the need for a sophisticated method to represent detailed narratives of migrant workers' dwelling spaces.

This research selected a Centralised Labour Quarters (CLQ) as a case study, focusing on construction site workers' quarters in the Klang Valley region of Malaysia. Due to spatial constraints at the construction site, this accommodation is situated within the building structure currently under construction, with the explicit approval of local authorities. Housing approximately 180 workers, the facility comprises bedrooms, a kitchen, a dining area, a rest area, toilets, a prayer space, and a canteen. The resident workforce primarily hails from Bangladesh, supplemented by individuals from Pakistan, India, Nepal, and Indonesia. The compact nature of these quarters necessitates meticulous spatial planning and is a prevalent strategy in urban locales to minimise expenses and commuting durations.

Employers favour such compact accommodations due to their ease of management and maintenance. In contrast to more permanent residential structures like apartment-style quarters commonly found in the manufacturing sector, the transient and adaptable nature of construction site workers' quarters presents a fertile ground for examining the spatial practices of migrant workers.

Observations and photography records were conducted in three different migrant workers' bedrooms and common areas, including the kitchen, dining, prayer room, laundry, and toilets. The three bedrooms housed varying Bedroom A accommodated eight individuals, while Bedroom B and Bedroom C

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accommodated twelve and thirty individuals, respectively. The case was conducted according to Zeisel's (2006) criteria for physical trace observation.

1. Everyday practices through the by-product of use encompass various aspects such as Usage of space, Display of public messages, Personalization of space, Litter areas in public indicating gathering spots, Erosion of buildings indicating human usage, Placement of objects, Furniture placement, Storage space and Personal items.
2. Space appropriation includes aspects such as Added space, which is new furniture or item placement; Altered space, which is signs of furniture not in its original place; Abandoned space, which is the absence of furniture or items in its original position; and Litter due to abandoned space.

Visual methods in qualitative research are often examined to create powerful illustrations to inform the understanding of occupied space and architecture and its transformation (Troiani & Ewing, 2020). Drawings are a form of critical visual practice (Hall et al., 2015), a mode of knowledge production that offers a unique understanding of academic texts (Lucas, 2020). Following the physical trace observation, the studied spaces were illustrated and acted as a form of critical visual text for analysis.

## ANALYSIS AND DISCUSSION

In general, Act 446 provide minimum standards for living conditions, namely bedroom size, toilet numbers, and other public facilities. For areas that are not regulated, options are limited to relying on the initiatives of employers or resident workers to ensure a comfortable, liveable environment.

### Changing Common Spaces

Common areas are equipped with supporting infrastructures for community living, essential for the workers' social life. By comparing the original spatial planning (Figure 1) with the layout mapped during field observation, it is discovered that some common areas have been rearranged and expanded (Figure 2). The kitchen extension indicated the need for a larger cooking space, as migrant workers tend to cook individually or in smaller groups rather than sharing cooking hobs. Rice cooking stations were also allocated for many individually owned rice cookers.

The dining space has been relocated beside the kitchen, improving the connection between these two areas. During lunchtime, it was observed that the workers placed their personal belongings in the rooms before heading to the kitchen to warm food, then settled down for lunch at the dining tables. Prayer rooms were relocated to near the toilet and bath area. A shorter distance between


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the washing area and prayer rooms is more convenient for migrant workers to perform ablution before praying rituals. The location of the rest area also differs from the original layout plan. The only "rest area" observed was three plywood platforms between the bedrooms and the dining area. A few workers were seen sitting at the resting platforms to take a break during lunch hours, but most were in the dining area instead.


**Figure 1:** Original spatial planning
*Source: Second Author*


**Figure 2.** Current layout with expanded common areas
*Source: Second Author*

In Act 446, the spatial standards for common areas are not detailed and only require ventilation and lighting. However, the socio-spatial qualities of common areas in this case study indicated that further considerations should be made when designing these areas. The layout changes observed suggest the importance of migrant workers' participation in the production of space to ensure a better living environment apart from adhering only to spatial standards.

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The utilisation of empty, unplanned corners of the case CLQ indicates possibilities that could have been ignored by the original design. User-led designs are generally implemented in individual housing projects, not temporary, collective dwellings like migrant workers' accommodations. However, as seen in the case of CLQ, these spaces are critical for living spaces that host inhabitants from various backgrounds and cultures.

Similar scenarios have also been observed in Gulf countries' labour camps, where migrant workers utilise empty spaces to build make-shift living areas and common prayer spaces (Annisa, 2020; Bruslé, 2021). "Neutral" spaces enhance the possibility of a better living environment in migrant workers' accommodations.

**Negotiating spatial privacy**

In the bedroom, the bed was re-appropriated for spatial privacy. Overcrowding issues were commonly discussed in research focusing on migrant workers' accommodations, and one of the consequences of overcrowding in bedrooms is the lack of privacy, leading to poor mental health and well-being (Reber, 2021). However, no spatial standard addresses privacy concerns in Act 446. The only relevant clause indicates that a minimum of 3 sqm shall be allowed for each worker in the dormitory rooms to avoid overcrowding. Nevertheless, the minimum distance between beds and the placement of beds is not regulated, while there is no limitation on the maximum number of workers hosted in one bedroom.

Vertical plywood boards were added to lower bunk beds to block views towards the sleeping area. In the largest bedroom observed, 6 of the 15 beds have vertical partitions on the lower bunk beds, each with different configurations (Figure 3). Some covered two sides of the beds, forming a cave-like space, while some covered only one side. Some workers used soft fabric partitions, including a type of Bangladeshi cloth known as "Lungi", bedsheets or towels hung on ropes tied to the bedframes. The placement of metal lockers also acts as a visual barrier. Although the practices of securing privacy vary among workers, they indicate the importance of visual privacy, especially in larger bedrooms.


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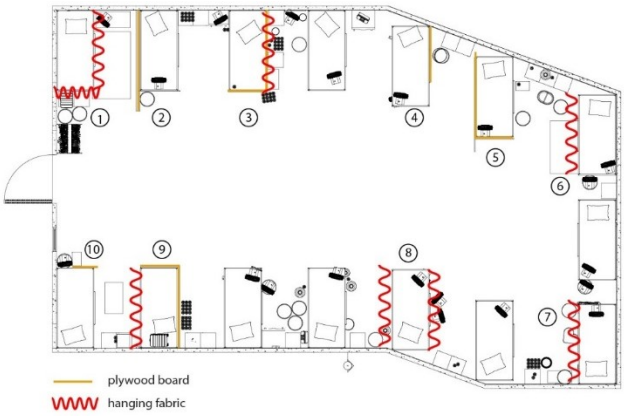


**Figure 3**: Bedroom plan indicating visual barriers initiated by resident workers
*Source: Second Author*

The findings suggest that privacy is a significant requirement even in temporary living environments, especially in rooms with more occupants. Similar observations were made by Misselwitz and Steigemann (2021), which indicated spatial appropriation by refugees in camps to establish physical boundaries for privacy.

**Expanding personal territories**

The placement of objects defines space and forms the spatial experience of users in a living environment (Paramita & Schneider, 2018). In the context of workers' accommodation, such acts could even expand personal territories to achieve better environmental comfort.

In bedrooms, personal items were placed in different areas of the room, although metal lockers were provided (Figure 4). For example, empty buckets can be used for storage or a table. The underneath of the lower bunk bed was also used to place objects. PVC poles or rebars were also used as frames for hanging laundry. There were self-made racks at the entrance of each bedroom to store shoes and personal protective equipment (PPE), such as safety boots and safety helmets.

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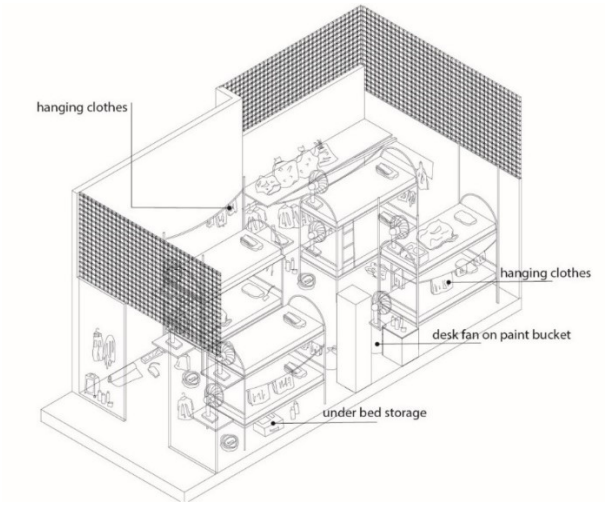


**Figure 4**: A bedroom axonometric drawing indicating various object placements and laundry hanging in the room
*Source: Second Author*

The bed was also re-appropriated to extend space. Plywood boards were added to the horizontal edge of upper bunk beds to form a platform for placing personal items, such as fans, chargers, and so on (Figure 5). As the CLQ did not provide fans, resident migrant workers bought their desk fans, and most were placed on the bed, reducing the sleeping space. Thus, extending platforms horizontally resolved the issue of tight sleeping space.

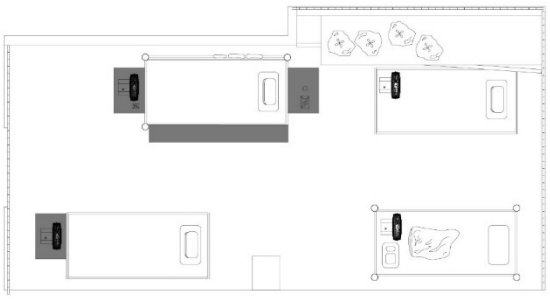

**Figure 5**: Bedroom plan indicating plywood bed extensions for object placement
*Source: Second Author*

In the dining space, seven long dining tables with benches made of recycled plywood boards were placed next to the kitchen area. There was no clear demarcation of dining areas, and the seating was far below the number of cooking stoves. Some workers brought plates of food to a further area with plywood platforms labelled as “rest area”.


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In the dining space, a row of self-made cabinets between the bedrooms and dining area was built to store kitchen utilities and food items. As a result, only minimal food items (for example, rice, cooking oil, flour) or cutlery were observed in the bedrooms or scattered in the kitchen/ dining area. As seen in other workers' quarters, the lack of storage space in the public kitchen may lead to the scattering of kitchen utensils and food packages. In comparison, the existence of such self-built cabinets reflects the storage requirement of resident workers and improves the quality of the environment.

Observing object placement and storage spaces in bedrooms and common areas suggests that minimum spatial standards in Act 446 are insufficient to ensure a comfortable living environment for temporary workers' quarters. The tidiness of these quarters relies on the spatial appropriation of resident workers.

Overall, the observations and drawings illustrated spatial appropriation at varying scales by the workers. As a collective, they made changes to the layout of the common spaces, and at an individual level, they negotiated spatial privacy. This finding concurs with Stanek's (2011) position that spatial appropriation occurs at varying levels and scales.

## CONCLUSION

From a Lefebvrian perspective, spatial practices and the production of spaces are an act of spatial negotiation between the used and the conceived space. In this case, the architectural plan has been altered to suit the different requirements of resident workers and has varied from the original spatial planning. Minor alterations not involving functional planning were also observed, especially within the bedrooms. This includes the claim of spatial privacy, expansion of personal territory and utilisation of undefined public areas. The spatial practices within the contested temporary accommodations of the workers prompt us to recognise how the material aspects of infrastructure co-constitute social relations.

Contradictory to some beliefs that migrant workers are ignorant of the quality of living in these temporary environments, there are indications of attempts to achieve a better environment. The investigation reveals that the case workers' accommodation spaces are dynamic and fluid. Improvisions constantly happen despite this being a temporary living quarter. The provision of 'neutral' informal spaces at a public scale, considerations of the interface between private spaces, and the allocation of small functional spaces at a personal scale may improve its living environment.

The everyday spatial practices observed through the physical settings illustrate the resilience and ingenuity of construction workers navigating regulatory constraints. By highlighting these specific instances, the research highlights the challenges these communities face and emphasises the importance of comprehensive policies and guidelines. The limitations of regulatory spatial

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standards can only be overcome by architectural design considerations due to the complexity of such accommodation contexts. The diversity of workers' backgrounds and site conditions requires a design framework adaptable to the changing socio-spatial needs. It advocates for policymakers and stakeholders to consider the lived experiences of migrant workers in crafting more effective accommodation regulations.

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## ETHICAL STATEMENT

The Ethics Committee of Taylor's University (FRGS/1/2021/SS0/TAYLOR/02/2) approved this study's ethical consent and protocol.

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# LOW-CARBON ADOPTION IN JOHOR HOUSING DEVELOPMENT

**Fara Diva Mustapa[1], Farah Kamilah Zainuddin[2], Tantish Kamaruddin[3], Nur Hajarul Falahi Abdul Halim[4], Mohd Saidin Misnan[5]**

[1,2,3,4,5]*Department of Quantity Surveying,*
*Faculty of Built Environment and Surveying,*
UNIVERSITI TEKNOLOGI MALAYSIA

## Abstract

Construction activities have been identified as one of the sectors that contribute to high gas emissions, which inspires low-carbon housing development. This paper discusses the adoption of low-carbon design/features in Johor housing development and its cost implications. Five landed and high-rise housing case studies were gathered and analysed from both expert interviews and document analysis. Findings indicate that landed housing exerted more low-carbon design/features than high-rise housing due to design economics implications with an additional cost of 17.5% for high-rise and 10% for landed. The hard costs accounted for 83.5% of high-rise projects and 66% of landed ones, while the soft costs accounted for 16% of high-rise projects and 27% of landed ones. The remaining land costs depend on the developer's land bank and the land's book value. In conclusion, despite the higher development costs, low-carbon design/features adoption is worth considering for a more sustainable housing development in Malaysia.

***Keywords***: Low-Carbon Adoption, Development Cost Implications, Gross Development Costs, Housing Development, Malaysia.

[1] Senior Lecturer at Universiti Teknologi Malaysia, Email: faradiva@utm.my

## INTRODUCTION

The living space environment is deteriorating annually due to the steadily increasing degree of environmental harm (Chengchao et al., 2021). People began to understand the urgency of saving the planet as natural disasters and climate change began to sound alarms and send sick sirens across the planet (Fawzy et al., 2020). In response, countries around the world have begun to implement a variety of effective policies, mostly aimed at achieving social, environmental, and economic benefits. It allows the maximisation of improving the serious environmental situation through low-carbon developments.

According to the United States Environmental Protection Agency, there have been various changes, which include the positive and negative effects on people, society, and the environment, including plants and animals in the report by indicators (United States Environmental Protection Agency, 2022). Based on the 2020 Global Status Report for Buildings and Construction, the emissions from building operations are about 28% of total global energy-related CO2 emissions in 2020. When emissions from buildings are included, this proportion increases to 38% of total global energy-related CO2 emissions (Global Alliance for Buildings and Construction, 2020). Emissions must be decreased by 45% by 2030 and achieve net zero by 2050 if the Paris Agreement's goal of limiting global warming to 1.5°C is to be met. With goals of attaining this by 2050, Malaysia is completely committed to playing an important role in the worldwide shift to a low-carbon, and eventually carbon-neutral society (United Nations, 2022).

However, there is a cost barrier to adopting sustainable components that produce sustainable developments. The perception that sustainable products are more expensive than conventional ones is already widespread (Lawrence, 2020). Since most people do not understand low-carbon or sustainable products, their understanding towards this concept is that the adoption will be expensive. Although the upfront costs may be higher in many circumstances, the overall life cycle costs are much lower because the products may be in use continually and sustainably (Luay et al., 2018). Hence, there is an evidence gap to debunk the perception that sustainable development, particularly housing is expensive as it is not always true, and choosing a sustainable choice is better for the environment and the wallet (Gammage, 2022). In terms of long-term benefits, this adoption is not only saving unnecessary expenses but also brings advantages to people. For example, efficient use of energy, water and other resources, usage of renewable energy to reduce the waste of energy, pollution, waste reduction measures, as well as the enabling of re-use and recycling (British Assessment Bureau, 2021). The utilisation of sustainable components will effectively reduce the impact of climate change.

Hence, it is crucial to study the adoption of low-carbon design/features and its development cost implications for better cost analysis as well as the return


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of investment analysis to encourage future adoption of low-carbon for the long-term benefits of ensuring a more sustainable housing development in Malaysia.

## LOW-CARBON DESIGN / FEATURES OVERVIEW

Low-carbon design/features is a method of design that combines sustainable practices and energy efficiency practices to minimise the environmental impact of a structure or a product (Chang, 2021). It is a comprehensive method of design and building that incorporates modern, ecologically friendly, and energy-efficient techniques utilised to create an improved future. In order to lower carbon emissions and advance sustainability, low-carbon design can be implemented in buildings, items, and even cities (Gustafson, 2023). The primary purpose of low-carbon building design is to optimise the building's orientation, structure, window/glazing position, size, and material selection in order to reduce carbon emissions and improve energy efficiency. Low-carbon design entails using low-carbon materials for building structures and finishes, minimising destruction, and reusing buildings and construction materials whenever practical. Reducing the carbon footprint of a building or product can also be accomplished by adopting awareness during the design and construction phases (Chang, 2021). Additionally, landscaping, massing and space layout; window design; shading device design strategies; cooling and heating system (HVAC); natural ventilation; building design, and design strategies are elements of low-carbon sustainable home design (Naief et al., 2015).

### Low-Carbon Adoption in Malaysia

According to Malaysia's finance minister, Malaysia is striving to move towards a low-carbon development and climate-resilient economy as its goal, which could allow the country to tackle a turning point in the climate and biodiversity crisis (Ministry of Finance, 2021). Malaysia also announced the launch of a comprehensive national energy policy soon following the release of the 12th Malaysia Plan (12MP), which aims to provide direction towards a low-carbon long-term strategy. According to Kasturi Nathan, KPMG's Head of Governance and Sustainability in Malaysia, the government has an important role to play in reaching the goal of net zero emissions by 2050. Firstly, the government needs to develop a clear implementation policy. Secondly, the support for small and medium-sized enterprises and investment in research and development will allow the public to realise their innovative potential. Thirdly, is to create market value for low-carbon services and products (KPMG, 2021).

### National Low-Carbon Cities Master Plan

In 2021, Malaysia announced a National Low-Carbon Cities (NLCCM) Master Plan at a conference on the theme of "Empowering Cities Towards a Low-Carbon

Pathway". The purpose of the master plan is to plan the strategies and objectives for the practice of low-carbon cities and the methods or actions to be taken in practice. The master plan emphasises the definition of three main elements, which include the pursuit of a systematic approach, the adoption of regional strategies and the setting of ambitious greenhouse gas reduction targets. Six of these categories demand a significant change in the way low-carbon development is carried out. The six categories are governance and implementation frameworks, urban planning, community engagement, finance and capacity building, data collection and analysis as well as built environment and physical infrastructure (Ministry of Environment and Water (KASA), 2021). The key directions, actions, and targets for the master plan are depicted in Figure 1.


**Figure 1**: National Low-Carbon Cities Master Plan
*Source: Ministry of Environment and Water (KASA) (2021)*

The primary directives of the National Low Carbon Cities master plan are further cascaded down into project planning and implementations, especially


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at the pre and post-contract stages. The following section explains the execution of the low-carbon initiatives adopted in the Malaysian construction industry.

**Green Building Index**

Sustainable or green developments are certified through the assessment tools or the environment rating system. In Malaysia, one of the well-established green building assessment tools is called Green Building Index (GBI) (Sollar et al., 2022). When a building achieves six GBI criteria such as Energy Efficiency, Indoor Environment Quality, Sustainable Site Planning & Management, Materials & Resources, Water Efficiency, and Innovation, it will receive a GBI certificate. The aim is to demonstrate that the building is compliant with low-carbon or sustainable design criteria. GBI is a guideline and criteria for developers, project team members, and building owners to build low-carbon or sustainable buildings which will bring benefits to the Earth. The utilisation of the Green Building Index tool does not grant the user or any other entity the right to publicly disclose the Green Building Index rating received without formal certification by an independent accredited GBI Certifier (Green Building Index, 2013). In addition, it is designed to encourage the construction of environmentally sustainable buildings in Malaysia and promote a more sustainable built environment. Buildings that meet the required criteria are awarded a GBI certification based on their level of achievement. GBI rating is divided into four categories, which are Certified (50 - 65 points), Silver (66 - 75 points), Gold (76 - 85 points), and Platinum (86 - 100 points). The higher the GBI rating point, the higher the level of achieved GBI criteria (Green Building Index, 2022).

**Common Low-Carbon Design / Features In Malaysian Housing Development**

With respect to the Green Building Index certification, building elements were developed with low-carbon designs/features, which are portions or features of a structure or development that are designed and built with a lower carbon footprint and fewer greenhouse gas emissions in mind. These components can include a variety of design methods, construction materials, and energy systems that aim to reduce the energy consumption and carbon emissions associated with building-related processes. Hence, the adoption of Low-Carbon can be in the form of either the process, the design, the construction, or the materials. Each option is totally up to the client and the design team to choose. Energy-efficient lighting, rainwater harvesting systems, green roofs, the Digital Industrialised Building System (IBS), and natural ventilation are all examples of low-carbon features (Ramli et al., 2023). These characteristics might be considered when adopting materials and construction processes.

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## DEVELOPMENT COSTS IMPLICATIONS FROM LOW-CARBON ADOPTION IN MALAYSIA

Typically, there are three development cost components in Malaysian home development: land costs, hard costs, and soft costs. Each component has its own elements and yardsticks, and the weightage varies depending on the project's location and scope.

Theoretically, compared with conventional buildings in the past, green buildings cost more but have lower operating and maintenance costs. Typically, green buildings cost about 28% more than conventional buildings, and costs for operation and maintenance are 35 to 41%, 26 to 30% and 6 to 18% lower than conventional buildings. Green buildings' life cycle costs are also 24% to 28% lower than conventional buildings (Achini Shanika Weerainghe, 2017). In order to meet the GBI rating criteria, developers will incorporate sustainable or low carbon in either the form of green systems, materials, or components. Each component and material used vary in terms of quality and price, which subsequently affect the final cost of the overall development costs. The differences between conventional building costs and low-carbon building costs should be explored in more depth as the corresponding analysis and conclusions. This analysis especially should focus on the differences in price between the hard costs, soft costs, and land costs of a low-carbon housing development and a conventional housing development.

### Land Costs

One of the main development costs which varies due to the project locality is land cost. The cost includes all costs related to purchasing a specific piece of property, as well as those related to preparing the site for construction (Saltler, 2020). Land is scarce in major cities and the prices depend on the location in terms of connectivity and scale of development. For a piece of land located in an established development area, the transaction costs would be higher. The conversion of land ownership to residential use will eventually lead to higher land costs. When the land costs increase, the overall development costs will also increase (Boon et al., 2018).

### Hard Costs

This cost component carries the highest weightage in any typical conventional housing development cost (Construction Industry Development Board Malaysia, 2021). It is a cost that is directly associated with building construction, which can be observed in both housing townscape and building scope (Megan Keup, 2022). From the building scope perspective, hard cost is the cost associated with building elements such as frames, finishes, and external works. Hard costs can be further debunked into expenses for elements like raw materials and direct labour for


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construction which raise the likelihood of a project's completion (Srivastav, ND). Hard costs also include additional expenses and other supplemental needs. When a project is in the construction stage, hard costs are incurred. Market circumstances have an impact on the cost of materials, labour, and project scheduling, which makes hard cost estimation reliant on them. A project's hard costs are calculated from its inception until the completion of the building process. Making a list of all the supplies and machinery needed for the construction tasks according to local prices will help in estimating the hard costs. The labour costs are then determined by comparing and investigating the number of man-hours needed for a comparable job in the past (Neenu, 2022).

**Soft Costs**

Soft costs are not directly related to and do not contribute to the actual building's construction. These are extra expenses that are not immediately connected to building development. Due to the possibility of it continuing even after the project has been finished and delivered, it is difficult to quantify and difficult to predict (Srivastav, ND). Some soft costs will be recurring and become a continued expense for maintenance and maintenance insurance. Throughout a project's lifespan, they could happen at any moment. These soft costs are certainly moving targets, but that doesn't mean it's impossible to estimate and monitor them. When forecasting the budget, it is vital to thoroughly consider everything from pre-construction to post-construction. Soft costs may be easy to overlook but once missed could account for between 25% and 75% of the overall construction budget. Some examples of soft costs are studies fees, equipment expenses, project management costs and taxes, and others (Megan Keup, 2022). To obtain a precise estimation of soft costs, it is crucial to take into account different scenarios and anticipate the potential cost range. This is because soft costs could be grown and altered (Thompson, 2022).

## LOW-CARBON ADOPTION IN HOUSING DEVELOPMENT

A better understanding of the low-carbon design/features implemented within housing development is required as there is no standard currently. Hence, this research proposed the well-established Green Building Index's six criteria as the basis to outline the common low-carbon design/features adopted within the housing development (Ab. Azis, 2021). The six GBI criteria are Energy Efficiency, Indoor Environment Quality, Sustainable Site Planning & Management, Materials & Resources, Water Efficiency, and Innovation. Each of the GBI criteria can also be observed in both townscape and building elements in a typical housing development.

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## RESEARCH METHODOLOGY

The research design was qualitative, with descriptive analysis using project case studies. This study delves deeper into the design and features of low-carbon dwelling development by Malaysian housing developers. The study's major goal was to review previous case studies with low carbon design/features and Green Building Index certification to determine the monetary effects of their adoption. For this study, the collected case studies are limited to low-carbon designs/features adopted by Johor housing development and the development costs were attained to study the monetary implications of the low-carbon adoption. To ensure a similar basis for comparison, low-carbon housing projects with a minimum of Certified Green Building Index certification, either for a new building or a retrofitting of a building are considered a suitable case study. Every housing development that is considered must have been carried out using low-carbon development. Therefore, all selected projects must apply several low-carbon designs/features in the housing development. The characteristics of the case studies are (1) housing projects achieved with GBI certification, (2) low-carbon design/features implemented in the housing projects with six GBI criteria: EE, EQ, SM, MR, WE, IN, as well as (3) the provision of ECA comprises land costs, hard costs, and soft costs.

Table 1 depicts a collection of five low-carbon Johor housing development projects, all of which have Certified Green Building Index accreditation. All case study information was gathered through interview sessions to determine the adopted low-carbon design/features and project development costs, which were then examined using document analysis. It was based on Malaysia's National Low Carbon Cities Master Plan principles as well as the six criteria in the Green Building Index (GBI), with a special focus on the developers' approach to designing and implementing low carbon design/features in their housing construction.


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**Table 1**: Five Case Studies Details

| | **Projects** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| **Type of Residential** | High-Rise Apartment | High-Rise Apartment | Landed – Double-Storey Terrace House | Landed – Double-Storey Terrace House | Landed – Double-Storey Semi-Detached House |
| **Type of Development** | Mixed Develop-ment | Mixed Develop-ment | Township | Township | Self-Contained Township |

*Source: Authors*

## RESULTS AND DISCUSSION

The interview questions were separated into three sections: part A, part B, and part C. The participating developers gave five case studies during the interview sessions. All five case studies were certified with the minimum GBI standard. The interview consisted of 20 questions designed to achieve Research Objectives 1 and 2, which were to determine the low-carbon design/features in the project case studies development and the development cost for the low-carbon home construction. The interviews were conducted in person.

### Low-Carbon Adoption in Johor Housing Development

Research Objective 1 is to study the low-carbon adoption in Johor housing development according to six GBI criteria. As highlighted, each of the criteria can be adopted in either or both housing townscape and building per say. Based on the five case studies provided by the developers, the common low-carbon designs/features adopted in Johor housing development were identified and illustrated in Table 2. The data is analysed according to the six criteria of GBI as explained previously.

**Table 2**: Low-Carbon Adoption in Johor Housing Development

| Low Carbon Designs/Features | Project 1 (high-rise) | Project 2 (high-rise) | Project 3 (landed) | Project 4 (landed) | Project 5 (landed) |
|---|---|---|---|---|---|
| **Energy Efficiency (EE)** | | | | | |
| LED Lighting | √ | √ | √ | √ | √ |
| Renewable Energy | √ | | | | |
| Lower Accumulation Heat | | | √ | | |
| **Indoor Environment Quality (EQ)** | | | | | |
| Daylighting | √ | | √ | √ | √ |
| Air-conditioning system | √ | √ | | | |
| Natural Ventilation | | | √ | | |
| **Sustainable Site Planning & Management (SM)** | | | | | |
| Reservoir | | | √ | | |
| Replanted Trees | | | √ | | |
| **Material & Resources (MR)** | | | | | |
| 3R Recycle Center | | | √ | | |
| Motion Sensor | | | √ | | |
| Solar Water Heater | | | √ | | √ |
| Low Volatile Organic Compound (VOC) | | √ | | | √ |
| Tempered Glass | | | | | √ |
| Floor-to-ceiling Window | | | | | √ |
| **Water Efficiency (WE)** | | | | | |
| Rainwater Harvesting System | | √ | √ | √ | |
| Water Efficient tap & fittings | | √ | | | |
| **Innovation (IN)** | | | | | |
| Green Park | | | | √ | |

*Source: Authors*

As observed, in terms of energy efficiency, the cost components can be categorised within both townscape and building. According to the common low-carbon designs/features adopted in Johor housing development identified as shown above, Project 3 has the highest number of low-carbon design/features adoption compared to other projects. Moreover, based on the analysis, it can also be found that every low-carbon housing development project adopted LED as the


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main lighting in their development. Besides that, daylighting is also one of the low-carbon designs/features that was accounted for in almost all of the case studies. It was observed that the developers focussed more on energy efficiency (EE) and indoor environment quality (EQ) features compared to sustainable site planning and management (SM), material and resources (MR), water efficiency, and innovation (IN). For high-rise projects, the application of LED lighting is adopted in all projects. For the high-rise projects, Projects 1 and 2, the adoption of LED was mainly in the common areas compared to landed projects as observed in Projects 3, 4 & 5. The adoption of LED lighting for landed projects is mainly observed in townscape components mainly for street and common space lighting. It is interesting to observe that the low-carbon design adoption varies from high-rise and landed housing development.

## Development Cost Implications from Low-Carbon Adoption in Johor Housing Development

Research Objective 2 is to study the development cost implications of low-carbon adoption in Johor housing development according to the aspect of land costs, hard costs, and soft costs. The housing developers have provided Elemental Cost Analysis (ECA) for the case studies as a basis to prove their figures as well as to justify their business strategy and decision-making regarding the low-carbon adoption in their housing development. To justify the cost implications, the gross development costs (GDC) and gross development value (GDV) of the five case studies were obtained and presented in Table 3 below.

**Table 3**: Development Costs Implications from Low-Carbon Adoption in Johor Housing Development

| **Element** | **Project** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| | **Cost (RM)** | **Cost (RM)** | **Cost (RM)** | **Cost (RM)** | **Cost (RM)** |
| Total Construction Cost | 152,345,343.00 | 118,065,387.00 | 50,673,999.00 | 279,017,023.00 | 87,072,651.00 |
| Land Cost | 1,237,444.00 | 3,963,543.00 | 5,115,541.00 | 6,919.00 | 7,700,558.00 |
| Hard Cost | 127,249,298.00 | 101,377,396.00 | 37,718,256.00 | 181,970,815.00 | 36,193,142.00 |
| Soft Cost | 19,317,250.00 | 12,530,230.00 | 7,840,202.00 | 91,491,128.00 | 50,781,355.00 |
| GDC | 156,586,591.00 | 118,065,387.00 | 50,673,999.00 | 279,017,023.00 | 87,072,651.00 |
| GDV | 169,778,600.00 | 161,358,750.00 | 70,325,995.00 | 395,015,279.00 | 41,183,200.00 |
| | High-rise | | Landed | | |
| Cost/sqft | 493.58 | 475.53 | 279.00 | 332.78 | 887.10 |

*Source: Authors*

Based on the table shown above, Project 4, a landed double-storey terrace project has the highest total construction costs and gross development value (GDV) although it is among the minimal low-carbon design adoption. In comparison to the conventional double-storey landed terrace, the adoption of low-carbon design/features increased the overall GDV from RM 200+ per square feet to RM 279+ per square feet, an increase of 39.5%. As for high-rise buildings, a 58.3% increase was observed from RM 300+ square feet to RM 475+ square feet. Although it is interesting to observe the cost increment, it is more interesting to observe the selling price increment of the low-carbon design adoption. For instance, Project 2 adopted mainly townscape features but have a much higher GDV compared to Project 1. Surprisingly, Project 3 adopted many features but did not receive as many GDV compared to Project 4. This suggests that the selection of low-carbon design be it at building cost or townscape cost did not have a direct correlation to the overall GDV of the project. Typically, for all case studies, it was found that the hard costs are the main costs that contribute to development cost implications. However, it was also noteworthy that different types of housing developments adopted different types of low-carbon designs/features according to the suitability of the project characteristics, as previously highlighted in the literature. It was obvious that the selection of design features was based purely on the developer's preference and their business strategies.

## CONCLUSIONS AND RECOMMENDATION

A greater understanding of the low-carbon design/features used by Johor housing developers, as well as the development costs associated with low-carbon adoption, has been achieved. The low-carbon design/features were identified using six GBI criteria, and because of the additional features compared to conventional housing, low-carbon adoption was slightly higher, with 17.5% for high-rise housings and 10% for landed housings. Interestingly, the pricing increase was predicated on the minimum GBI certification. The increased cost can be detected from either the townscape or the building scope, or a mix of both, depending on the project's characteristics. It is preferable to assess the cost implications of low-carbon design/features using the Elemental Cost Analysis (ECA) format, which is a well-known international format. However, due to confidentiality concerns, respondents were reluctant to give detailed costings, limiting the cost analysis to the conventional building element categories.

Despite the higher development cost implications, low-carbon adoption is still worth looking at from the long-term benefits of ensuring a more sustainable housing development in Malaysia. Additionally, the knowledge obtained from this study can assist industry players in the decision-making process to better understand the benefits of low-carbon adoption and its corresponding


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development cost implications as each low-carbon design/feature adopted will have a monetary impact on the housing development costs. The results of this study should also be explored in more depth as future research, focussing on the differences between land costs, hard costs, and soft costs of a low-carbon housing development compared to a conventional housing development.

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# DEVELOPMENT OF PROCEDURAL FRAMEWORK FOR 6R IMPLEMENTATION IN CONSTRUCTION WASTE MANAGEMENT

**Joshua Chua Shu Min[1], Hong Wan Thing[2], Chai Yoon Jing[3], Abba Tahir Mahmud[4], Mohd Ashraf Mohd Fateh[5]**

[1,2,3] *School of Energy, Geoscience, Infrastructure and Society,*
HERIOT-WATT UNIVERSITY MALAYSIA
[4]*School of Civil Engineering and Surveying,*
UNIVERSITY OF PORTSMOUTH, UK.
[5]*School of Construction & Quantity Surveying, College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA (UITM), MALAYSIA

## Abstract

Sustainable construction has become a top priority in most developing countries including Malaysia. With the rapid development progress in Malaysia, construction waste continues to rise and putting pressure on the social, economy, and environmental sustainability of the nation. Effective construction waste management (CWM) is crucial for achieving the sustainability goals. A well-designed waste management strategy is essential to minimise the environmental impact of waste generation for a more resilient built environment. Past researchers have identified a lack of systematic procedures for CWM and implementation by contractors. This research aims to address this gap by developing a procedural framework for implementing the 6R approach - refuse, reduce, reuse, recycle, recovery, and reflect in the local construction waste management. An extensive literature review on the CWM practices was conducted followed by a preliminary focused-group interview with the Solid Waste Management and Public Cleansing Corporation (SWCorp). A draft procedural framework focusing on 6R waste management was developed following the pilot group studies. To improve the developed framework, semi-structured interviews with the main contractors were conducted for their insights on the current practices and challenges faced in construction waste management, and the feasibility of the proposed procedural framework. The interview findings showed great support to the developed procedural framework with little recommendations incorporated. A final procedural framework was then concluded for implementation. This study presents a significant opportunity for the main contractor in practising sustainable construction waste management (SCWM) through the recommended procedural model.

***Keywords***: Construction Waste Management, Main Contractors, Procedural Framework, Reduce, Reuse, 6R Implementation

[3] Correspondence Email: Y.chai@hw.ac.uk

## INTRODUCTION

The rapid growth of the Malaysian construction industry has led to a challenge in dealing with the upsurge of construction waste. Despite efforts being made to manage construction waste, disposal in landfills still seems to be Malaysia's preferred solid waste management option (Iacovidou and Ng, 2020). Although the Construction Industry Development Board (CIDB) and Construction Research Institute of Malaysia (CREAM) have introduced training modules to promote SCWM, these initiatives remain insignificant (Kathiravale et al., 2020) and therefore impeded the efforts of Malaysia progressing towards the United Nation (UN) 17 Sustainable Development Goals (SDGs). It is also worth noting that solid waste management in Malaysia is not fully under the authority of the Federal government. In this context, the effective management of construction waste must be highlighted to realise the national sustainability objectives. As the development in Malaysia accelerates, construction waste generation escalates in parallel, placing substantial strain on the nation's SDGs (Nagapan et al., 2012). The rise in waste output has not just triggered the depletion of natural resources but also upscaling issues related to illegal dumping. Perhaps this could be attributable to the absence of robust enforcement measures in the construction sector and limited access to waste-sorting facilities. While it is evident that Malaysia has listed the types of waste that should be managed holistically in the 11th Malaysia Plan, this research has a parallel mission in construction waste management. Past research by Cheen et al. (2018) mentioned the most practical waste management approach should embrace *reduce, reuse, recycle, and* then dispose in a proper dumpsite. To complement a holistic CWM approach, *refuse*, *recover* and *reflect* shall also be incorporated into the practice. This research aims to develop a procedural framework embracing the 6R principles, which cover "*refuse*, *reduce*, *reuse*, *recycle*, *recover*, and *reflect*" for full implementation.

## CHALLENGES OF IMPLEMENTING EFFECTIVE CONSTRUCTION WASTE MANAGEMENT WITH 6R APPROACH

In 2022, there was a significant increase in illegal dumping hotspots in Malaysia, with 29 out of 42 reported hotspots being associated with construction waste. Kuala Lumpur alone accounted for 326.0 tonnes of construction waste out of a total of 344.3 tonnes of illegal waste (TheStar, 2023). Studies by Lin et al. (2021) and Ngapan et al. (2012) mentioned research conducted by Faridah et al. (2004) identified six types of waste on 30 construction sites in the following composition: wood (69.10%), concrete (12.32%), metal (9.62%), bricks (6.54%), plastics (0.43%), and other waste (2%). Currently, Malaysian contractors are facing several challenges in implementing effective CWM, which include time constraints, limited resources, lack of enforcement of legislation and guidelines, lack of knowledge about construction waste, and limited space on construction sites. It was highlighted that CWM often takes a backseat to the primary


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objectives of completing projects on time and within budget, which are considered more critical in the construction industry (Chidiobi et al., 2023). Studies conducted by Ng et al. (2017) and Salleh et al. (2022) highlighted inefficient implementation of 3R practices by contractors resulting in unsustainable CWM and an increase in waste being sent to landfills or illegal dumping, which is a major concern in areas with limited land available for waste disposal. In addition. the National Solid Waste Management Department (JPSPN) and SWCorp are responsible for policies and regulations implementation and enforcement for solid waste management of the country. However, solid waste management in Malaysia is not fully under the authority of the Federal government. Out of thirteen (13) states and three (3) federal territories, only six (6) states and two (2) federal territories have accepted and committed to it (SWCrop,2018; Iacovidou and Ng, 2020). This situation emphasises the need for a more structured and systematic approach to CWM that aligns with the UN SDGs. However, there is a lack of readily available frameworks or guidance for contractors in Malaysia. Previous research has discussed topics such as a procedural framework for assessing construction and demolition waste management performance by Wu et al. (2019), a waste management process modelling for construction and demolition waste by Esguícero et al. (2021), or a sustainability framework for waste management by Taelman et al. (2018), all of which emphasise the importance of waste management. Still, their findings are not sufficient for direct application in the Malaysian context.

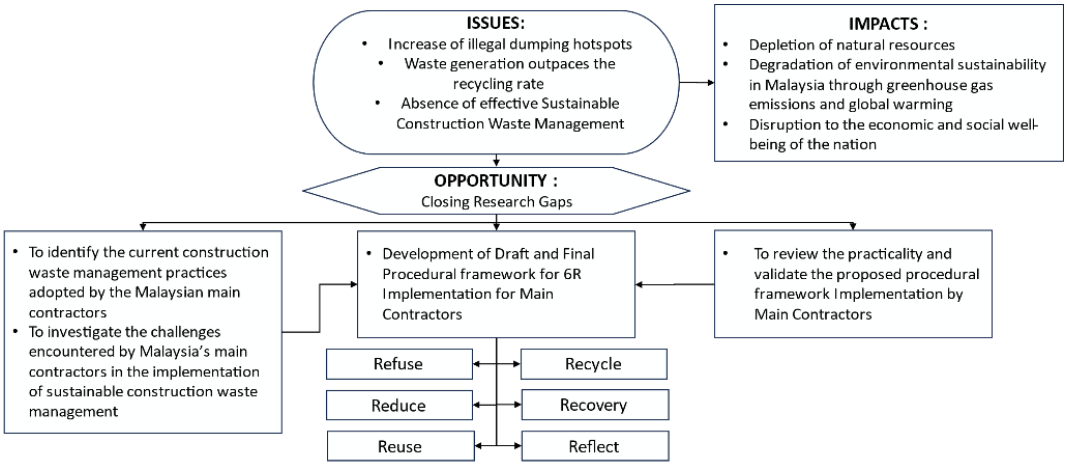


**Figure 1:** Current CWM issue, Potential Research opportunity and Objectives

Figure 1 demonstrates the issues, factors and impacts in relation to subpar practices in managing construction waste, as well as the research

opportunities for proposing a systematic and holistic approach to implement effective CWM. Zainon et al. (2022) claimed that understanding evidence-based trends in common CWM practices is crucial in developing a solid waste management framework. To address the research gaps, the development of a procedural framework for 6R implementation in construction waste management is recommended. The 6R principles of refuse, reduce, reuse, recycle, recovery, and reflect are complete reflections of SCWM which can be considered in practice. The proposed framework will comply with Act 672 requisites published under the Solid Waste and Public Cleaning Management Act (revised 2017). The first principle that shall be incorporated into the framework begins with *refuse* wasteful or non-recyclable products. Next, the recommended procedures include: - *reduce* project waste generation by decreasing construction mistakes, ordering the right quality/ right quantity of materials, *recycle reusable* materials, improving CWM planning, appointing on-site waste management officers, and providing secure site storage. Nagapan et al. (2011) supported that additional ordering has significant impacts on construction waste generation. The appointment of a licensed waste collection service provider, and establishment of site storage, collection points, and receptacles, are mandated in Part VIII of Act 672. Apart from this, Eusuf et al. (2012) further supported that the ordered materials must be securely stored and appropriately packaged. Then, the option to *recover* waste resources to produce other valuable products could optimise the values created from waste. This forms a part of a circular economy, in which the waste is minimised thereby reducing the need for landfill space. The option for landfill disposal must always be the last resort. The last recommended procedure is to rethink and *reflect* on the overall CWM practices and recommend further improvements that benefit the entire project life cycle for the subsequent projects. A systematic and holistic procedural framework for 6R implementation as proposed above is significant to ensure an effective SCWM practice among the local main contractors.

## RESEARCH METHODOLOGY

This research utilised the qualitative research method, which is well-suited for the research context requiring more in-depth thoughts and insights of the targeted respondents. Figure 2 illustrates the research methodology applied. Prior to the scheduling of the preliminary group interview, an extensive literature review about the local CWM practices and issues was conducted to identify the gaps in the research opportunity. Then, an unstructured pilot group interview with the SWCorp personnel was conducted for the development of a draft procedural framework focusing on 6R waste management. SWCorp is a government agency established under the Ministry of Housing and Local Government and the Solid Waste Management and Public Cleaning Corporation Act (Act 673), which aims to create a comprehensive, integrated, cost-effective and sustainable solid waste


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management system. The pilot group interview with SWCorp benefits the feasibility of the 6R approach as well as enhances and improves Malaysia CWM. Five (5) personnel including the director, assistant director, and three executive engineers were involved in the face-to-face group interview. All their responses and recommendations were recorded for developing a draft 6R procedural framework for the contractor's implementation. Suggestions from the interview were also taken into consideration for refining the semi-structured interview questions prepared for main contractors in the next agenda.

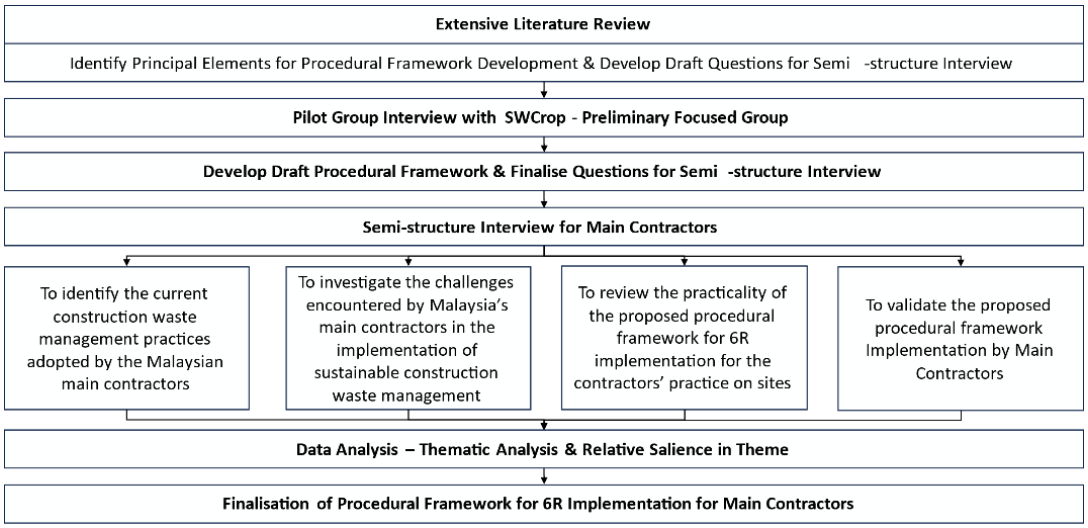


**Figure 2:** Research Approaches for Data Collection.

Thereafter the draft procedural framework was developed, and the semi-structured interview questions were refined, targeted interview participants were identified through purposive sampling method. Grade 7 (G7) main contractors registered under the Construction Industry Development Board (CIDB) within Klang Valley, Malaysia, who have direct exposure and experience in construction waste management were contacted for interviews. Given that the targeted audience was somewhat hard to reach, the snowball sampling technique was utilised. The semi-structured interviews were conducted with the G7 main contractors in face-to-face mode, which included the organisation executives and managerial personnel. The interviews explored the participants' current practices in construction waste management, the challenges they encountered in implementing SCWM, the feasibility of the draft procedural framework and the proposal for improving the procedural framework for 6R implementation. Qualitative studies often yield limited data results, relative salience in themes was integrated into the thematic analysis for data analysis. Data collected from these interviews are thematically analysed, wherein the findings are systematically

organised and categorised. The data are organised into themes by identifying key concepts, grouping them into categories, refining through iterative review, and finally defining and naming each theme. Relative salience in theme was integrated to further enhance the data analysis based on the frequency of the points/topics discussed and its alignment with the research objectives. The key findings from this holistic approach were then used to enhance the procedural framework, facilitating the effective adoption of the main contractor's implementation in 6R waste management.

## RESEARCH FINDINGS AND DISCUSSION

### Preliminary Focused Group Interview

The findings of expert group interview with SWCorp Malaysia are presented in this section. From the group discussion, all participants strongly agreed that main contractors play a crucial role in reducing construction waste. While main contractors must follow the client's and designers' instructions, the main contractor also plays an important role in reducing construction waste through proper storage and ordering the necessary quantity of construction materials. Two prominent challenges to implement SCWM were identified i.e. lack of legislation enforcement and outdated waste management guidelines. They urged that these CWM guidelines should be eliminated and replaced accordingly. These statements were supported by Ng et al. (2015) who emphasised the significance of policy and legislation in reducing waste during the construction stage. The lack of strict enforcement in CWM can be observed as the reason for the lack of awareness among contractors. Perhaps, the existing guided procedures should be more comprehensive in this context.

During the group discussion, principal elements required for the procedural framework development were outlined and presented to the expert group. Five suggestions were conveyed for consideration in commencing the procedural framework for 6R implementation. Firstly, SWCorp suggested the appointment of waste management officer on-site and identification of waste disposal facilities in advance to facilitate waste management. Second, more information should be provided for non-recyclable, lead-free and asbestos-free materials in developing the framework. Next, the framework should consider the appointment of waste collection service providers during the pre-construction stage, as waste is inevitably generated during site preparation. Besides, certain contracts under the Jabatan Kerja Raya (JKR) require contractors to order 20% of construction materials upfront to receive their first payment. Hence, the term "required quantity" is subjective in the outline. This serves as a reminder to contractors, that the practice of excessive ordering often leads to on-site waste. The last suggestion was about the international recognition of the 6R practices which is essential for continuous improvement and introducing new habits to construction practices. The inputs by SWCorp are valuable, insightful and have


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comprehensively captured the essential elements for the development of the procedural framework. Figure 3 illustrates the proposed procedural framework as a result of the group discussion.

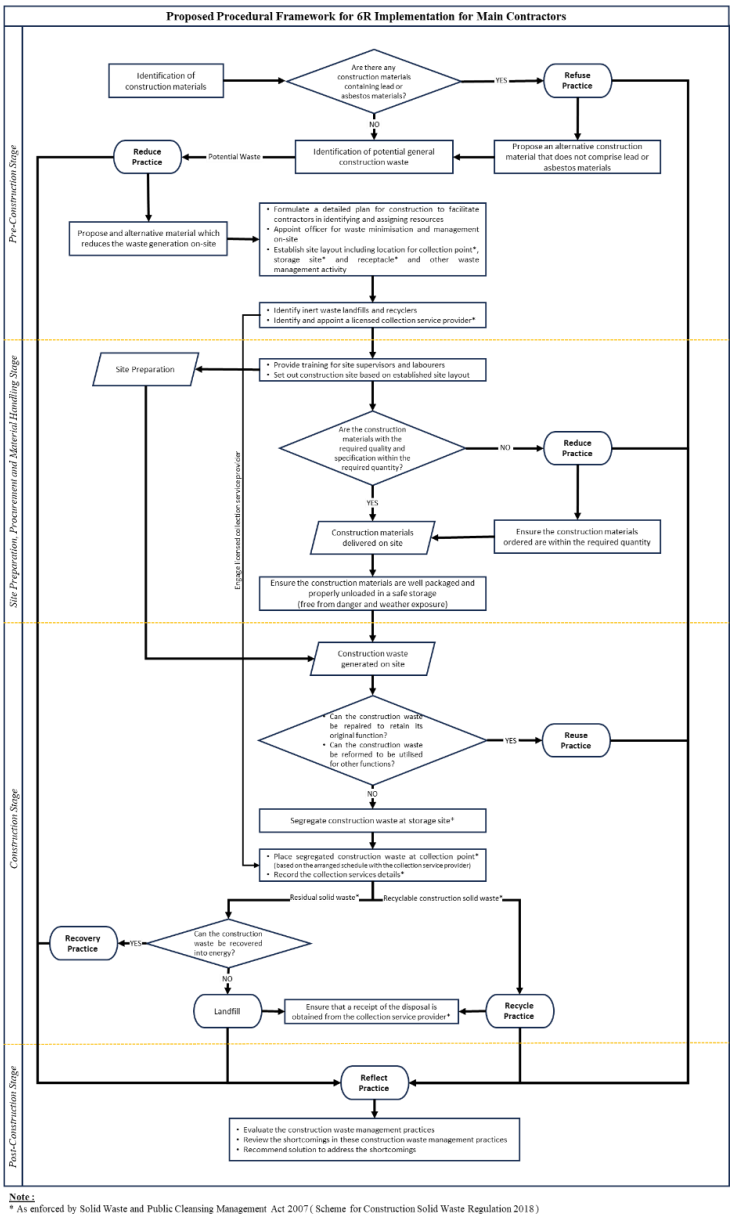


**Figure 3:** Proposed Procedural Framework for 6R Implementation for Main Contractors

**Interviews with Main Contractors**

The interviewees are made up of professionals of different position levels in the construction industry, ranging from Chief Operating Officer to Managing Director and Senior Manager, with an average of 22.8 years of working experience. A set of open-ended semi-structured questions and the proposal of the procedural framework for 6R implementation were prepared for the interviews. The collected data was then analysed thematically, ensuing four main themes that captured the results and findings from these interviews.

***Main Contractor's Construction Waste Management Plan***

All interviewees correspondingly agreed that contractors play a crucial role in reducing construction and demolition waste on site. This includes substituting potential waste materials for more sustainable alternatives, ordering materials in the specified quantities, and ensuring proper handling and storage. Based on the collected data, it was observed that most of the main contractors adopt three primary approaches to reduce waste in construction: i) Industrialised Building System (IBS), ii) Prefabricated Components, and iii) Adoption of metal formwork. Among the different types of construction waste, timber is a significant contributor. This finding is supported by Lin et al. (2021) and Faridah et al. (2004) that timber waste usually occupies at least two-thirds of the overall construction waste, due to massive use of timber formwork. While alternative formwork methods could help reduce waste and eliminate the need for timber formwork, challenges arise when dealing with complex curved structures that cannot accommodate these alternative methods. Albeit to completely eliminate timber formworks from the waste stream remains a challenge, all interviewees reassured that they make efforts to reuse timber formworks for multiple cycles. When the timber can no longer serve its original purpose, two interviewees shared their experience in repurposing the timber for site offices or as temporary sheds.

***Complexities in Implementing Sustainable Construction Waste Management (SCWM)***

The implementation of Sustainable Construction Waste Management (SCWM) in Malaysia faces significant challenges, as pointed out by the respondents. The main challenge conveyed is about cost limitation, with half of the interviewees noting that competitive project awarding based on price often compels contractors to reduce their profit margins during tendering, leading to a focus on cost reduction throughout the construction stage. Sustainable materials like metal formworks, although beneficial, can be more expensive than conventional timber formwork, making them financially prohibitive for some projects. Insufficient space on construction sites, both large and small, can impede proper waste segregation and management. Even when space is available, all interviewees have


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concerns about coordination issues that may arise as construction progresses, requiring constant adjustments to storage and segregation areas.

All interviewees experienced appointing licensed service providers for construction waste disposal. However, there are doubts on where the waste will be disposed after it leaves the sites. It is believed that most of waste collection service providers have inadequate waste management facilities, especially the problems of landfill shortage. This may have impacts on the construction disposal processes and end up illegal dumping may happen. Such results will further complicate the efforts of the main contractors. Inadequate CWM facilities in Malaysia, including a shortage of landfills and a lack of plants of waste-to-energy (WtE) incineration, hinder sustainable practices. Moreover, all interviewees have also mentioned time constraints issues for implementing proper waste disposal process, particularly in fast-tracked projects. Fast-tracked projects may discourage the implementation of waste segregation processes due to the additional time and cost required for coordination. Interestingly, most interviewees do not consider the lack of knowledge among construction workers as a major challenge, as training programs are in place to promote awareness and understanding. However, language barriers may pose difficulties when foreign labourers are involved. The poor attitudes of construction workers, influenced by cultural practices, can be an obstacle, but organisations can foster a culture of sustainability to shape behaviours.

Lastly, all interviewees have highlighted that the lack of precise legislation enforcement and detailed guidelines for construction solid waste management is a notable challenge. Interviewees suggest the need for improved communication and engagement to ensure compliance with sustainable practices in the industry. Yadav et al. (2022) supported this statement in their research on the challenges in implementing SCWM, which emphasised the lack of proper regulations for waste sorting, the lack of coordination among government bodies, and the absence of an effective waste tracking system.

Overall, all interviewees highlighted the difficulty in implementing sustainable construction waste management in Malaysia, identifying various challenges such as cost limitations, insufficient space for waste segregation on construction sites, doubts about the disposal destinations of waste collected by service providers, inadequate waste management facilities, time constraints, language barriers with foreign labourers, cultural influences, and the lack of precise legislation enforcement and detailed guidelines for construction solid waste management.

***The Practicality of the Procedural Framework for 6R Implementation***

Over 65% of the interviewees revealed that their companies are implementing a systematic procedure for CWM in compliance to the 3R practices in Malaysia. The suggestion to incorporate the additional CWM practices i.e. *refuse*, *recover*,

and *reflect* has gained positive response among the interviewees, as the additional 3R practices supplement the current. Two interviewees expressed consensus that these practices include the refusal of asbestos and lead mineral materials, but it was suggested that contractors should inform designers and propose alternative materials. Nevertheless, there are differing opinions on whether contractors can suggest alternative materials while declining those with such minerals. Notably, all interviewees agreed on the practicality of *recovery* and *reflect* practices. Overall, the concept of *reflect* practice received unanimous approval as it promises continuous improvement in project performance by incorporating sustainability and waste management practices.

In summary, the main contractors collectively believe that the proposed 6R procedural framework holds significant promise in facilitating the effective implementation of SCWM practices throughout their projects. However, interviewees acknowledge that successful adoption depends on the availability of additional funds, the engagement of suitable personnel and legislation enforcement.

**Validation of Procedural Framework for 6R Implementation**

The draft procedural framework for 6R Implementation (see Figure 3) was presented to the interviewees for their valuable comments to enhance the effectiveness of the procedural framework for Main Contractors. One suggestion is to create of a platform for knowledge sharing on SCWM practices, which allow contractors to exchange insights on challenges and best practices. Another proposal is to include appropriate materials handling, storage, disposal, and 6R practices in project kick-off meetings. These meetings are deemed essential by all project stakeholders, emphasising the importance of early engagement and effective communication. Active participation from the client and consultant teams during the pre-construction stage is encouraged to implement this recommendation. The goal is to promote brainstorming and collaboration among stakeholders for a comprehensive and successful implementation of 6R practices, distributing responsibility and accountability across the entire project team. Additionally, all interviewees unanimously agree on the need for a reward and penalty system to motivate and enforce SCWM practices. While back charges currently serve as penalties for material damage, it is suggested that a balanced reward and penalty system be implemented. This approach would create accountability and provide incentives for exemplary practices. Besides, using visual reminders on construction sites has been proposed to reinforce SCWM practices among workers. Similar to safety signage, these visual reminders would help workers remember proper waste disposal and handling procedures, indirectly reducing construction waste. Incorporating the term "unloading" into the procedure is also recommended. Proper unloading practices are important for fragile components like glass and masonry, as improper handling can lead to


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waste. By emphasizing careful unloading, the aim is to minimise material damage and waste during construction. Moreover, it was recommended to prepare CWM evaluation reports to be submitted to government bodies such as the Ministry of Housing and Local Government (KPKT) and the Solid Waste Management and Public Cleansing Corporation (SWCorp). This reporting process should document the effectiveness of SCWM practices of a project, and facilitates collaboration with regulatory bodies for improvements. It creates a feedback loop for ongoing refinement and innovation in SCWM practices. Finally, one interviewee suggests that government bodies should offer incentives to encourage contractors in Malaysia to adopt 6R practices, aligning with national sustainability goals.

In summary, these recommendations reflect the collective wisdom and insights drawn from extensive experience in the construction industry. All interviewees emphasised the need of knowledge sharing, good communication, balanced reward & penalty systems, visual reinforcement, attention to unloading procedures, regulatory collaboration, and incentivization. These factors are essential for implementing successful SCWM practices within the proposed procedural framework for main contractors. These valuable suggestions provide a roadmap for refining and enhancing SCWM practices in the construction sector, aligning with Malaysia sustainability objectives.

**Development of Procedural Framework for Main Contractor's Implementation**

The proposed procedural framework for 6R implementation demonstrates the roles and waste management processes that main contractors should comply with during the pre and post construction stages. Following the pilot group interview with SWCorp, a draft framework is developed as shown in Figure 3. The framework firstly begins with the rejection of wasteful or non-recyclable products by main contractors. Next, the process to reduce potential construction waste on-site via substitution of sustainable materials is a vital move. Then, the contractors should minimise waste generation through appropriate site planning and management in relation to the construction process, and material arrangement. It is also important that the contractor is aware of the appointment of a licensed collection service provider and the location of the landfills and recyclers. Moving on, all construction materials should be ordered in the required quantities and the specification of the materials should be within the required quality. As mentioned in the previous section, these materials must be securely stored and appropriately packaged. For any unavoidable waste generation, main contractors should first evaluate whether the waste can be reused by repurposing it for other applications. If these options are not feasible, the waste should be segregated into residual solid waste and recyclable construction solid waste at the storage site, as required by supplementary legislation under Act 672. Once the receptacle is full, it should be

placed at the designated collection point. Furthermore, recording the details of the collection services is mandatory. The sorted recyclable construction solid waste should be sent to recycling facilities, while the residual solid waste should be delivered to recovery facilities. Landfilling should only be considered when the construction waste is no longer reusable, recyclable, or recoverable. Finally, main contractors should reflect on the implemented CWM practices by evaluating them and recommending further improvements for future projects. Although the supplementary legislation under Act 672 does not apply nationwide, it is still advisable to adopt these good practices to facilitate sustainable construction waste management. The drat procedural framework aims to support main contractors in implementing successful SCWM through the incorporation of 6R practices throughout their entire project. However, the draft framework requires criticism on its practicality and validation from the users i.e. the main contractors.

The interviews with main contractors revealed all respondents collectively acknowledged the proposed 6R procedural framework holds significant promise in facilitating the effective implementation of SCWM. Additional recommendations were derived from the interview data to finalise the procedural framework. These recommendations are in reference to the section *Validation of Procedural Framework for 6R Implementation* and are summarised as: establishing a knowledge-sharing platform, proper materials handling, storage & disposal, including 6R practices in the kick-off meeting agenda, involvement of top management in SCWM, balanced reward and penalty system, visual reinforcement of SCWM practices, documentation of SCWM practices for KPKT and SWCorp approval, and government incentives and rewards. The finalised procedural framework is illustrated in Figure 4.


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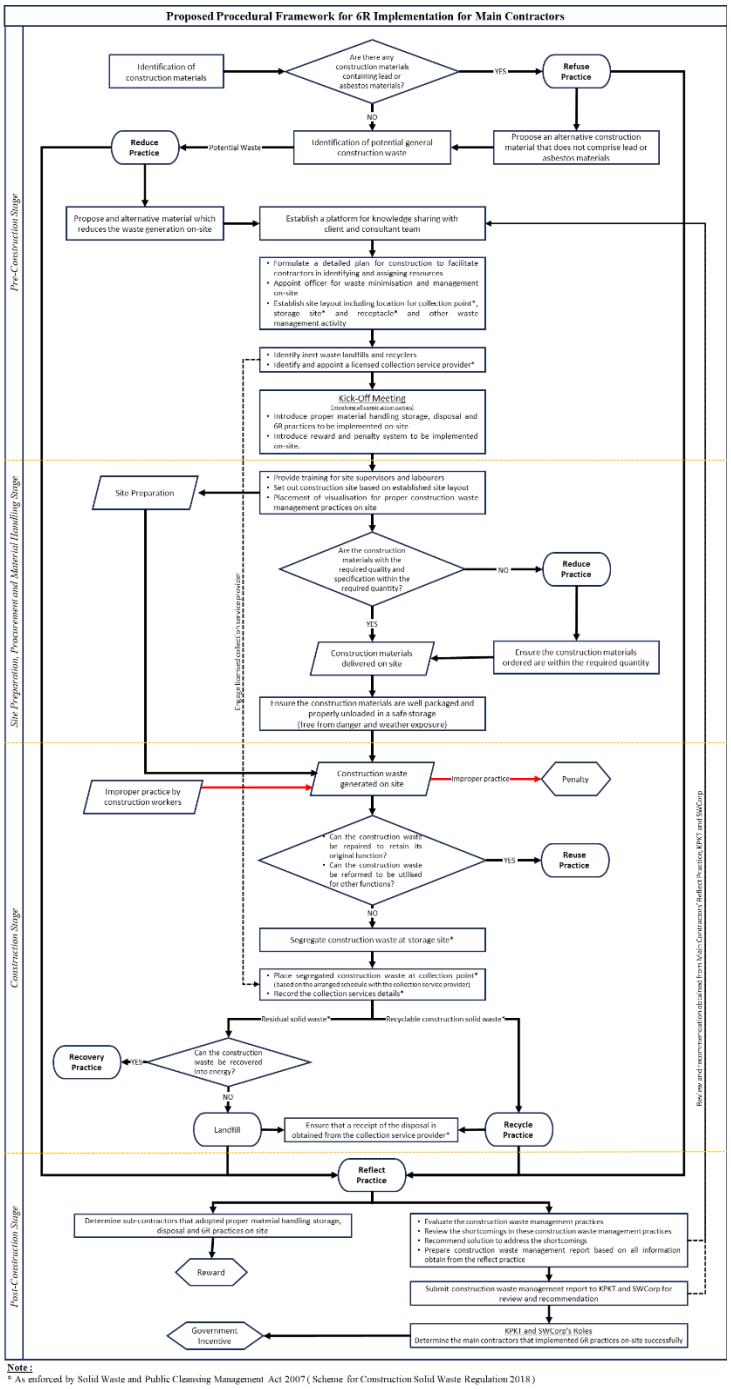


**Figure 4:** Finalised Procedural Framework for 6R Implementation for Main Contractors

## CONCLUSION AND FUTURE RESEARCH

The research aims to improve the SCWM practice of the contractors in Malaysia by developing a procedural framework for 6R implementation. Pilot group interviews were conducted with SWCorp and semi-structured interviews were carried out with main contractors to gain insights into current CWM practices, challenges faced, how the issues can be solved via a procedural framework and the viability of the developed framework. The research findings revealed that the most commonly adopted CWM practices are *Reduce* and *Reuse*, with the remaining waste being collected by licensed waste collectors. However, these practices do not align seamlessly with the comprehensive CWM guidelines outlined by SWCorp (2018). From the perspective of contractors, cost limitations pose a significant obstacle to the adoption of SCWM practices, particularly for large to small-scale construction firms. This issue has become more prominent when considering advanced construction methods (usually higher cost) such as metal framework and prefabricated components, making contractors hesitant to spend for SCWM. The additional practices on *refuse*, *recovery*, and *reflect* were suggested to complement the current 3R practices in Malaysia. The results notably indicated that contractors were majorly receptive to the *recovery* and *reflect* practices. The *reflect* practice was considered essential for a project to improve its sustainability aspect. All recommendations received to improve the procedural framework were evaluated and wisely incorporated into the finalized procedural framework for 6R implementation as shown in Figure 4.

The procedural framework was developed in mind to improve the current practices and resolve the challenges faced by local contractors. The study concluded the final product is well-accepted by contractors and deemed feasible for implementation. It is important to note that the final procedural framework can be suitably applied into the federal territories and certain states in Malaysia. The research contributes a systematic procedure for main contractors' application in managing construction waste throughout the project phases. The study is particularly significant in the area of sustainable construction, promising a healthier and more resilient built environment by supporting the UN SDG 12: Responsible Consumption and Production and SDG 13: Climate Action. There is a suggestion that future research can focus into evaluating the effectiveness and impacts of implementing the developed procedural framework in real construction projects. Exploration into the barriers to adopting the procedural framework for successful SCWM practices, incentives to main contractors, as well as the economic implications of applying the framework are also within the future research directions.


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# IMPLEMENTATION OF ZERO WASTE CONCEPT IN MALAYSIA: FROM CONTRACTORS' PERSPECTIVE

**Habizah Sheikh Ilmi[1], Jing Wen Yee[2], Kenn Jhun Kam[3], Tze Shwan Lim[4] and Lam Tatt Soon[5]**

[1,2,3,4,5]*School of Architecture, Building and Design,*
TAYLOR'S UNIVERSITY, MALAYSIA

## Abstract

Construction waste is one of the major contributions to severe environmental issues. However, this construction and demolition (C&D) waste issue is often neglected by the stakeholders. Instead, they focus more on cost, time and quality as their priority. In Malaysia, the lack of knowledge and awareness of sustainable zero waste practices have become a major obstacle to sustainable development in the construction industry. To address this, the implementation of Zero Waste concept should be widely promoted to reduce the solid waste production and mitigate the depletion of natural resources. Hence, this study is to identify the challenges of implementing zero waste concept among the contractors. This research focuses on building contractors by using a quantitative research method to collect data from the targeted population. The findings of the study highlight that waste reduction, curbing illegal dumping and reducing public health risks are the primary concerns in relation to the Zero Waste concept. The study reveals that contractor's attitude and reluctant behaviour, inadequate policies and the absence of mandatory zero waste management are the main barriers for the implementation of zero waste concept in Malaysia. The government should play an important role to develop C&D waste concept and to identify suitable C&D waste models which can be used in Malaysia. By adopting zero waste concept, the construction industry in Malaysia can move towards a more sustainable future and develop its sustainability targets under Sustainable Development Goal (SDG) 12.

***Keywords***: building contractors, Construction and Demolition (C&D) waste, sustainability, waste management, Zero Waste concept

[1] Lecturer at Taylor's University, Malaysia. Email: Habizah.ilmi@taylors.edu.my

## INTRODUCTION

Rapid urbanization and industrialization symbolize the accelerated development of the economy and the increasing population growth in a country. However, there are some aftermaths which come along with the evolution and alterations. The rise in community living standards has significantly boosted waste generation in the world, especially in developing countries (Guerrero et al., 2013). It is essential to have an effective approach to the management of solid waste which has been adopted in several developed countries to promote sustainable development, namely Zero Waste concept. This concept is used to reduce the production of solid waste that can mitigate the depletion of natural resources as well as achieve waste minimization to its lowest level (Hairul et al., 2019). Zero Waste is considered a means of waste management, which is also an ambitious goal to cope with waste. Basically, it is about managing the waste by eliminating, minimising and/or recycling waste wherever possible and feasible. The term "Zero Waste" was first introduced in the 1970s by Paul Palmer, a PhD chemist at Yale. This approach is somewhat philosophical because it is impossible to control waste to 0% or completely eliminate waste because there will always be a residue (Christof, 2016).

Construction industry has become a major generator of waste due to the massive amount of waste that can be generated throughout the year. Most of the construction and demolition (C&D) waste being sent to landfills has resulted in several issues in various aspects such as environmental aspect, social aspect and economic aspect and the like. To date, landfilling has been the most common disposal method for C&D waste. The major environmental impacts include land space consumption, resource depletion, pollution in air, noise, soil and water, depletion of landfills, and energy and non-energy resource consumption as well (Chen et al., 2020). According to Chooi et al. (2018), the comparison of the damage assessment on the environmental impacts has clearly stated that the business as usual (BaU) waste flow will keep rising at the rate of 20.2% in the year 2025 without any proper measure. Improper planning management during the construction phase leads to the generation of C&D waste. According to Rahim et al. (2017), people who live in certain places in Malaysia has raised their concern regarding illegal dumping activities which contribute to environmental issues and the negative image of the areas. In March 2021, five contractors were caught for illegal dumping at different sites in Klang, Malaysia and fined RM2,000 each (Rajendra, 2021). In 2020, a waste contractor was found guilty and was fined RM13,000 in the first illegal dumping case carried out in Putrajaya (EdgeProp.my, 2020).

Currently, Malaysia produces an average of approximately 23,000 tonnes of waste per day at a recycling rate of 5% (Sreenivasan et al., 2012). According to Bernama (2022), there are nearly 40,000 tonnes of waste generated per day and an estimated 95% of waste would eventually result in landfills as


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well. Furthermore, the implementation of the zero-waste concept in Malaysia is significantly behind other countries, especially the neighbouring country, Singapore. Sustainability is the main consideration for Singapore's development, hence they have built a zero-waste master plan according to three different aspects, for example, climate resilience, resource resilience and economic resilience. Moreover, Singapore converts waste into resources by applying waste-to-energy (WTE) incineration plants (Zero Waste SG, 2020).

## PROBLEM STATEMENTS

In the construction industry, construction waste is one of the major contributors to severe environmental issues, especially in developing countries (Eusuf et al., 2012). The generation of C&D waste has been rising continuously which is parallel with the rapid development of the economy in Malaysia. Unfortunately, Malaysia has poor C&D waste management despite introducing several methods to cope with it. Nowadays, limited landfills have created plenty of hardship for local and federal governments to dispose of the waste generated. In addition, the average lifespan of landfills in Malaysia is two years at maximum, whereas landfills in Western countries can last up to ten years. According to Muhamad and Seow (2014), it proved that the city centres have the most solid waste generated each year, compared to other cities such as Kuala Terengganu and Seremban. Until recently, this issue has not been improved and limited landfills availability issue has worsened. The Zero Waste concept and effective waste management approach need to be conducted to tackle the waste problems and mitigate environmental issues since construction waste management is still not widely adopted.

Nagapan et al. (2012) stated that illegal dumping has become a serious issue in Malaysia due to the insufficiency of waste management practices in the related industry. Solid Waste and Public Cleansing Management Act 2007 is one of the regulatory policies of waste management in Malaysia under Solid Waste Management and Public Cleansing Corporation (SWCorp), however, more attention is given to domestic waste instead of construction waste. According to Nazerry and Abdul (2007), illegal dumping has proven to put risks on human health and the environment. There are numerous factors that influence the individual or organizations conducting illegal dumping deliberately, such as increasing waste disposal fees owing to rigorous regulations of waste management and human behaviour towards handling waste and environment conservation. Begum et al. (2009) have demonstrated that a positive attitude and behaviour of a contractor towards waste management practices could influence the performance and growth of the construction industry. Moreover, the data of construction waste material density in Malaysia in which the mixed waste/demolition waste holds the highest density among all the other waste compositions (Shivaraj et al., 2018).

Nevertheless, the implementation of the Zero Waste concept is still not widely practised by most contractors in the Malaysia construction industry. Evidently, there are numerous barriers that the construction players will encounter, and even further developments and alterations are required to execute this practice. The low level of awareness by the contractors in Malaysia has caused the low adoption of the Zero-waste concept. Several challenges such as reluctance to change, financial issues and the like become obstacles for them to move towards sustainable waste management practices. Poor waste management may increase the amount of waste material on site. The execution of reuse, reduce and recycle are recommended to minimise waste production by the contractors at construction sites, hence the need for new resources can be reduced and resulted in cost savings for waste transportation and landfill disposal (Che Ahmad et al., 2014).

Therefore, this research paper will identify challenges faced by contractors to implement the sustainable Zero Waste concept in the construction projects.

## CHALLENGES IN IMPLEMENTING ZERO WASTE CONCEPT

### 1. Human Factor

According to Agamuthu and Fauziah (2010), despite the fast-paced economic growth in Malaysia, public concern and understanding are not growing in parallel. The involvement in Zero Waste approach to sustainable waste management is significantly inadequate. Lack of awareness on the Zero Waste concept is one of the main reasons for not conducting it. This is because the poor implementation of educational programs, training, and awareness campaigns among the contractors leads to a low level of public education hinders the understanding and practice the Zero Waste concept. Besides that, challenges related to the lack of leadership of professionals involved also contribute to the failure of delivering technical knowledge to contractors. Moreover, in the construction industry, poor guidance of the professionals as well as insufficient planning, monitoring and performance evaluation processes are also identified as barriers to effective C&D waste management (Mohd Nasir et al., 2016).

Ng et al. (2017) have noted that it is not an obligatory requirement for construction companies to conduct 3R practices. Some contractors in Malaysia are reluctant to try out new methods which could benefit them since they have been lacking proactivity. They are more comfortable with the current traditional waste disposal approaches and are not concerned about sustainability ways. A research from Moh and Abd Manaf (2014) highlighted that there is approximately 70% to 80% of the waste s recyclable in landfills in Malaysia. Besides the high cost of implementation of the Zero Waste concept, contractors prioritize their project's progress rather than waste minimization (Liyanage et al., 2019). In Malaysia, sustainable waste management remains a low priority among


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contractors. Ineffective cooperation among different project stakeholders causes challenges in carrying out new management instead of traditional methods due to poor communication and coordination between various parties (Muhamad and Seow, 2014).

Since Malaysian construction sector remains labour intensive, the attitudes and behaviours of individuals involved in the sector have significant impacts on its development and effectiveness (Begum et al., 2009). The negative behaviour and attitude of contractors determine the effective implementation of the sustainable Zero Waste concept in the construction industry.

## 2. Institutional Factors

### 2.1 Policy and Regulation

Zero Waste management in Malaysia is not mandatory which is identified as one of the barriers, and as a result, proper waste management is being neglected and not practiced by the construction players, especially contractors. The lack of institutional factors is largely a result of the lack of a suitable policy to implement regulations or legislation regarding the proper measures of waste management which the contractors should adopt to provide a sustainable waste management system and sustainable landfill practice in the construction sector (Agamuthu and Fauziah, 2010). Besides that, insufficiency in the enforcement of the law on waste management has lowered the level of awareness of zero waste management among contractors. This is because the policy and legislation play significant roles in the 3R (reuse, recycle and reduce) approach of the Zero Waste concept. The Act 672 is enforced by the Solid Waste Management and Public Cleansing Corporation, known as SWCorp Malaysia, which has the power to take control of solid waste management from local authorities. This has resulted in confusion and overlapping of enforcement powers between the corporation and the local authorities (Muhamad and Seow, 2014). In fact, the effective adoption of zero waste management policy reflects the sustainability of the waste management system. To achieve the goal of sustainable development, policy implementation is vital. Additionally, the government does not provide any support such as financial assistance and incentives to contractors for undertaking zero waste management in which these management methods require high budget costs to operate (Ng et al., 2015).

### 2.2 Facilities

Despite the existent of approximately 289 landfills in Malaysia, it is unfavourable to handle waste by disposing them because it may be discharged into the environment, which is the lowest priority in the sustainable waste management hierarchy (Nazerry and Abdul, 2007). Hence, the lack of waste plants is identified as one of the barriers of adopting the Zero Waste concept. In Malaysia, there are approximately seven mini-incinerators with capacities between 5 to 20 tonnes per

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day, but the majority of these incinerators do not have energy recovery systems. Due to high operating costs, these incinerators operate once a week which appears to be unsustainable even though it reduces large volume of waste generated. Additionally, air pollution might occur by applying this method (Aja and Al-Kayiem, 2013). Currently, there is only one existing Energy-from-Waste (EfW) plant in Malaysia located in Semenyih, Malaysia, Kajang Waste-to-Energy (WTE) Plant which was constructed in 2009, in which municipal solid waste (MSW) is transformed into refuse-derived fuel (RDF) to be used in an integrated steam power plant for the purpose of environmentally friendly MSW disposal and generating renewable power (Power, 2010). Furthermore, another WTE facility is called SMART (Solid Waste Modular Advanced Recovery and Treatment) WTE, built for converting solid waste to energy (electricity) in light of the concept of sustainable and integrated waste management. It is located at Ladang Tanah Merah, Port Dickson, Negeri Sembilan (Azman, 2020). However, this WTE facility is not yet officially operational despite obtaining a 98% completion rate (Abdullah, 2022 and The Edge Malaysia, 2023).

**2.3 Management Factor**

Muhamad and Seow (2014) have highlighted that the waste materials removed from the illegal dumping sites are dumped in landfills which causes the area in the landfill to fill up sooner than expected. Consequently, it hampers the undertaking of sustainable landfilling since the waste materials gathered do not receive any pre-treatment before being disposed. Additionally, in Malaysia, moist and putrescible materials are heavily mixed in with the waste that is dumped into landfills. The waste may contain between 70% to 80% of moisture. Landfill gas generation starts early under tropical circumstances and becomes a crucial aspect to be taken into consideration in landfill management because of the country's warm climate (27-34°C throughout the year), which accelerates the rate of decomposition of putrescible components. The fundamental issue with waste management nowadays is the accumulation of waste in landfills owing to space constraints, resulting in less rigorous environmental protection legislation governing landfilling operations (Liyanage et al., 2019). Poor waste management can be caused by lacking expertise in material handling and inadequate knowledge in the design stage. Waste separation is not a typical practice in Malaysia (Aja and Al-Kayiem, 2013).

Furthermore, the ineffective management system with immature recycling technology challenges undertaking the Zero Waste concept among contractors. It is pivotal for material selection by contractors with quantity reduction of waste while strengthening the quality. The underdeveloped market for C&D waste materials and immature recycling market operation is also identified as the barriers influencing the utilisation of the Zero Waste concept (Huang et al., 2018). Besides that, majority of the landfills in Malaysia have lack


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of infrastructure for the collection of landfill gas and leachate that rely primarily on natural clay lining as their landfill liners. The construction of these disposal facilities was mostly established by the conventional concern with waste disposal (Agamuthu and Fauziah, 2010).

## RESEARCH METHODOLOGY

In this research, the data collection was done via a questionnaire survey. Quantitative method is applied in this research study. It is a systematic method of gathering and analyzing quantifiable and verifiable data. A larger size of sample will represent the entire target population in the study which will ensure the research finding is impartial and trustworthy.

Likert scale of five (5) points is used in the questionnaire. Choices provided for respondents, such as the preferred level of agreement to a certain question by respondents in a range from strongly disagree to strongly agree are frequently referred to as categories (Samuels, 2020). This method assists them in reflecting their perspectives on the nearest options from a list of possible responses.

Based on Tholibon et al. (2021), Relative Importance Index (RII) is used as the value of the index which specifies the ranked degree of importance. Sakhare and Patil (2019) have stated that researchers in the fields of construction and facilities management frequently utilise the Relative Importance Index (RII) which is a non-parametric technique to analyse structured questionnaire responses for information including ordinal measurement. RII illustrates that the variables' criteria were more significant in line with the higher the RII rating and vice versa.

Reliability which also refers to internal consistency, is measured by Cronbach's alpha. The reliability of surveys with Likert scale questions is evaluated by using Cronbach's alpha tests. It allows to test how closely connected a group of things are to one another because these questions gauge latent variables which have the character of concealed or unapparent that are challenging to measure in real life (Fikri Hasmori et al., 2020). The reliability level of variables varies depending on the value of the coefficient of Cronbach's alpha (Mat Nawi et al., 2020).

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**Table 1.** The Range of Reliability Level and Its Coefficient of Cronbach's Alpha

| Coefficient of Cronbach's Alpha | Reliability Level |
|---|---|
| More than 0.90 | Excellent |
| 0.80 - 0.89 | Good |
| 0.70 - 0.79 | Acceptable |
| 0.60 - 0.69 | Questionable |
| 0.50 - 0.59 | Poor |
| Less than 0.59 | Unacceptable |

*Source: Zahreen Mohd Arof et al. (2018)*

## ANALYSIS AND FINDINGS

### Demographic Analysis of Respondents

There is a total of 307 respondents who have participated in the data collection stage. The target population is focused on all grades of building contractors in Malaysia.

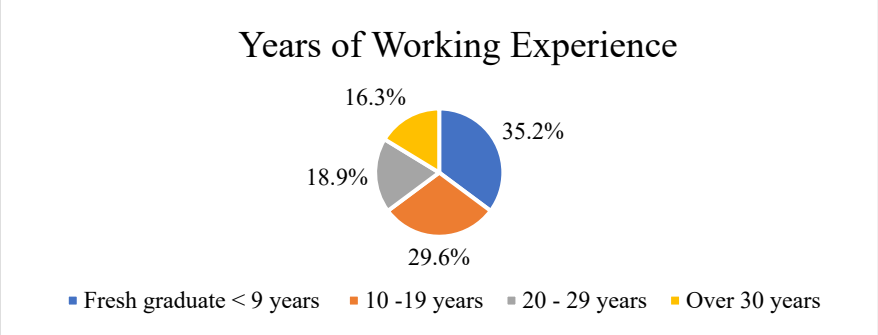


**Figure 2.** Analysis for Years of Working Experience

Figure 2 demonstrates the years of working experience of the respondents in the Malaysian construction industry. Majority of the respondents have 9 years of working experience (35.2%), followed by 10 - 19 years (29.6%), 20 - 29 years (18.9%) and lastly, 16.3% of respondents acquire over 30 years of working experience. This indicates that data collected is reliable and useful.


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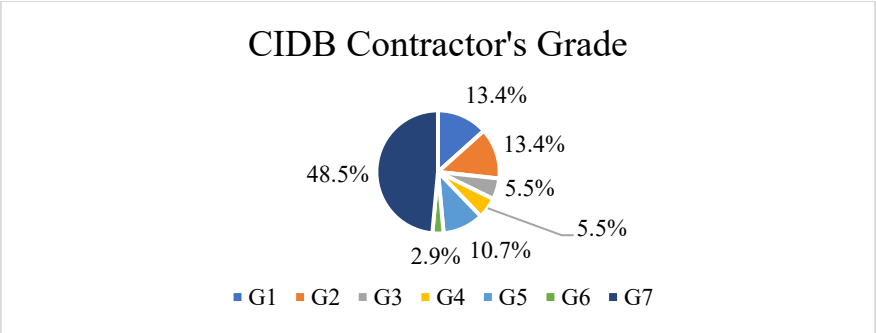


**Figure 3.** Analysis for Contractor CIDB Grade

According to Figure 3, majority of them are G7 contractors which holds 48.5%. G1 and G2 contractors constitute 13.4% each of the overall respondents, followed by G5 contractors (10.7%); G3 and G4 contractors comprise of 5.5% each and lastly 2.9%of them are G6 contractor. This indicates G7 contractors shows an interest fill in their opinions and find out about Zero Waste concept.

**Awareness of Zero Waste Concept in the Malaysian Construction Industry**

Figure 4 shows majority of the respondents (67.8%) are aware of the Zero Waste concept in Malaysia. However, there is still low adoption of the concept in the construction industry concept despite knowing the presence of this concept. Thus, there may be some reasons or challenges faced which resulted non-application of the concept.

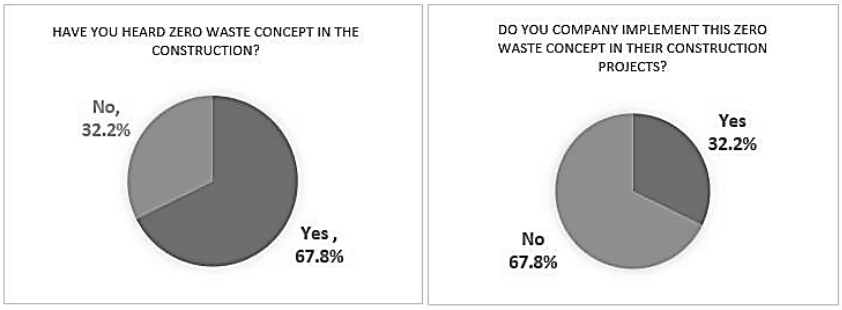


**Figure 4.** Awareness and Implementation of Zero Waste Concept in the Construction Projects

## Perception of Possible Implementation of Zero Waste by the Contractors

**Table 2.** Perception of Implementation of Zero Waste Concept

| | Question on Perception of Implementation of Zero Waste Concept | Mean | RII | Rank |
|---|---|---|---|---|
| K1 | Do you think that Zero Waste concept can benefit the company? | 4.162 | 0.832 | 2 |
| K2 | Do you think that Zero Waste concept can benefit society and the environment? | 4.541 | 0.908 | 1 |
| K3 | Do you think that Zero Waste concept will be a trend in construction industry in the future? | 3.946 | 0.789 | 3 |

Table 2 demonstrates the perception of possible implementation of Zero Waste concept for construction projects in Malaysia among the building contractors. The willingness to implement the concept can be realized by appreciating the benefits brought into the construction sectors as well as further development in the future. Most respondents think that Zero Waste concept in the construction industry will benefit society and the environment rather than for the company. Moreover, it can be seen that there are still high chances of the Zero Waste concept becoming a trend in the construction industry in the future.

## Challenges of Implementing Zero Waste Concept in Malaysian Construction Industry

**Table 3.** Analysis on Challenges of Implementing Zero Waste Concept in Malaysian Construction Industry

| | Variables | Mean | RII | Rank | Overall Mean | Overall Ranking |
|---|---|---|---|---|---|---|
| B. Human Factor* | | | | | | |
| B1 | Lack of awareness of Zero Waste concept in Malaysia. | 4.135 | 0.827 | 3 | 4.097 | 1 |
| B2 | Absence of leadership of professionals involved. | 4.162 | 0.832 | 2 | | |
| B3 | Poor guidance of the professionals. | 3.973 | 0.795 | 5 | | |
| B4 | Attitude of reluctance to try out new methods (Zero Waste concept) by contractors as they prefer traditional waste disposal. | 4.216 | 0.843 | 1 | | |
| B5 | Ineffective cooperation among different project stakeholders has caused challenges in carrying out new management. | 4.000 | 0.800 | 4 | | |
| C. Institutional Factor* | | | | | | |
| C1 | Nonmandatory of zero waste management in Malaysia. | 4.108 | 0.822 | 3 | 4.081 | 2 |


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| | Variables | Mean | RII | Rank | Overall Mean | Overall Ranking |
|---|---|---|---|---|---|---|
| C2 | Insufficiency in the enforcement of the law on waste management. | 4.216 | 0.843 | 1 | | |
| C3 | Support by the government such as financial assistance and incentives to contractors. | 4.189 | 0.838 | 2 | | |
| C4 | Lack of waste plants. | 3.811 | 0.762 | 4 | | |
| D. Management Factor* | | | | | | |
| D1 | Improper waste management as the waste materials gathered do not receive any pre-treatment before being disposed of. | 4.081 | 0.816 | 2 | 3.955 | 3 |
| D2 | Space constraints for landfills. | 3.676 | 0.735 | 3 | | |
| D3 | Ineffective management system with immature recycling technology. | 4.108 | 0.822 | 1 | | |

* Item is tested for reliability test and is valid to analyse.

According to Table 3, human factor (B) has the highest overall mean value of 4.097 which ranked first among other major barriers of aspect which supports the research by Agamuthu and Fauziah (2010). It is found that the human factor is one of the main elements that challenge the implementation of Zero Waste concept that a proper treatment system is required. The societal mentality regarding the awareness of the significance of the Zero Waste concept remains low. Malaysians tend to prioritize working for direct personal benefits such as incentives for participating in waste management (Harun et al., 2019). Furthermore, institutional factor (C) ranked 2nd with an overall mean value of 4.081. The current policies and regulations in Malaysia make sustainable landfilling hard to perform and achieve. It is also noted that the effective adoption of zero waste management policy reflects the sustainability of the waste management system (Ng et al., 2015). Lastly, management factor (D) ranked last (3rd) with an overall mean value of 3.955, as mentioned by Huang et al. (2018) that the underdeveloped market for C&D waste materials and immature recycling market operation has caused difficulties in adopting Zero Waste concept.

**Strategies to Improve Awareness and Application of Zero Waste Concept in Malaysian Construction Industry**

There are several suggestions can be considered to address the challenges faced by the contractors in implementing sustainable Zero Waste concept. It is essential that the government plays the role in implementing a new concept since support from the government is required (Abas and Seow, 2014). The government can focus on GHG mitigation efforts related to developing and adopting low carbon construction material as mentioned by CIDB (2022). Good governance, which

influences policy, management and resource allocation, requires the engagement and cooperation of all key stakeholders in the field. As mentioned by Ng et al. (2017), in order to inspire contractors to manage and supervise C&D waste efficiently in the construction sector through the use of the Zero Waste concept, a variety of initiatives including education programmes, awareness campaigns, and training should be promoted. This is also supported by Imroatu et.al (2023) that environmental awareness campaigns can give positive outcome towards appreciation of clean environment and sustainability. It is essential to plan the construction materials throughout the design phase to prevent construction material waste (Huang et al., 2018). Lastly, adopting innovative technologies and market models from developing countries such as prefabrication technologies are useful for the enhancement of sustainability in the construction industry.

## CONCLUSION

In conclusion, the research found that majority of the building contractors understand and see the value of Zero Waste concept which brings advantages to them and even to society and the environment. However, in the real world, various kinds of challenges that they have encountered become obstacles in adopting the concept despite the high desire of implementing it is shown by them. Every individual must perform their own role, responsibilities and obligations, hence good coordination and cooperation between various parties can be formed to assist in developing the Zero Waste concept in the Malaysian construction industry. The handling methods of C&D waste in developing countries can be referred to and applied the appropriate and optimal model for Malaysia. For sustainability, some Targets under SDG 12 in Malaysia can be improved and developed like Target 12-2 (sustainable management and use of natural resources), Target 12-4 (responsible management of chemicals and waste), Target 12-5 (substantially reduce waste generation), and Target 12-6 (encourage companies to adopt sustainable practices and sustainability reporting). Although it is impossible to minimize C&D waste to zero, there is a high possibility of utilizing them to the fullest value.

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# EXPLORING THE POTENTIAL OF SOLAR POWER FOR RESIDENTIAL USE IN MALAYSIA: INSIGHTS FROM SOLAR COMPANIES AND LOCAL AUTHORITIES

**Kai Chen Goh[1], Jia Wen Kong[2], Changsaar Chai[3], Chia Kuang Lee[4]**

[1,2]*Faculty of Technology Management and Business,*
UNIVERSITI TUN HUSSEIN ONN MALAYSIA.
[3]*School of Architecture, Building and Design,*
*Faculty of Innovation and Technology,*
TAYLOR'S UNIVERSITY, MALAYSIA.
[3]*UTM Construction Research Center (UTM CRC),*
UNIVERISTI TEKNOLOGI MALAYSIA.
[4]*Faculty of Industrial Management,*
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH, MALAYSIA

## Abstract

With extremely strong solar radiation during the year, Malaysia has the greatest potential for solar-energy implementation. However, despite the widespread interest in the country, solar energy is still not widely utilized in residential buildings. Thus, this research aimed to identify the implementation and challenges of implementing solar energy in residential buildings and strategies to promote solar energy in Malaysia. Thirteen responses from representatives of solar companies in Malaysia were obtained through interviews. Through the research results, the implementation and challenges faced in implementing solar technologies were identified, together with strategies to promote solar technology. High installation costs, lack of awareness, and lack of incentive schemes are the barriers that prevent people from installing solar technology, as revealed by the interviews. Therefore, the government should make greater efforts to promote solar energy to the public. Interviewees suggested successful financial incentive schemes, personal tax exemptions, and public awareness programs to attract consumer interest as ways to increase solar adoption. The findings of this research may be used to help the government develop policies to promote solar energy for electricity consumption in residential buildings.

***Keywords***: Solar energy, potential, residential buildings, companies, local authorities

[3] Associate Professor at Taylor's University Malaysia. Email: cs.chai@taylors.edu.my

## INTRODUCTION

Solar energy, often known as solar power, is produced by converting renewable energy from sunshine to electricity by using photovoltaics (PVs) or concentrated solar power, or by collecting heat from the sun (Kamaruzzaman et al., 2012). The year-round availability of sufficient sunlight in Malaysia is conducive to the development of solar energy (Mekhilef et al., 2012). Northern Malaysia and a few eastern regions have the highest potential for solar energy deployment owing to their year-round exposure to high levels of solar radiation (Kamaruzzaman et al., 2012). However, most of Malaysia's energy production continues to depend on limited fossil fuel resources, such as oil, coal, and natural gas, and only a minor amount of electricity is generated from renewable sources (Alam et al., 2016). Fossil fuels are non-renewable resources that emit greenhouse gases, which are highly polluting. Large amounts of carbon dioxide, also known as greenhouse gases, are released into the atmosphere when fossil fuels are burned, causing global warming. Global warming will cause the global average temperature to exceed 1.5°C, thereby causing increased sea level rise and extreme weather, which will lead to poor health, food shortages, and poverty for millions of people around the world (Schleussner et al., 2016).

Approximately 7.5 million of Malaysia's total energy users are residential consumers (Abdullah et al., 2019). It may reduce greenhouse gas emissions by nearly 20% and avoid the use of fossil fuels by increasing the use of solar energy in the residential sector (Basri et al., 2015). Solar energy has seen tremendous growth amid growing concerns about climate change, but its implementation of solar energy is still in an early stage in Malaysia (Mekhilef et al., 2012). In order to support the use of solar energy, the Malaysian Government has implemented several incentives, programs, and strategies, including National Renewable Energy Policy, SURIA 1000 program, Feed-in Tariff (FiT) mechanism and Net Metering (NEM) Scheme (Kamaruzzaman et al., 2012). The FiT mechanism was introduced in 2011 but ended in 2017 and was replaced with NEM (Lau et al., 2022). With plentiful solar radiation and government initiatives, Malaysia still relies primarily on non-renewable resources for its energy needs despite the country's abundance of solar energy (Abdullah et al., 2019).

Thus, this research aimed to determine the implementation and challenges of solar energy technology, as well as the strategies to promote solar energy in Malaysian residential buildings. Owing to insufficient policy incentives and the absence of rules and regulations, the development of solar technology in Malaysia is trailing behind (Lau et al., 2022). To support the use of solar energy, it is necessary to understand how solar technology is implemented in residential buildings, and the Malaysian Government should take necessary action by promoting solar technology to the publics (Ho Soon Min et al., 2019).


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## LITERATURE REVIEW

Solar energy is a clean, renewable energy source that can power the world indefinitely and keep it habitable. In fact, the sun supplies our planet with more energy in one hour than the entire human population of the globe consumes in one year (Kabir et al., 2018). Malaysia has one of the highest solar utilization potentials because of its strategic location near the equator, which creates climatic conditions with sufficient sunshine throughout the year. Malaysia's monthly sun irradiation is predicted to be 4 kWh/$m^2$–5 kWh/$m^2$, which is suitable for the development of solar energy (Abdullah et al., 2019; Sahid et al., 2021). The hot and sunny climate of Malaysia offers a great opportunity for solar power (Kamaruzzaman et al., 2012).

The three primary methods for collecting solar energy are the Photovoltaic Energy System, which directly transforms sunlight into usable power: the utilization of the sun's thermal energy to power massive electrical turbines, known as Concentrated Solar Power (CSP); and hot water can be provided via a Solar Water Heating System, which collects thermal energy from the sun (Nadarajah Kannan & Divagar Vakeesan, 2016). Solar energy is regarded as a non-polluting, sustainable, and renewable source of energy (Hui & Kock, 2017). Solar energy has a favorable influence on the environment primarily by reducing carbon emissions and greenhouse gases, as it relies primarily on the sun (Kabir et al., 2018). In addition, solar energy is obtained for free, and anywhere can be used as long as sunlight shines (Shafie et al., 2011). With solar power, electricity bills can be significantly reduced (Khalil et al., 2017).

There are several limitations associated with solar technology, although it is very reliable. Previous research has established that high costs, lack of awareness, insufficient government incentives are the barriers that prevent people from installing solar technology (Florez-Perez & Ghazali, 2020; Kamaruzzaman et al., 2012; Mohd Zainal Abidin Ab Kadir et al., 2010; Muhammad-Sukki et al., 2011; Sen & Ganguly, 2017). The main barrier for the implementation of solar technologies that is seen in a vast majority of the literature reviews is the installation cost of these systems. Residents may be reluctant to invest in PV systems because of their high initial costs and the complexity of the technology required to operate them (Kamaruzzaman et al., 2012; Mekhilef et al., 2012). A study conducted by Florez-Perez and Ghazali (2020) found that most of the respondents agreed they would be interested in installing one if the government would subsidize the cost. Cost reduction is vital for solar energy technologies to become widely accepted. Therefore, more financial incentives are crucial for increase implementation of solar technologies among the residents.

Another barrier that must be overcome when implementing solar technology is the lack of interest and awareness among the residents. Muhammad-Sukki et al. (2011) indicated that residents in Malaysia have

inadequate knowledge and awareness of solar technology and government programs, particularly the benefits of installing solar panels and the long-term investments involved. The public generally ignores environmental and energy issues, because they assume that the government seek solutions when problems occur. Therefore, the government should take initiatives to ensure that customers are aware of renewable technologies and their benefits. As many consumers become more aware of environmental issues related to fossil fuels use, they become more willing to switch to green energy technologies.

High costs and lack of awareness can be concluded to be due to insufficient incentives and awareness programs. There is a strong push for solar power by the Malaysian Government and incentives are still lacking. The existing government programs do not have a high level of support to encourage users to shift to renewable energy (Florez-Perez & Ghazali, 2020). To ensure the successful implementation of solar projects, financial supports are essential to solar adopters. Similar net metering schemes exist in many countries, notably in the United States and several European countries, such as Italy, Belgium, Denmark, Greece and the Netherlands, to provide incentives for solar technology (Shahsavari & Akbari, 2018). Policy mechanisms such as FiT subsidies in Germany, Spain, Italy, France, Japan, China, the United States and other countries have played a considerable role in the promotion of solar technology (Shahsavari & Akbari, 2018). FiT can easily be associated with other support programs like tax credits or capital subsidies. Consequently, the government have to formulate a series of policies on solar energy development or introducing a significant support program in promoting solar energy adoption.

## METHODOLOGY

To achieve the research objectives of this study, a qualitative research method was utilized. This approach is widely employed in social sciences to allow researchers to gain profound insights and knowledge about a topic (Edwards & Holland, 2013). Interviews, in particular, are commonly used in qualitative research, enabling researchers to engage in discussions with participants. This often results in a deeper understanding of the interviewees' opinions and experiences regarding specific issues.

The research gathered two types of data: primary and secondary. As noted by Sospeter (2020), primary data is derived from direct evidence. Therefore, interviews were chosen as the method for collecting data. The respondents included registered PV service providers and local authorities in Malaysia, ensuring a comprehensive perspective on the implementation of solar energy technologies in residential buildings. Additionally, Goundar (2012) mentioned that secondary data comes from existing documents and literature, also referred to as second-hand data. The researcher examined previous studies


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and various sources like journals, websites, and government records to gather relevant information for this research (Sospeter, 2020).

For the primary data collection, two professional categories were targeted: local authorities and industry players. These professionals were selected to gain a comprehensive understanding of the development of the solar industry and its policies in Malaysia. A semi-structured interview method was employed to obtain more profound and insightful outcomes. Invitations for interviews were sent via the respondents' emails, sourced from their company's official websites. Out of 30 invitations, 13 received responses. The interviews were conducted using Google Meet, facilitating quicker and more convenient scheduling. With the participants' consent, the interviews were audio-recorded and transcribed. The entire conversation content was manually transcribed into text. The interview responses were then analyzed and organized according to various themes, with a summary of the responses presented in Table 2.

## ANALYSIS AND DISCUSSION

Semi-structured interviews were conducted to better understand opinions of the implementations and challenges of implementing solar energy technology, as well as the strategies to promote solar energy in Malaysian residential buildings. The interview invitation was sent via the respondent's email, which was available on the official website of the respondent's company. A total of 30 invitations were sent out, of which 13 were replied. Table 1 indicates the respondents profession and classified into two categories: local authorities and PV service providers registered with SEDA. Every individual of the respondents has been given their own unique identifier in the form of an R number, where R stands for "respondent." Among all the respondents, six respondents have five years of working experience in the solar industry. The remaining respondents have 5 years of work experience. All respondents had sufficient experience and knowledge to participate in this research. The summary of the responses is portrayed in Table 2.

**Table 1**. Summary of the respondent profile (source: author)

| Respondent | Position of Respondent | Service years | Department |
|---|---|---|---|
| R1 | Assistant Director | 6 | Department of Strategic Communications |
| R2 | Authorized Business Partner | 2 | Private Company |
| R3 | Consultant | 4 | Private Company |
| R4 | Director | 10 | Private Company |
| R5 | Information Technology Manager | 4 | Private Company |

| Respondent | Position of Respondent | Service years | Department |
|---|---|---|---|
| R6 | Head of sales coverage | 4 | Private Company |
| R7 | General Manager | 6 | Department of Renewables |
| R8 | Sales engineer | 2 | Private Company |
| R9 | Assistant Director | 1 | Regional Office |
| R10 | Analyst | 2 | Greenhouse Gas Advisory & Consultancy in Climate Action Group |
| R11 | Director | 9 | Private Company |
| R12 | Technical Specialist | 8 | Department of Energy Efficiency & Renewable Energy |
| R13 | Analyst | 7 | Department of Energy Efficiency & Renewable Energy |

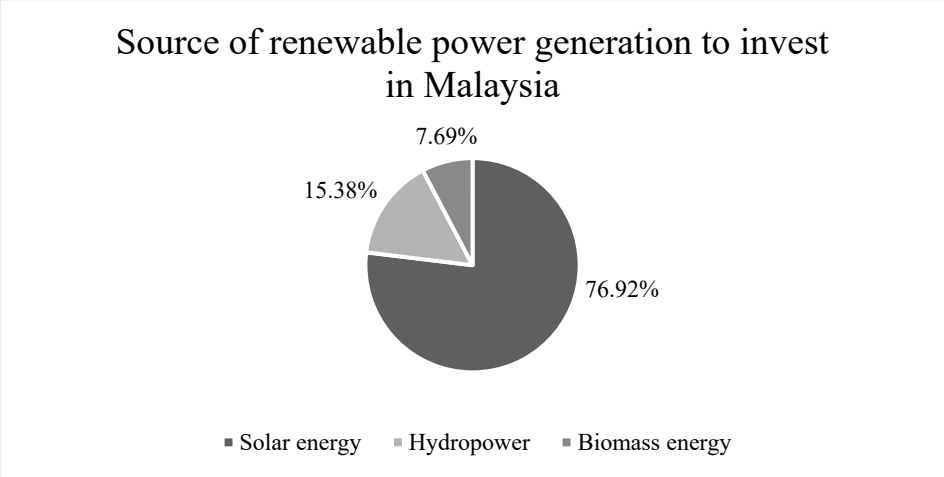


**Figure 1**. Source of renewable power generation to invest in Malaysia
*Source: Author*


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**Table 2**. The summary of the responses

| | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 | R13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Motivation to invest in a renewable energy technology** | | | | | | | | | | | | | |
| Environment protection by reduce the carbon footprint | | | √ | √ | √ | √ | √ | | | √ | √ | √ | |
| Affordable and efficient | | √ | | | | | | √ | | | | | √ |
| Free and unlimited sources | √ | | √ | | | | | | √ | | √ | | |
| Better ROI | √ | √ | | | | | | | | | | | |
| **Benefits of installing solar energy technology** | | | | | | | | | | | | | |
| Reduce electricity bills | √ | | √ | √ | | | | √ | √ | √ | √ | | √ |
| Reduce electricity consumption | | | | | √ | | √ | | | | | √ | |
| Environment friendly | | √ | | √ | | √ | | | | | √ | √ | |
| Free and unlimited sources | | | | | | √ | | √ | | | | | |
| **Factors encouraging people towards solar technology installation** | | | | | | | | | | | | | |
| Low installation cost | √ | | √ | √ | √ | √ | | | √ | | | | |
| Incentive and scheme | | √ | | | | | | | √ | √ | √ | | √ |
| Saving in electricity bills | √ | | | | | | √ | √ | | | | √ | |
| **Main barriers preventing people from supporting solar technology** | | | | | | | | | | | | | |
| High installation cost | √ | | √ | √ | | √ | | | √ | √ | √ | | |
| Lack of knowledge and awareness | | √ | | | | | | | √ | √ | | | √ |
| High capital investment | | | | | √ | | √ | | | | | √ | |
| Tariffs and installation rules | | | | | | √ | | | | | √ | | |
| Lack of government initiatives | | | √ | √ | | | | √ | | √ | | | |
| **Strategies promoting solar energy technology to households** | | | | | | | | | | | | | |
| Through social media | | | | | | | | | | √ | | | |
| More incentive scheme | √ | √ | √ | | | √ | √ | | √ | √ | √ | √ | √ |
| Awareness programs | √ | | | √ | | | | | | | | | |
| Tax exemption on individual | | | | | √ | | | √ | √ | | | | |

*Source: Author*

The responses presented in Figure 1 indicated that solar energy might be the field in which to make the best investments in Malaysia. Because of its geographical location, Malaysia is well-suited for the generation of electricity from solar sources. The climate in Malaysia is one of the most favorable in the world for the creation of solar electricity. On average, it receives between six and eight hours of sunshine every day, contributing to its high solar radiation potential. This statement is supported by Kabir et al. (2018), who stated that Malaysia is located in the equatorial region, with daily average solar radiation as high as 4,500 kWh/$m^2$, as well as sufficient solar radiation; about 10 hours per day is most suitable for harnessing solar energy and developing solar technology. Thus, while comparing to the others source of renewable power generation, solar energy is the most suitable source of renewable power generation to invest in Malaysia based on the geographical location and climatic conditions with sufficient sunshine throughout the year for harnessing solar energy.

Most respondents indicated that their motivation to invest in renewable energy technologies was to protect the environment. The consumption of energy has a direct impact to the climate change. The burning of fossil fuels to generate electricity, such as coal and oil, will release large amounts of carbon dioxide which can causes climate change and global warming. By replacing or reducing the use of other energy sources that have a negative impact on the environment, solar energy can indirectly have a good effect on the environment. According to Shahsavari and Akbari (2018), solar energy contributes the least to global warming emissions and creates little to no pollution. Their findings confirmed this assertion. In conjunction with other renewable sources, it can help reduce carbon dioxide emissions from residential buildings, thereby reducing the severity of climate change.

The respondents stated that the number of solar installations has increased significantly over the past five years based on their experience. It is impressive to observe an increase in the use of solar technology. People are becoming aware of and implementing solar energy technology. Florez-Perez and Ghazali (2020) mentioned that if there is high awareness among the public, there is a push to implement solar technology and eliminate carbon emissions. It is encouraging to see that more individuals are becoming aware of environmental pollution and solar technology are putting it into practice. Kabir et al. (2018) stated that the use of solar energy can virtually eliminate all these environmental hazards. People are aware of the problems associated with global warming, and as a result, renewable energy technology is gaining attention. By increasing the use of solar power among the publics, the country is one step closer to achieving net-zero greenhouse gas emissions. Three to four tons of carbon dioxide emissions per year can be avoided by installing a standard solar panel system at a home (Khalil et al., 2017). The effects of global warming can be mitigated by


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the reduction of carbon footprints, which in turn will contribute to the protection of the ecosystem.

Installing solar technology not only can protect the environment, but also reduce electricity bills. According to a study conducted by Kabir et al. (2018), homeowners and business owners no longer need to rely solely on electricity from utility companies when they install solar technology. Generating own electrical power will reduce the dependency on the utility company and result in instant savings on the cost of electricity. If the solar system produces more energy than the home or business actually consumes, excess power enters the utility grid. This excess energy can be sold to a local power company, thus making a profit.

However, high installation costs are the most highlighted main barriers identified by the interviewees. Many authors also have identified the high cost and low efficiency of solar energy technologies as the most significant barrier in relation to solar energy utilization (Florez-Perez & Ghazali, 2020; Kamaruzzaman et al., 2012; Mohd Zainal Abidin Ab Kadir et al., 2010; Muhammad-Sukki et al., 2011; Sen & Ganguly, 2017). In comparison to the high costs of solar technology, the affordable cost of fossil fuels has proven becoming more popular to residents. If the price of fossil fuels were about the same as the price of solar energy, residents would be willing to install solar technology rather than use fossil fuels to generate electricity. This study's findings found that the interviewees most frequently emphasized low installation cost as a key factor that could encourage individuals to adopt solar technology. Therefore, receiving financial support from the government is an effective way to increase the use of solar energy. Besides, lack of knowledge and awareness also one of main barrier preventing people from supporting solar technology. This scenario contributed to the slow adoption of solar technology. Interviewees also claimed that the current government policies are insufficient in promoting public understanding and acceptance of solar energy. This statement is supported by Sen and Ganguly (2017), which stated that there are no effective awareness programs in place, and that the government has not done enough to increase the public awareness. Currently, there are awareness initiatives like the Annual Malaysian Photovoltaic Industry Association National Solar Roadshow, which focus on teaching and promoting the installation of solar PV on commercial and industrial rooftops, rather than residential residences (Lau et al., 2022). During the 10th Malaysia Plan (2006–2010), incentives like Green Investment Tax Allowance (GITA) and Green Income Tax Exemption (GITE) were introduced to encourage firms to adopt renewable energy technologies (Lau et al., 2022). However, households have not gained any advantages from these incentives. This demonstrated that the government's efforts to promote solar technology have thus far failed to garner popular interest. The government should organize more awareness and education

campaigns for the public, emphasizing all government incentives and policies that might positively impact the economy, community welfare and the environment.

Most interviewees expressed their belief that the use of solar energy may be encouraged through the implementation of policies such as incentives and tax exemptions. The findings suggested the possibility of policymakers introducing more incentive schemes to residents to increase the installation of solar technology. Similar to the findings of a study conducted by Kamaruzzaman et al. (2012), residents claimed that they lacked the financial resources necessary to purchase solar technology owing to the high installation cost of solar technology. According to the results of their study, more than 80% of the respondents said that receiving financial support from the government is an effective way to increase the use of solar energy. Hence, the government should develop subsidy or incentive programs to decrease the payback period and initial expenses of solar technology, in order to motivate residents to adopt the technology. The Malaysian Government can utilize the practical knowledge of other governments to create appropriate support programs for solar PV adoption. For example, Australia offers solar incentive schemes from both the State and Federal Government to promote the adoption of solar PV systems in households (Lau et al., 2022). The results indicated a lack of public awareness about government-introduced solar schemes and the environmental advantages of solar energy. Public awareness and education efforts should be initiated to inform households about government solar projects and the significance of adopting solar technology to reduce pollution. The government can collaborate through mass media and social media to deliver information to the public regarding solar projects and their advantages. The people should get education on renewable energy and engage in related activities starting at a young age in schools. The course familiarises students with various forms of energy and their environmental effects. In short, educating the public is a crucial strategy for the government to promote the use of solar technology.

## CONCLUSION

This study investigated various existing solar technologies, gaining an understanding of each solar technology and its related issues, which will serve as a good foundation for assessing the strengths and limitations of solar implementation in Malaysia. The findings indicated that solar energy is the most suitable power generation source to invest in Malaysia because of its strategic location near the equator, which causes climatic conditions with sufficient sunshine throughout the year. A series of barriers to solar technology implementation were identified and examined by using a combination of literature review and interviews. High installation costs, lack of awareness and


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insufficient government incentives are the main barriers that prevents people from installing solar technology. Currently, residents are reluctant to install solar technology because the cost of installation is too high and there are limited financial incentives from the government. Over the decades, the government has introduced a number of incentives or policies related to solar energy, including the National Renewable Energy Policy, SURIA 1000 scheme and NEM scheme. This indicates that the general public has little awareness of the numerous incentives and programs related to solar technology. This needs to be seriously addressed not only by the government but also by the private sector. Educational programs on solar technology should be implemented at all levels of educational institutions, from primary to tertiary education, to enhance awareness and knowledge. The mass media should allocate certain sections for promoting solar technologies. By providing sufficient awareness through mass media, it is possible to break through this barrier and see the successful penetration of renewable energy in Malaysia. However, without proper public awareness, the solar program may not reach its full potential. Thus, the government should make more efforts to promote the benefits of implementing solar energy by increasing financial incentives or awareness campaign among the publics. When the publics are aware of government's effort related to solar energy, they will be interest to use renewable energy as power generation, thus can increase the implementation of solar energy while achieving low-carbon footprint goals in the future.

In future research, a larger sample size or a mixed research approach, combining qualitative and quantitative research methods, could be considered to gain a deeper understanding of the strengths and weaknesses of solar energy policies in Malaysia. Additional comparative research may be conducted among developing countries to examine the effectiveness of their current solar-related policies. Such research could probably provide important lessons for the developing countries in refining their solar policies, and hence enhancing the use of solar energy. Furthermore, future research could also examine the energy sectors of other developing countries and make comparisons across these countries with renewable energy technology that has been adopted. In addition to the use of solar technology, there are other renewable energy sources that may be effective to use available resources to minimize the environmental impact of power generation systems.

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# EVALUATING LEAN GOVERNANCE OF URBAN GREEN COMMUNITY RETROFIT UNDER PUBLIC-PRIVATE PARTNERSHIP

**Meng Qingbiao[1], Faraziera Mohd Raslim[2], Nur Syaimasyaza Mansor[3]**

[1,2,3]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

The urban community, which is the fundamental unit of the city, has recently been governed inefficiently and extensively. Common occurrences like the dirty-disorderly-disparity appearance and slow operations of local public facilities have become a barrier to the growth of resilient urban oasis. The concept of lean governance emerges in the community retrofit at the right time under Public-Private-Partnership (PPP) to incorporate the "Green, Ecological and Low-Carbon" philosophy in the life cycle of the urban green community. In the life cycle of a green community retrofit, there are a variety of stakeholders whose objectives and interests are both in line with and at odds with one another, particularly during the community retrofit or construction management phases. Rebuilding a lean governance performance evaluation system is the goal to increase effectiveness and appease stakeholders in community retrofit under a PPP model. Principal component analysis (PCA) and data envelopment analysis (DEA) are used to build the input-output performance evaluation index system of the lean governance of the urban community. It compensates for the lack of domestic and international research on the assessment of the lean obsolete community governance level. In addition, the paper uses eighteen urban old communities in China that were renovated under PPP model as the subject of an empirical study. It uses a quantitative model to assess the level of lean governance in these communities and offers recommendations for performance enhancement. To successfully implement the new-type urban green community retrofit under the PPP model, a co-governance mechanism is established.

***Keywords***: -

[2] Corresponding author. Email: faraziera@usm.my

## INTRODUCTION

In China, with the deterioration of the aging communities, many troubling issues have emerged such as "being dirty and messy", gathering of vulnerable people and "weak network" under grid management. It is a concentrated contradiction of unbalanced and inadequate development in urban renewal. The aim of the urban community green retrofit is to coordinate the development of society, economy and environment, and focus on the harmony of humanity and nature, with the full wishes and joint participation of all stakeholders. This requires that an appropriate management model is established and a platform for stakeholders to participate in urban green community management is provided. These tasks for the community green retrofit cannot be achieved by relying on traditional urban management. Therefore, the Public Private Partnership (PPP) model has gradually become a new approach and effective way of urban governance (Nguyen, M. D. 2022). The effective evaluation of lean governance is a key for the sustainable program in the urban green community retrofit. Applying the green community retrofit projects, stakeholders include governments of public, social groups related with enterprises, and community residents (Fikfak, Bugaric & Plicanic, 2019). Establishing a multi-governance model led by the government and drawing attention to the potential and marginal stakeholders towards the incorporation mechanism are crucial to achieving sustainable development of the urban community green retrofit.

Community green retrofit under PPP involves improving living surroundings and community governance services and increasing happiness among its residents (De Paula, Marques, & Gonçalves, 2023). In the construction stage of previous urban community green retrofit projects, the PPP model has revealed its advantages and formed a good start with its abundant capital and technical coordination ability. However, in the future, what is uncertain is whether the various stakeholders can establish a good cooperative relationship, risk and benefit distribution mechanism, etc. It may emerge that challenges include service standards and specifications in operation and maintenance unsatisfying the design requirements, the environment quality and energy efficiency is lower than the design indicators, and how to hand over or exit after the Concession time. All the above challenges will depend on the advantages of the PPP model to continuously improve and upgrade (Sun, Zhong, & Han, 2023; Shen, Zhao, & Mu, 2019). According to the data analysis from the Ministry of Housing and Urban-Rural Development, about 167,000 old communities are updated in China with an investment of RMB 660 billion and influencing more than 29 million families in 2018–2022. The inputs and outcomes of urban community green retrofit under PPP is discussed commonly by releasing the lean governance evaluations, which can encourage stakeholders to improve their strategies to achieve the most outcomes. As for past research, the evaluation methods are mostly subjective judgements from the public while few quantitative

evaluations for the performance is based on actual situation data (Zhu, S., Li, D., & Zhu, J. 2019). Hence, it is vital to evaluate the holistic performance to establish effective guidelines for urban renewal under PPP.

## LITERATURE REVIEW

Research on old residential community renewals focus on the aspects such as retrofit content and governance methods and use technologies such as energy efference and saving (Kamel, E., & Memari, A. M. 2022), and sponging technology (Wright, Liu, Y., & Engel, 2016) to improve functions of the urban community. In China, the attention to old community retrofits originates from physical environment governance such as greening (Li, & Jia, 2023), and suitable aging (Yung, Conejos, &Chan, 2016). In Malaysia, sustainable urban regeneration plays a vital role in addressing the multi-faceted challenges of aging cities and reviving history (Nik Hashim, Dali, & Alias, 2023).

In terms of urban community green governance partnerships under PPP, some scholars focus on a single stakeholder, such as proposing policy optimization suggestions from the governmental perspective (Othman, K., & Khallaf, R. 2022). There are parts that explore the value and methods of market intervention in the community green retrofit under the PPP perspective (Alvanchi, A., Jafari, M. A., Shabanlou, M., & Meghdadi, Z. 2021). While others discuss the obstacles to public participation and the measures to overcome it from the perspective of residents (Li, Gu &Wang, 2019). The rest of the scholars paid attention to the interaction of stakeholders and proposed that an overall pattern of multi-stakeholder consultation and joint governance should be constructed together (Abdullah Hashim, Sapri & Ab. Azis, 2019). They mainly analysed their governance and effects qualitatively according to the community lean governance effects, such as economic, social and environmental benefits. Whereas only a few scholars carried out quantitative analysis on evaluating the lean governance, such as constructing an economic and social benefit evaluation model based on the AHM fuzzy comprehensive evaluation method (Zhang, Hu &Yang, 2017), or using hierarchical regression analysis to test the impact of community green renewal on residents' recognition and satisfaction (Chang, Xie, Chen, Wu, 2019). There are also a few that combined an evaluation of the combination of old communities green retrofit and lean governance under PPP. As the necessary of community participation in urban renewal widely accepts, increasing calls for more engagement and collaboration among stakeholders under PPP model, mainly nurtured by critical reflection on the previous urban renewal. Residents' recognition, perceptions and behaviours will inevitably affect the efficiency of lean governance in the community green retrofit under PPP (Zhang, Pan & Qian, 2023).

PPP has been claimed to set a range of advantages and benefits to accelerate project implementation in a timely manner, reduce life-cycle costs, and


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upgrade the maintenance service (Almarri, K., & Boussabaine, H., 2023). However, a multi-stakeholder management is more complex in green retrofit projects, which will draw more stakeholders to be involved compared with the traditional method. It consists of many participants like the private investments and effective finance that have decisive roles on the retrofit. Besides that, the renewal quality of PPP, the trust of stakeholders, effective incentives and political certainties are important factors for the success of community green retrofit (Deng, B., Zhou, ..., & Li, X. 2021). A few studies focused on the crisis successful management factors that are considered as effective factors towards improving the PPP model (Muhammad, Kwang Sik, Johar, & Sabri, 2016).

The current literatures classify the lean management factors in existing urban old community retrofit under PPP projects into different items. The factors are identified as human factors, retrofit technologies, public policies, stakeholder needs and other uncertain factors by successful lean management (Khan, M., & Khan, S. 2023). It pays more on upgrading the function of communities, which is to improve facility and property services, and enhance social safety and energy efficiency. Although the risks vary in the public sustainable development policies, it can help to achieve a feasibility between low-carbon and retrofit function following the financial pressure under the PPP (Selim, A. M., & ElGohary, A. S. 2020).

Lean concepts of retrofit in PPP projects is a new paradigm that aim at value-for-money (VFM) rather than others in the traditional methods. The lean governance in the community retrofit construction is concerned with concurrent and continuous improvements in all dimensions, which involve decision-making, bidding, designing, implementing, financing, operating, maintenance, and post-evaluation (Li, S., Fang, Y., & Wu, X. 2020). Green technological innovation plays a pivotal role as catalyst to keep sustainability in the community retrofit under PPP, which will promote the competitive advantages of green technological industry and encourage the private sector to adopt green retrofits (Xiong, W., Chen, B., Wang, H., & Zhu, D. 2020). The evaluating framework with key performance indicators (KPIs) are proposed to serve in performance measures on PPP projects (Malaeb, & Hamzeh, 2018). Based on the characteristics of urban renewal development in Guangzhou, an urban renewal performance evaluation system is proposed and verified by PCA-DEA, which is evaluated the performance of urban renewal, aiming to promote the sustainable development of urban renewal work (Duan, J., & Wang, Y. Urban (2023). It takes Jiangsu Province as an example to study the investment performance in real estate projects. The input-output performance evaluation index system is built and analyzed through PCA-DEA (Sui Y., Lu H. 2020).

At present, few studies have systematically concentrated on the relationship between lean governance and renewal effects in urban community under PPP. Greater attention will be paid to the factors that influence lean

governance and the relationship between lean governance and community renewal. Therefore, novel methods are applied to comprehensively understand and analyse the lean governance relationships between stakeholders. The aim of this article is to build a quantitative evaluation for lean governance performance of urban community green retrofit under PPP based on Principal Component Analysis (PCA) and Data Envelopment Analysis (DEA). The objectives are as follows:

(1) Analyse the lean governance indicators assessing urban community green retrofit under PPP and evaluating index through literature review.
(2) Discuss the methods of PCA-DEA and apply a feasible method to discover the relationship in the evaluating index.
(3) Use empirical analysis in urban community green retrofit under PPP in China to illustrate that the model works in a stepwise manner, and enlightenments and suggestions are put forward to promote existing urban community green retrofits under the PPP model in China.

## RESEARCH METHOD

The advantage of DEA is that it does not need to unify dimensions or expert's judgment on indicator weights when analysing multiple input-output indicators in the research and the evaluation results are more objective (Xu, Y., & Sim, J. Y. ,2022). DEA can reveal the reasons for invalid results and the direction of improvement, and it will make resource allocation more effective (Hatami-Marbini, Hekmat, & Agrell, 2022).

Currently, the most concerning issues are on obtaining larger green retrofit efficiency and higher balance between the stakeholders as well as the social output, with less economic and humanity investment through lean management and control during the urban community renewal. This is the concept expressed by "relative efficiency" in DEA. Therefore, this article selects DEA as a performance evaluation method for lean governance in the urban community green retrofit under PPP.

DEA acts as a mathematical evaluation method that quantitatively evaluates the relative efficiency among the decision-making units (DMUs) with inputs and outputs through data envelope curves. Charnes, Cooper & Rhodes (CCR) and Banker, Charnes & Cooper (BCC) are the most classic models and have been widely used in efficiency evaluation in various fields. CCR are based on constant returns to scale and BCC are variable returns to scale respectively. The governance of old community green renewal is not a purely economic investment issue, but a more complex practical issue with many influencing factors. Mostly, it is impossible to increase output in equal proportions by increasing investment. It is found that variable returns to scale are more feasible with the actual situation of lean governance in the urban community green retrofit


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under PPP. Therefore, this article uses the BCC model to analyze its lean governance performance.

**DEA-oriented input-output index**

This paper mainly collects the performance evaluation indicators of lean governance in the urban community green retrofit under PPP from the literature review. Since there are few articles and documents related to the evaluation of old community green retrofit, the collection scope is expanded to the fields of community governance evaluation and urban renewal. Through the combined search of keywords such as "urban", "community", "retrofit", "old community", "evaluation" and "DEA", it was found that the DEA evaluation method has significant effects on urban development efficiency, economic efficiency, infrastructure efficiency, tourism efficiency, land use efficiency, environmental governance efficiency and other aspects. It is rarely used in urban renewal and old community green reconstruction. Therefore, the application of the DEA method in the evaluation of old communities retrofit under PPP will be done.

As a practical issue, the lean management of urban community green retrofit under PPP should be combined with the actual reconstruction contents and field survey results in addition to reference indicators. With the field survey on the retrofit of old communities in China, it was found that in the process of renovating old communities, the retrofit content is different according to the characteristics of each community. By considering the existing literature review indicators comprehensively, the actual situation of old community retrofit projects, quantifiable principles and input indicators are selected from two aspects: economic input and human input, while output indicators are selected from three aspects: environment, economy, and society. The results are shown in Table 1.

**Table 1**: the evaluating index of the community green retrofit under PPP

| **Classification** | | **Indicator** | **Literature review** |
|---|---|---|---|
| Input | Economy | Retrofit investment T1 | Nguyen, M. D. (2022); Zhu, Li, … & Zhu, (2019); Kamel, E., & Memari, A. M. (2022). |
| | Human | Manpower T2 | De Paula, Marques, & Gonçalves, (2023);Zhu, Li, … & Zhu, (2019); |
| | | Participate unitT3 | Muhammad, Kwang Sik, Johar, & Sabri, (2016); Alvanchi, A., Jafari, M. A., Shabanlou, M., & Meghdadi, Z. (2021); Othman, K., & Khallaf, R. (2022) |
| | | Residents' attendingT4 | Li, Gu, & Wang, (2019); Chang, Xie, Chen,Wu, (2019);Zhang, Pan, & Qian, (2023) |
| Output | Environment | Reduce energy consumptionC1 | Kamel, E., & Memari, A. M. (2022);De Paula, Marques, & |

| Classification | | Indicator | Literature review |
|---|---|---|---|
| | | | Gonçalves, (2023); Wright, Liu, Carroll, Ahiablame, & Engel, (2016);Li, Li, Liu, Wang, & Jia, (2023) |
| | | Improve environment C2 | Li, Li, Liu, Wang, & Jia, (2023); |
| | Economy | Space re-development income C3 | Li, Gu, & Wang, (2019); Muhammad, Kwang Sik, Johar, & Sabri, (2016) |
| | | Investment return C4 | Yung, Conejos, & Chan, (2016);Zhang, Hu & Yang, (2017).;Seo, (2020) |
| | | Special financial subsidies C5 | Muhammad, Kwang Sik, Johar, & Sabri, (2016) |
| | | Preferential financing policy C6 | Almarri, K., & Boussabaine, H. (2023); Muhammad, Kwang Sik, Johar, & Sabri, (2016) |
| | | Preferential green retrofit policy C7 | Deng, B., Zhou, ..., & Li, X. (2021); Muhammad, Kwang Sik, Johar, & Sabri, (2016) |
| | | Growing value of property rights C8 | Almarri, K., & Boussabaine, H. (2023); Muhammad, Kwang Sik, Johar, & Sabri, (2016) |
| | | Tax incentives C9 | Almarri, K., & Boussabaine, H. (2023); Muhammad, Kwang Sik, Johar, & Sabri, (2016) |
| | Society | Community harmony C10 | Othman, K., & Khallaf, R. (2022); Malaeb, &Hamzeh, (2018); Li,Gu, &Wang, (2019) |
| | | Integration industrial chains C11 | Alvanchi, A., Jafari, M. A., Shabanlou, M., & Meghdadi, Z. (2021);Li,Gu, & Wang, (2019) |
| | | Increasing employment C12 | Deng, B., Zhou, ..., & Li, X. (2021) |
| | | Residents' satisfaction C13 | Chang,Xie,Chen, Wu, (2019); Zhang, Pan, & Qian, (2023). |

In terms of investment, the economic investment in the lean governance of urban community green retrofit under PPP is mainly measured by the investment. The amount of investment in each project can be obtained through surveys. The PPP project requires the participation of many stakeholders, including the government, construction agents, communities and residents. Since the participation number of residents, communities and government is difficult to calculate, human resources are measured with the manpower of the community under PPP. In addition, another characteristic is co-governance and resident participation. Therefore, the number of participating units and the number of times residents attending meetings or delivering suggestions during the retrofit period were selected for quantitative evaluation. In terms of output, based on


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relevant policies, the environmental improvement includes house appearance, community roads, increased parking, fire safety protection, greening facilities and reusable spaces. These have become the components of green community renewal evaluation. Reducing energy consumption and improving environment condition indicators are summarized to evaluate the reference as the environmental output.

The economic output includes the growth in the value of the property rights after renovating the community houses. In addition, to attract more social capital to enter green community renewal, the state has given great support in all aspects, including space re-development income, investment returns, special financial subsidies, preferential financing policies, preferential green retrofit policies, tax incentives, the growing value of property rights and other indicators. Social output mainly includes indicators such as increasing employment, community harmony, resident satisfaction, and promoting the integration of industrial chains. Increasing employment and promoting the formation of industrial chains are mainly achieved by introducing professional property companies for service management. Community harmony and resident satisfaction are reflected in community security such as the number of complaints and the reduction in the frequency of crimes.

**Principal component analysis (PCA)**

A performance evaluation index system for lean governance of old communities is established based on DEA, which includes 4 input indicators and 13 output indicators. Due to the current excessive number of indicators and certain correlations between the above indicators, it is easy to differentiate the DEA model and it will directly affect the quality of the final evaluation. Therefore, the existing index system needs to be reduced dimensionally. PCA can reduce the dimensionality of multiple indicators with little information loss, and it will obtain more objective weight information based on the original information provided by the indicators.

In general, the extracted comprehensive indicators are called principal components. Every principal component is expressed as a linear combination of the original indicators, and the principal components are linearly unrelated to each other. The principal component index will be obtained through such conversion that has superior performance than the original index. The ranking of the principal component score can reflect the maximum comprehensive difference between evaluation objects with reducing variables and improving the efficiency of analysis.

The sample values of the lean management input-output indicators of the old community green retrofit were obtained through field survey. Assuming that there are ‘n’ old communities as evaluation objects and the sample input and output data matrices are ‘M’ and ‘N’ respectively. Then the principal component

index can be simply summarized. To ensure the effect of principal component analysis, KMO value and Bartlett sphericity test will be obtained to verify the higher correlation data by reliability test. When conducting adaptability testing, the original data should simultaneously meet the criteria that the KMO value is not less than 0.6 and the Bartlett sphericity test significance is less than 0.05. Based on the eigenvalue $\gamma_i \geq 1.0$ and the cumulative contribution rate on the principle of $\Sigma C_i \geq 60\%$, $k_1$ principal components are selected as new input variables and $k_2$ principal components are selected as new output variables in the same way. Calculate the new index weight. Perform a weighted sum of the extracted $k_1$ and $k_2$ principal components. The ratio of the single principal component contribution rate to the sum of the contribution rates of all principal components is the weight of the principal component.

## EMPIRICAL ANALYSIS

This article takes 18 urban retrofit projects as an example to quantitatively evaluate its lean governance performance and explore ways to improve the lean governance performance in urban community green retrofit under PPP in China. These cases are collected from the official website Chinese Procurement (http://www.ccgp.gov.cn/), which include the detail budget and bidding price, the summary of the projects. The corresponding input and output index data were extracted by questionnaires with the experts in the industry and then entered into the PCA-DEA performance evaluation system for calculation and analysis.

### Extraction of principal component indicators

This article uses SPSS 26.0 to conduct an adaptability test on the input-output data of 18 old communities with lean management in the urban community green retrofit under PPP. The KMO values of the input index and output index of the sample data are 0.687 and 0.609 respectively, and the Bartlett sphericity test significance, sig. is 0.000 and 0.001. It passes the reliability test and is suitable for principal component analysis. The input and output indicator indexes were extracted to obtain the contribution rate of each component by PCA. One principal component indicator (named G1) was extracted from the original 4 input indicators, with a cumulative contribution rate of 60.579%; 4 principal component indicators (named F1, F2, F3, F4) were extracted from 13 output indicators, with a cumulative contribution rate of 78.441%, which can basically cover most of the information. The new comprehensive indicators are summarized based on the input and output indicator component matrix and named by the original indicators that are included. The results are shown in Table 2. Since the input principal component, G1 covers all input original indicators, G1 is named the comprehensive input indicator. The renewed items such as house appearance, community roads, increased parking, fire safety, greening facilities and space reusability in the output principal component F1 are all basic contents


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of renovating old communities. Therefore, F1 can be named as the basic revenue output, covering housing, transportation and overall environment. The number of complaints during the retrofit process, the demolition area of illegal construction, the number of carport retrofits and the area of newly built places provide the community with a good atmosphere for living and working, so F2 is named as an expanded revenue output. Green community retrofit under the PPP brings policy dividends to social capital, which mainly reflects financial subsidies and preferential treatment of finance interest rates. F3 is summarized as the viability gap funding output. Social harmony and residents' satisfaction are the guarantees for the smooth implementation of community green retrofit under PPP, so F4 can be named as a social responsibility output.

**DEA analysis**

The original data of the principal component index according to the PCA score matrix is obtained. Based on the min-max normalization, the data is converted into a mapping relation between [0.1, 0.9] following the formula (1). Then, the data envelopment analysis results are obtained by the DEA-BCC model. This article uses DEAP2.1 software for calculation, and the calculation results are shown in Table 3.

$$y = \frac{x_i - x_{min}}{x_{max} - x_{min}}(0.9 - 0.1) + 0.1 \quad , \quad i = 1,2, \dots, m \qquad (1)$$

Fifteen communities achieved technical effectiveness, three communities are ineffective, and the average efficiency is 0.988, closing to 1. The lean governance performance of the urban community green retrofit under PPP is generally higher. There are two main reasons why the scale efficiency is less than 1. The first reason is that the community retrofit scale is too small to reach the optimal output scale. The second is that the scale is too large with redundancy occurring. Theoretically, according to the existing community retrofit scale, it should produce greater output. Judging from the analysis results, the community green retrofit whose scale efficiency has not reached 1 are all experiencing diminishing returns to scale. It is indicated that the scale is too large, and the input does not catch up with the output in the lean governance of the urban community green retrofit, resulting in a decrease in efficiency. It is necessary to reduce scale and input or increase output. Taking the three communities with the lowest scale efficiency as an example, they are packaged into one project during the construction process. Through field research, it's said that the final investment in these three projects was expanded half approximately than the beginning. The detailed decision-making program plan and lean governance layout under PPP are affected as well as the final efficiency. In addition, these three projects were built for decades with poor congenital conditions, small retrofit spaces, and

limited parking spaces, which also results in high investments that cannot be perfectly converted into output.

**Table 2:** Extracted indicator principal component eigenvalues and contribution rate

| Classification | Principal Component | Eigenvalues | Contribution rate | Cumulative contribution rate | Raw indicator involved |
|---|---|---|---|---|---|
| Input (I) | Comprehensive input G1 | 2.423 | 60.579 | 60.579 | T1, T2, T3, T4 |
| Output (O) | Basic revenue F1 | 5.731 | 44.082 | 44.082 | C1, C2, C3, C4 |
| | Expanded revenue F2 | 2.052 | 15.781 | 59.863 | C8, C11 |
| | Viability gap funding F3 | 1.320 | 10.154 | 70.017 | C5, C6, C7, C9 |
| | Social responsibility F4 | 1.095 | 8.424 | 78.441 | C10, C12, C13 |

**Table 3**: the DEA analysis results of lean governance in community green retrofit

| DMU | TE | PTE | SE | RTS | DMU | TE | PTE | SE | RTS |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 1 | 1 | 1 | - | A10 | 1 | 1 | 1 | - |
| A2 | 1 | 1 | 1 | - | A11 | 0.977 | 1 | 0.977 | DRS |
| A3 | 1 | 1 | 1 | - | A12 | 0.922 | 1 | 0.922 | DRS |
| A4 | 1 | 1 | 1 | - | A13 | 1 | 1 | 1 | - |
| A5 | 1 | 1 | 1 | - | A14 | 1 | 1 | 1 | - |
| A6 | 1 | 1 | 1 | - | A15 | 1 | 1 | 1 | - |
| A7 | 1 | 1 | 1 | - | A16 | 1 | 1 | 1 | - |
| A8 | 0.885 | 1 | 0.885 | DRS | A17 | 1 | 1 | 1 | - |
| A9 | 1 | 1 | 1 | - | A18 | 1 | 1 | 1 | - |

Note: TE=PTE * SE, technical efficiency; PTE is pure technical efficiency; SE is scale efficiency; RTS is returns to scale; DRS is diminishing returns to scale; - is constant returns to scale.

The difference between the original value of input and output and the target value calculated by the input angle BCC model is the improvement value. The higher the improvement ratio, the gap will be greater compared with the ideal value, which requires special attention. It is no improvement that the original value is equal to the target value if the decision-making unit is valid. If the decision-making unit is invalid, a negative input improvement value indicates that the input is redundant while a positive output improvement value indicates that the item has not reached the ideal output. Under the fix investment amount and without reducing the output scale, the reason for redundancy in


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comprehensive output is that the ideal output is unreachable, and the focus is on analysing the difference between the output and the target value.

## SUGGESTIONS

Based on the results of empirical cases by DEA-PCA and field surveys, this article puts forward the following suggestions for the lean governance in the urban community green retrofit under PPP.

### Establish detailed decision-making program plan to achieve lean governance layout under PPP

The analysis and calculation results show that most communities are in a state of diminishing returns of scale, and inputs have not been converted into ideal outputs. The main problem is that the detailed decision-making program plan is unsystematic and unrigorous. There is quite a large difference on the investments and renewal plans between the beginning of the project establishment and the ending of completion acceptance and settled accounts. Therefore, in the future, sufficient field survey should be conducted before a detailed decision-making program is planned. Accurately, to further grasp the needs of stakeholders and the actual situation of the community green retrofit under PPP, multiple factors should be fully considered to achieve a lean integration design. It is strongly advocated to promote the area-based coordinated retrofit under PPP model. Package one or more old communities and adjacent urban renewal areas to form a comprehensive old community retrofit group.

### Standardize construction processes and standards to achieve lean construction management

The lean governance in urban community green retrofit under PPP should have more efficient construction requirements than in the traditional construction method. The construction unit that is selected by bidding should be the best economically and technically. Additionally, unified construction processes and standards should be formulated to avoid waste of resources. Facing the phenomenon of the reworking situation in the retrofit of some communities that emerged during the survey, rationalized measures should be made in advance including a retrofit program review, the arrangement entry of the power and material, and the admission sequence of each construction unit.

### Pay attention to green retrofit and achieve the goal of the sustainability on lean governance in the urban community

From the input perspective of the BCC model, calculating the input-output improvement value of the non-effective decision-making unit, some communities need to increase their green satisfactions. According to the survey, it is known that some communities have reduced greening in order to increase parking spaces

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or build new activity areas to get more rent by the operators. Some residents also want to harden the ground in front of the door. However, in fact, the renewal at the expense of green area is not conducive to the sustainable development of the community environment and will also cause a decline in the quality of urban life in the future. Therefore, in future community green retrofits under PPP, attention should be paid to greening retrofit, restoring the exposed ground surfaces, and increasing plant varieties.

**Introduce professional property management companies to achieve long-term lean governance**

In order to make full use of the advantages under PPP, the introduction of professional property companies is the key partner of all stakeholders and it plays basis and premise roles for achieving long-term lean governance in the urban community green retrofit. As the operation and maintenance of the PPP model, good property management can ensure the cleanliness of the community environment, orderly parking, and residents' sense of security. In the process of social capital involvement in the retrofit of urban community green retrofit, the support policies by the government have a positive role in promoting the concession rights of social capital. The concession operations include property management income, service repair indoors, and other needs. The policy supports social capitals involved in the retrofit of urban old communities to have an operating period in the community green retrofitted within the legal scope. It should also strengthen the supervision of the operation of relevant projects by social capital after the retrofit.

## CONCLUSION

This article combines urban old communities retrofit with lean governance under the PPP model to explore their quantitative evaluation and improvement paths. Lean governance in the urban community green retrofit under PPP is a complex system that includes environmental, economic, social and other aspects, involving many indicators and high correlations between them. Empirical analysis results show that the PCA-DEA evaluation model can play their respective advantages effectively to solve the problem that the DEA model is affected by the number and correlation of input-output indicators, causing the evaluation results to lose distinction. To ensure the original information completely, a scientific and objective evaluation of the lean performance is conducted in the urban old communities in China. Countermeasures and suggestions are put forward to guide and promote the sustainable and efficient development of lean governance in the urban community green retrofit in China.


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# SUSTAINABLE GREEN BUILDING INITIATIVES IN MALAYSIA: ISSUES IN THE IMPLEMENTATION PRACTICES

**Zuhaila Zakaria[1,2], Nor Rima Muhamad Ariff [1], Nur Maizura Ahmad Noorhani[3], and Mohd Mawardi Hussain[4]**

[1] *College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA (UiTM) SHAH ALAM, SELANGOR
[2] *Interior Design Department,*
RAFFLES COLLEGE OF HIGHER EDUCATION, KUALA LUMPUR
[3] *College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA (UiTM), PUNCAK ALAM, SELANGOR
[4] *Green Building Department,*
KOLEJ KEMAHIRAN TINGGI MARA (KKTM) SRI GADING,
BATU PAHAT, JOHOR

## Abstract

In recent years, green building practices have received tremendous global attention for their ability to protect the environment and foster sustainable development, and Malaysia, one of the fastest-growing countries, is enthusiastically embracing the green building movement. However, throughout the construction period of this green building, many issues occurred that contributed to the deterioration of the performance of the building itself. This research aims to identify the main issues faced by green building projects in Malaysia to ensure the performance of the building can be maintained and improved, by using a questionnaire survey that collects the views of 72 experienced participants. The findings reveal that operation and maintenance are urgent issues that need to be addressed in Malaysian green building projects, underscoring the need for policy intervention. Overall, this study can support the regulation of green building maintenance, underlining the critical nature of recognizing and addressing these issues collectively to foster the growth and success of green building initiatives in the Malaysian construction industry, thereby contributing to a more sustainable construction environment throughout the country.

***Keywords***: Green Building, Green Building Issues, Operation and Maintenance

[2] Corresponding Author: norri550@uitm.edu.my

## INTRODUCTION

Green buildings, also known as environmentally sustainable buildings, aim to reduce environmental impacts from construction to operation. They maximize energy and material efficiency while minimizing negative effects on people and the ecosystem (Sulzakimin, 2019; Kamarulbaid, 2021; Karr, 2021). Malaysia promotes energy efficiency and green building construction, but these buildings face challenges that hinder their widespread adoption and efficient management (Ali et al., 2018; Darko, 2019; Wong et al., 2021; Kamarulbaid, 2021).

Key issues include team collaboration, inexperienced labour, high maintenance costs, regulatory challenges, and the availability of eco-friendly materials. Additionally, operational and maintenance problems increase costs and energy consumption (Islam, 2019; Ping & Chen, 2016). The lack of skilled professionals and awareness among building owners exacerbates these challenges (Shafii et al., 2006; Yee Sin et al., 2021). There are several categories of challenges have been discussed, namely. (Gou, 2016; Lee et al., 2020)

i. Design and Maintenance Challenges: Addressing issues in early design stages and post-construction maintenance complexities.
ii. Maintenance Concerns: Highlighting the importance of proper maintenance for the full implementation of green buildings in Malaysia.
iii. Awareness and Implementation: Assessing knowledge and implementation levels among stakeholders and the impact of conventional construction approaches on costs, environmental concerns, and social aspects.
iv. Public Demand for Sustainable Buildings: Analyzing the demand for energy-efficient buildings and financial obstacles to their adoption.

Addressing these challenges can advance green building practices in Malaysia, contributing to sustainable construction and the country's development goals. Despite the focus on sustainability, the industry still faces labor exploitation, cost overruns, waste generation, environmental degradation, and inefficient resource utilization.

## RESEARCH METHODOLOGY

### Literature Review:

A systematic review of existing scientific works on green buildings, covering the pre-construction, construction, and post-occupancy stages. This review identifies key issues affecting green building performance, examines barriers, and explores their impact on each construction phase. The goal is to improve sustainability and performance in green buildings by creating a symbiotic relationship between design, construction, and maintenance phases.


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**Survey Questionnaire:**
A survey designed using Google Forms to collect data from experts in green building construction. Distributed via email and messaging, the survey uses random sampling for high generalizability (Sarfo et al., 2022). The data will be analyzed using mean analysis to identify factors contributing to the decline in Malaysian green building performance, focusing on operation and maintenance issues.

**Questionnaire Structure:**
**Part A: Respondent Background (Demographic)**
Collects demographic information such as age, nationality, education, job title, and years of experience in green building construction. This data helps tailor sustainable construction policies and initiatives.

**Part B: Green Building Issues in Malaysia**
Investigates critical aspects of green buildings in Malaysia using a five-point Likert scale to measure agreement on various issues. The study population includes 73 respondents from Selangor and Kuala Lumpur, consisting of facility managers, consultants, and operations managers, particularly those with non-residential project experience and registered with the Construction Industry Development Board (CIDB).

The survey combines quantitative data from a broad sample with qualitative insights from specific green building projects. The Mean Value and Rank method will analyze the data, helping to prioritize aspects based on their importance to respondents. The research aims to provide valuable insights into green building practices, contributing to better implementation and advancement in Malaysia.

## LITERATURE REVIEW

### Green Building

According to the Green Building Index website, a green building focuses on increasing the efficiency of resource use – energy, water, and materials – while reducing building impact on human health and the environment during the building's lifecycle, through better siting, design, construction, operation, maintenance, and removal. Green Buildings should be designed and operated to reduce the overall impact of the built environment on its surroundings (Farahin Ahmad et al., 2019; Mat Yaman & Ariff Abd Ghadas, 2020). Green buildings, which are defined as environmentally sustainable buildings, are intended to reduce their environmental impact over their entire existence, from design to operation to eventual demolition (Sulzakimin, 2019; Kamarulbaid, 2021; Karr, 2021). A green building is an eco-conscious construction methodically designed, erected, and maintained to reduce its environmental impact and maximize

sustainability (Kriss, 2014; Liphadzi et al., 2023; Wani & Mushtaq, 2018). This prioritizes energy efficiency, water conservation, appropriate resource utilization, and indoor air quality enhancements. Darko (2019) and Wong et al. (2021) emphasize that green buildings achieve their goals by utilizing renewable energy sources such as solar panels, optimizing insulation and ventilation systems, and employing recycled or locally sourced materials, all of which contribute to reduced carbon footprint through innovative technological and design practices. However, Sharif et al. (2018) contends that the commitment to sustainability extends beyond the original construction stage, with long-term performance, maintenance, and adaptation being crucial factors. Furthermore, Yacob et al. (2019) emphasizes the overarching objective of green building: to integrate structures with their natural surroundings, save resources, reduce greenhouse gas emissions, and improve the quality of life for present and future generations. It is a comprehensive strategy that integrates environmental, economic, and social factors to establish a balance that benefits the world and its inhabitants.

The green building movement is not restricted to environmental considerations alone; it also promotes occupant health. Natural lighting, green spaces, and the use of non-toxic materials, as suggested by several authors, including Darko (2019), add to the health and comfort of those who live and work in these sustainable structures. Yacob et al. (2019) assert that the United States LEED (Leadership in Energy and Environmental Design) standards and certifications serve as guiding lights and benchmarks for the industry as part of a more significant trend toward environmentally responsible practices in construction and architecture. The collective knowledge of these experts highlights the significance of green building principles in creating a more sustainable and resilient built environment for the greater welfare of our planet and its inhabitants.

**Issues in Green Building Practice**

The construction sector in Malaysia is moving towards greener practices due to increased awareness of the environmental impact of construction. Industry players acknowledge the need for greener practices (Abd Hamid et al., 2017; Pramanik et al., 2019), but significant obstacles arise from the earliest design stages (Dipta et al., 2022). Post-construction issues such as maintenance difficulties, cost overruns and environmental impacts hinder further progress (Saleh et al., 2021).

Successful green buildings in Malaysia require smart design and durable maintenance solutions (Sharif et al., 2018; Reza Esa & Arif Marhani, 2011). However, the lack of knowledge and training in this field means that experts are sometimes unprepared for the unique needs of green buildings (Hauashdh et al., 2020; Reza Esa & Arif Marhani, 2011).


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Despite the growing demand for energy efficient buildings, low awareness and expertise among construction professionals limits the transition to sustainable development (Mohd Nordin et al., 2018; Sabar et al., 2018; Khalid et al., 2019). The high cost of environmentally friendly products is often mistakenly considered a barrier. The Green Building Index (GBI), developed by the Association of Architects Malaysia (PAM) and the Association of Consulting Engineers Malaysia, reflects progress in green assessment methodology and government support (Kamil et al., 2017; Lee et al., 2020; Ming et al. , 2021).

However, bureaucratic inefficiency, licensing issues and policy contradictions often hinder progress despite the National Green Technology Policy (NGTP 2009) (Gündes & Yildirim, 2015). A comprehensive approach involving expertise development, incentives for sustainable practices, legislative support, and collaboration between government entities and the building sector is needed for sustainable and ecologically responsible construction.

Budget 2024 shows Malaysia's commitment to renewable energy, with RM2 billion allocated to the National Energy Transition Fund and RM200 billion to promote a low-carbon economy. Emphasizing energy efficiency, along with proper operation and maintenance practices, is essential to advancing sustainable practices in the Malaysian construction industry, which benefit both current and future generations.

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**Table 1:** List of review articles on the issues in green building practices

| No. | Author | Title | Operational & Maintenance | High Cost / Financial Related | Lack of Coordination | Legislation Challenge | Lack of Knowledge and Expert | Assessment Tools (GBI) |
|---|---|---|---|---|---|---|---|---|
| 1. | (Hussin et al., 2013) | The Way Forward in Sustainable Construction: Issues and Challenges | √ | √ | √ | | √ | |
| 2. | (Mohammad et al., 2014) | Critical Factors that Lead to green building operations and maintenance problems in Malaysia | √ | √ | √ | √ | √ | √ |
| 3. | (Ali et al., 2016) | Issues and Challenges Faced by Government Office Building in Performing Maintenance Work | √ | √ | √ | √ | √ | √ |
| 4. | (Pramanik et al., 2019) | Green Smart Building | | | √ | √ | √ | |
| 5. | (S. Y. Wong et al., 2021) | Barriers to Green Building Implementation in Malaysia's Construction Industry | √ | | √ | √ | | √ |
| 6. | (Yee Sin et al., 2021) | Challenges of green office implementation: A case study in Penang, Malaysia | √ | √ | | √ | √ | |
| 7. | (Kalyana Chakravarthy et al., 2022) | Barriers to Green Building Implementation in Malaysia | √ | √ | | √ | √ | √ |
| 8. | (Samari et al., 2013) | The investigation of the barriers to developing green buildings in Malaysia | √ | | | √ | | √ |
| 9. | (Kalyana Chakravarthy et al., 2022) | Barriers and project management practices in green buildings | √ | √ | | | | |
| 10. | (S. Y. Wong et al., 2021) | Barriers to green building implementation in the Malaysian construction industry | √ | √ | | √ | √ | |
| 11. | Carlander et al. 2023 | Barriers to implementation of energy-efficient technologies in building construction projects | √ | √ | | √ | √ | |



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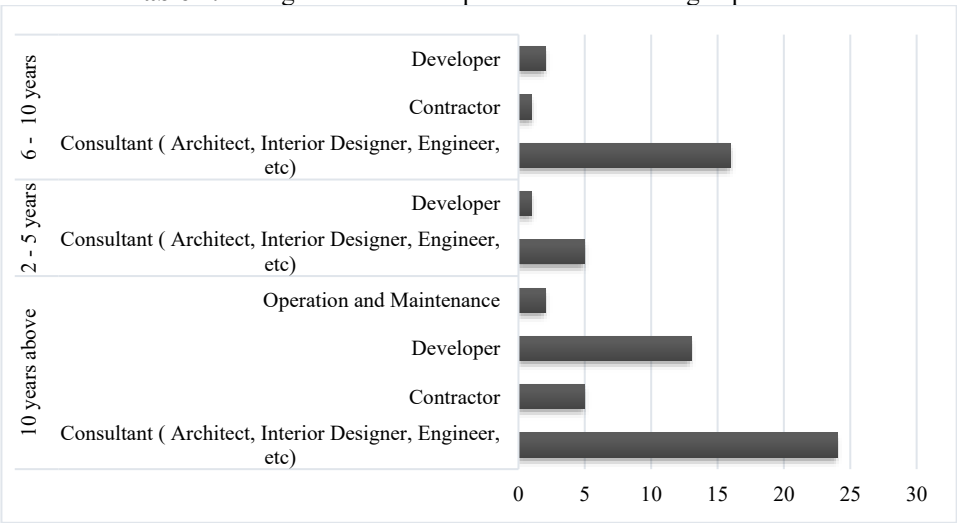
Table 1 presents an overview of articles focused on issues faced in green building practices. Proving common challenges such as operational difficulties, high costs, and issues with certification and legislation across various studies in the Malaysian context. Notably, the difficulty of "Operation & Maintenance" was consistently recognized as a significant barrier in ten studies, underlining the urgent need for refined management and maintenance protocols in the domain of sustainable construction. Financial concerns were also prominent, with the issue of "High Costs and Finance Related" cited in eight articles, pointing to the large economic investment and fiscal challenges inherent in adopting green building practices. Additionally, a similar number of studies draw attention to "Legislative Challenges," which indicate potential deficiencies in the regulatory landscape governing green building standards. Additionally, "Lack of Coordination" and "Lack of Knowledge and Expertise" were cited as significant barriers in six and five studies, respectively, reflecting communication gaps and deficits in industry-specific expertise. Finally, although rarely reported, the need for standardized assessment metrics, such as those provided by the Green Building Index (GBI), was recognized by two studies as critical to advancing the field.

## ANALYSIS AND DISCUSSION

### *Demographic Analysis*

**Table 2:** Background of the respondents and working experience




*Source: Authors (2023)*

Table 2 shows the position of the respondents and their years of working experience. The respondents are consultants (consisting of architects and

engineers), contractors, developers, and operations managers around Selangor and Kuala Lumpur. A total of 120 forms were distributed, however, the number of returned questionnaires was 73. The ages of the respondents who replied to our survey demonstrate that most of them are in the advanced stages of their careers. Forty percent of them, or 29 people, are between the ages of 31 and 35. The age group between 36 and 45 is closely represented by 38% (27 people), showing that this group is both experienced in green building and still in the process of growing professionally. A notable 22% (16 people) of the respondents are seasoned experts between the ages of 45 and 55. This makes sure that the survey is full of seasoned insights. It's not very representative of people at the ends of their careers; only 5% of those surveyed are under 26 years old and 3% are over 55. This is because entry-level and near-retirement roles are becoming less common in the modern workplace. To the question of nationality, the survey shows a concentrated demographic, with all 72 respondents identifying as Malaysian. This gives a detailed look at the professional setting in Malaysia, but it also warns people not to apply these results too broadly to other cultures or countries. When it comes to jobs held, consultants make up the largest group with 39% (28 people), which suggests that the survey included a lot of professionals who give specialized advice. Twenty-five percent (18 people) of the survey population are developers and contractors, which gives the results a broader view. On the other hand, only 5% are in operations and maintenance, which may limit the insights that can be gained from this sector.

Lastly, the level of experience of the respondents shows that the survey is aimed at professionals with a lot of experience. More than half of the respondents (36 people) had more than 10 years of experience in green building projects. People with 6 to 10 years of experience make up 29% of the group (21 people), which is a good representation of professionals in the middle of their careers. The survey seems to underrepresent newcomers to the industry; only 21% of those who answered had between 2 and 5 years of experience in green building projects and only 21% had less than 2 years (15 individuals).

## *Issues in Implementing Green Building*

Table 3 below provides a detailed summary of the results gathered from the online questionnaire survey. It comprises selected issues from impactful articles. An article that examines the issues that arise in green buildings. By providing an in-depth analysis of the six factors that influenced the survey's findings.


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**Table 3:** Survey results: Issues of Green Building in Malaysia Context

| No | Issues | Rating Scale | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | Mean Score |
| 1. | Operational and Maintenance (O&M) | 3 | 4 | 14 | 25 | 27 | 3.95 |
| 2. | High Cost (Construction Materials and Planning) | 7 | 6 | 18 | 25 | 17 | 3.53 |
| 3. | Lack of Coordination | 6 | 7 | 20 | 16 | 25 | 3.68 |
| 4. | Legislation Challenge | 6 | 10 | 18 | 25 | 14 | 3.42 |
| 5. | Lack of Knowledge and Expertise | 3 | 12 | 21 | 27 | 10 | 3.40 |
| 6. | Assessment Tools (GBI) | 3 | 4 | 14 | 25 | 27 | 3.95 |

***1. Operational and Maintenance (O&M)***

With an estimated mean score of 3.95, O&M has the highest score among concerns, indicating that the majority of respondents agree that this is a significant concern. Based on the distribution of responses showing that the majority of respondents (25 responses) tend to "Agree" or "Strongly Agree," O&M is an important determinant that affects respondents' operations. A few of the respondents only expressed a difference of opinion (3 "Strongly Disagree" and 4 "Disagree"). Potentially indicating respondents' encounter with the complexity, expense, and nature of ongoing operational and maintenance challenges is a large level of consensus. This may suggest that respondents perceive O&M as a formidable obstacle that hurts operational efficiency, expenditure, and overall performance term (Roslee et al., 2022; Yusof & Jamaludin, 2014). A strong consensus may indicate that better operations and maintenance (O&M) methods, maintenance investments, or the implementation of new technologies to speed up the process are needed. (Ali et al., 2018; Azmi et al., 2022; Zhang et al., 2023)

***2. High Prices (Construction Materials and Planning)***

The average score for the High-Cost issue is about 3.53. This indicates that there is a moderate level of consensus, although it is lower than O&M. A large number of participants disagreed (n=73) or disagreed (6 responses) regarding the importance of this matter. Variability in responses could potentially be attributed to different respondent experiences or preferences. Certain individuals may experience the effects of overspending with greater intensity, either due to geographic differences in material expenditures or the magnitude of their efforts (Dwaikat & Ali, 2018). Potentially as a result of having greater resources or more effective cost control mechanisms, some individuals may not perceive cost as a barrier. This discrepancy implies that although cost is a factor to consider, its effects may not be equally distributed among participants (Indriani et al., 2020).

***3. Lack of Coordination***

The mean score for Lack of Coordination was approximately 3.68, with most respondents expressing a neutral stance (20 responses). This spread of responses suggests that while coordination is recognized as an issue, its severity may vary based on factors like project complexity, stakeholder count, or communication barriers (Gündes & Yildirim, 2015). The ambivalence might indicate that coordination difficulties are acknowledged but not always seen as a major obstacle (Lee et al., 2020).

***4. Legislation Challenge***

Legal Challenges had a mean score of approximately 3.42, with most comments being neutral (18 responses). This low level of consensus suggests that views on legal challenges vary by industry, location, or familiarity with the legal environment. While regulation can pose difficulties, it is not universally seen as a major concern. This may be due to some domains having well-established frameworks, while others face more dynamic or restrictive rules (Ghabra, 2018; Indriani et al., 2020).

***5. Lack of Knowledge and Expertise***

Lack of Knowledge and Expertise has the lowest mean score, about 3.40, which is almost neutral. This finding shows that the majority of respondents have a neutral stance regarding the importance of this matter. Responses showed a slight, if not significant, tendency toward agreement. Concerns with the lowest scores may indicate that respondents believe that they have sufficient access to knowledge and skills in their business or through partnerships, despite the importance of expertise (Au-Yong et al., 2022; Set et al., 2017; Haushdh et al., 2020). Additionally, this may reflect that respondents are more concerned with other issues than the need for additional expertise, or it may indicate that they are confident in their ability to overcome knowledge-related barriers through hiring or training.

***6. Assessment Tools***

The GBI assessment tools line-item measures respondents' agreement on the significance of assessment tools, possibly associated with the Green Building Index" (GBI) or a similar acronym depending on the survey's context. It has a high relevance ranking of 3.95, equal to "Operational and Maintenance (O&M). Only 3% of respondents considered it unimportant, while 66% showed moderate to high agreement. This is a base for creating sustainable building and development. Chan (2021) and his team's analysis highlighted how specific measures were carefully designed to reduce energy usage and carbon emissions in buildings, demonstrating Malaysia's dedication to environmentally friendly practices in the construction industry.


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## CONCLUSION

This paper discusses Malaysia's efforts towards sustainable green buildings and the challenges faced in implementation, such as maintenance difficulties, coordination problems, and high costs. This research highlights the need for better operational efficiency, financial management and expertise. To address these issues, the paper recommends a holistic strategy with extensive training and education for industry professionals, better coordination mechanisms and regulatory adjustments. A multi-stakeholder approach is encouraged to integrate these strategies into national policies for sustainable urban development. This study emphasizes the importance of informed and methodical efforts to advance green building practices in Malaysia.

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# PSYCHOLOGICAL EFFECTS OF GREEN SPACES ON WALKING ACCESSIBILITY

**Filzani Illia Ibrahim[1], Nur Alia Nadia[2], Chen Xingrui[3]**

[1,2.3] *School of Architecture, Building and Design,*
TAYLOR'S UNIVERSITY, MALAYSIA

## Abstract

In the face of accelerating global urbanization, urban walkability has garnered increasing attention as an essential component of urban sustainability and residents' quality of life. This study focuses on Malaysia, a rapidly urbanizing country, examining the effects of natural environments and greenery on residents' psychological perception of walking accessibility. Adopting a quantitative research methodology through survey analysis, our findings reveal that natural environments and greenery significantly enhance urban residents' psychological perceptions of walking environment quality, improving visual quality, thermal comfort, safety perceptions, and trip distance perceptions. Consequently, this promotes walking accessibility, highlighting the critical role of green spaces in urban planning and public health strategies. This study fills a critical gap in existing literature by quantitatively assessing the psychological effects of green spaces on walking accessibility within an urban Malaysian context. By highlighting the substantial influence of natural environments on enhancing walkability, our research offers valuable insights for urban planners and policymakers aiming to improve public health and urban sustainability through the strategic incorporation of greenery. This contribution is particularly relevant for rapidly urbanizing countries facing significant environmental and public health challenges.

***Keywords***: Greenery, Urban, Neighborhood, Walkability

[1] Lecturer at Taylor's University, FilzaniIllia.Ibrahim@taylors.edu.my

## INTRODUCTION

Walkability is essential for healthy, sustainable cities and resident well-being (Seifi et al., 2024). In recent years, the relationship between natural elements in urban environments and walking behavior has increasingly attracted researchers' attention. Studies have shown that a good walking environment can not only increase residents' walking frequency (Wu, Zhao, Wang, et al., 2021) but also affect path selection preferences (Kim et al., 2024), and improve the significance of greenery in promoting walking (Cooley et al., 2021).

In the exploration of urban walkability, the role of psychological perceptions is often overlooked. However, as urbanization accelerates, the psychological reactions of individuals to the quality of their living environment become increasingly significant. This study aims to fill this research gap by employing quantitative research methods and designing a questionnaire survey to meticulously explore how urban residents in Malaysia psychologically perceive their community environments, particularly how natural environments and greenery impact their psychological perceptions of walkability.

## LITERATURE REVIEW

### Positive impacts of greenery and the natural environment on walkability

Green spaces and natural environments play a crucial role in enhancing urban walkability, not merely for their ability to beautify the urban landscape but more importantly, for their direct impact on increasing residents' willingness to walk and enhancing the walking experience. This is particularly the case in countries with tropical climates like Malaysia, where appropriate greening measures can not only embellish the urban landscape but also effectively improve thermal comfort and enhance a sense of safety, thereby significantly improving the walkability of cities (Ki & Lee, 2021; Sun et al., 2021).

Studies indicate that green spaces and high-quality natural environments significantly enhance a city's visual appeal, attracting more people to walk and engage in outdoor activities. Research by Ki and Lee (2021) , utilizing Google Street View and deep learning technologies, demonstrates that the Green View Index (GVI) of neighborhood streets has a significant positive effect on walking duration, particularly among lower-income groups, suggesting that a high GVI can encourage walking behaviors. Furthermore, a street greening case study by Sun et al. (2021), optimized based on walk scores, significantly improved the walkability of urban areas.

In tropical countries like Malaysia, high temperatures and humidity are primary factors affecting pedestrian comfort. Increasing urban green coverage can effectively lower surface temperatures, thereby improving thermal comfort. A study by Gholami et al. (2022) on a 3D urban digital twin system developed in Imola, Italy, shows that a Green Pedestrian Network (GPN) can significantly assess and enhance pedestrian thermal comfort. Moreover, a review of urban

cooling strategies by Mohammad et al. (2021) highlights the importance of green infrastructure and design solutions in mitigating urban heat island effects and enhancing urban liveability.

Green spaces and natural environments also significantly impact the enhancement of pedestrians' sense of safety. Using automated audits of Google Street View images, Koo et al. (2023) explored how micro-scale pedestrian streetscape features enhance macro-urban form accessibility and pedestrian safety perceptions, with results indicating that good micro-scale streetscape design significantly improves pedestrians' safety perceptions and willingness to walk. Research by Zuniga-Teran et al. (2019) examining the impact of urban walkability on the frequency of residents' use of green spaces found that enhancing neighbourhood walkability, especially through improving walking environments and increasing greenery, can encourage residents to use green spaces more frequently, thereby enhancing their sense of safety and health levels.

In summary, greening and natural environment play a key role in enhancing urban walkability. In countries with tropical climates such as Malaysia, greening becomes a key factor in enhancing walkability by improving visual appeal, thermal comfort and safety perception. Therefore, urban planning and design should give due consideration to the combined benefits of greening and natural environments in order to promote pedestrian-friendly cities.

## METHODOLOGY

In this study, a quantitative research approach was adopted to delve into the psychological perception impact of natural environments and greenery on the walkability of communities. Through systematic data collection and analysis, we aim to uncover the effects of natural environments and greenery on walking behaviours and attitudes among residents in Malaysian communities, as well as how these natural elements promote or hinder walkability within communities.

The primary reason for selecting a quantitative research method lies in its ability to provide a structured and objective pathway for quantifying and analysing the public's psychological perceptions of natural environments and greenery, and their impact on community walkability. By designing and conducting a questionnaire survey, we were able to gather substantial data to support our research hypothesis, while also numerically analysing participant feedback, thereby ensuring the reliability and universality of our findings.

Our study, through the form of a questionnaire survey, aimed to assess the public's views on the presence of natural environments and greenery in their communities and its impact on walking behaviour. This includes exploring the aesthetic perception of greenery, its influence on walking comfort, and the potential role of greenery in enhancing a sense of safety while walking. The questionnaire was designed to consider multiple dimensions related to walking, such as visual appeal, thermal comfort, sense of safety, and perception of walking


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distance, in order to comprehensively understand how natural environments and greenery influence walking willingness and behaviour.

By quantitatively analysing the results of the questionnaire survey, we aimed to reveal the specific contributions of natural environments and greenery in promoting community walkability, as well as residents' psychological perceptions of this impact. This method allows us to quantify the impact of natural environments and greenery in a scientific manner, providing a solid foundation for evidence-based urban planning and design.

**Data Collection**

This study utilizes a questionnaire as the principal tool for data collection to evaluate the impact of natural environments and greenery on the psychological perception of walkability in Malaysian residential areas. The questionnaire design incorporates demographic information, perceived impacts of natural environments and greenery, as well as other relevant walkability attributes. Moreover, the development of the questionnaire is based on literature review and perceptual statements, using a five-point Likert scale to assess respondents' perceptions and attitudes. Table 1 displays the details of the questionnaire development.

**Table 1.** The details of the questionnaire development.

| Section | Description | Literature |
|---|---|---|
| Demographic Information | Contains six questions exploring the impact of gender, age, income, neighbourhood area, duration of residence, and lifestyle on respondents' perception and walking behaviour. | ------ |
| Perception of Natural Environment and Greenery | Aims to assess the perceived impact of the natural environment and greenery on community walkability, including visual appeal, thermal comfort, safety, and perception of walking distances. | (Niu et al., 2022; Yan et al., 2023; Yang et al., 2021; Zuniga-Teran et al., 2019) |
| Other Walkability Attributes | Provides a comprehensive evaluation of the correlation between greenery and community walkability, as well as other walkability attributes beyond greenery. | (Frank et al., 2022; Jin et al., 2022; Ki & Lee, 2021; Kim et al., 2020; Wu, Zhao, Li, et al., 2021; Yang et al., 2019) |

*Source: Author*

To ensure the breadth of data collection and the accessibility of the questionnaire, this study distributed the survey both online and offline. Online

questionnaires were mainly disseminated through community or neighbourhood Facebook groups, a method that aids in the rapid and widespread gathering of data, while also reducing geographic limitations. For offline respondents, the research team provided a live link to the same online Google form and offered on-site query responses in the questionnaire, a hybrid approach intended to maximize the coverage of the survey and ensure participation from a diverse group of individuals. Additionally, the research team directly informed the public about the purpose and importance of the study through live interactions at community events, not only increasing the willingness of respondents to participate but also helping to enhance the accuracy and reliability of the data.

Despite certain academic research ethics potentially limiting data collection via social media, this study opted to distribute online questionnaires through community or neighbourhood Facebook groups based on the following considerations: Firstly, this approach allows the research to quickly and broadly reach the target audience(Arrigo et al., 2021), especially considering the growing use of social media among residents of Malaysian communities; secondly, data collection via social media can effectively reduce geographical constraints(Opara et al., 2023), ensuring wide participation from residents of different areas.

**Data Analysis Method**

In this research, a comprehensive analysis was conducted on the data collected to uncover how natural environments and greenery affect the psychological perception of walkability among residents of Malaysian communities. The analysis followed rigorous statistical procedures to ensure the reliability and universality of the research outcomes.

Initially, descriptive statistical analysis was employed to outline the respondents' reactions to various items on the questionnaire, including calculations of frequency, mean values, and standard deviations. This step provided us with a preliminary understanding of the overall perception of natural environments and greenery within the community as viewed by the respondents.

Subsequently, the data underwent analysis for arithmetic means and standard deviations to evaluate the central tendency and dispersion of the psychological perception of walkability in various dimensions influenced by natural environments and greenery. Moreover, correlational and regression analyses were utilized to investigate the statistical relationships between the natural environments and greenery and the psychological perception of walkability, as well as to ascertain the level of support for the research hypotheses. All statistical tests were conducted at a 95% confidence level with a significance level set at $p < 0.05$, to ensure the statistical significance of the research findings.

To gain an in-depth understanding of the open-ended responses provided by the respondents in the questionnaire, content analysis was also


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adopted in this study. This method involved categorizing and summarizing respondents' comments, summaries, and suggestions. This qualitative analytical component provided us with additional insights, aiding in the understanding of the deeper motivations and viewpoints underlying the quantitative data.

## RESULTS

### Data Analysis

The study begins with a careful descriptive analysis based on the 167 total number of respondents' demographics, socioeconomic status, and lifestyle, aiming to understand how these contextual factors may influence their perceptions of the research topic.

**Table 2:** Gender and Age Group Cross-analysis.

| Age Group / Gender | Male (45%) | Female (55%) |
|---|---|---|
| **0-25 years (53%)** | 24% | 29% |
| **26-45 years (28%)** | 12% | 16% |
| **46-55 years (19%)** | 9% | 10% |

*Source: Author*

**Table 3:** Income and Occupation Cross-analysis.

| Income / Occupation | Students (49%) | Professionals (25%) | Others (26%) |
|---|---|---|---|
| No Income (41%) | 20% | 12% | 9% |
| Below RM2000 (18%) | 9% | 6% | 3% |
| RM2001-RM4000 (18%) | 9% | 5% | 4% |
| RM4001-RM6000 (9%) | 4% | 3% | 2% |
| RM6001-RM8000 (7%) | 3% | 2% | 2% |
| Above RM8001 (7%) | 4% | 2% | 1% |

*Source: Author*

**Table 4:** Lifestyle and Age Group Cross-analysis.

| Lifestyle / Age Group | 0-25 years (53%) | 26-45 years (28%) | 46-55 years (19%) |
|---|---|---|---|
| Very Active (5%) | 2% | 2% | 1% |
| Moderately Active (36%) | 19% | 10% | 7% |
| Lightly Active (54%) | 28% | 15% | 11% |
| Sedentary (5%) | 3% | 1% | 1% |

*Source: Author*

Through descriptive statistics, we found that community members come from extremely diverse backgrounds, and this diversity may have an impact on their perception of the natural environment and greenery and its influence on walking behaviour. Subsequently, the questionnaire data analysis showed that a good natural environment and greenery can significantly enhance the visual appeal of a community, improve residents' mood, and provide necessary shade,

which work together to enhance comfort and safety while walking, thus promoting residents' willingness and behaviour to walk in their community.

**Table 5:** Respondents' Ratings of Perceived Community Walkability Dimensions.

| Perception Dimension | Average Score | Standard Deviation | Interpretation |
|---|---|---|---|
| Visual Attractiveness | 4.71 | 3.853 | Strongly Agree |
| Mood Improvement | 4.49 | 4.035 | Strongly Agree |
| Shade Provision | 4.39 | 3.843 | Strongly Agree |
| Comfort and Safety | 4.37 | 3.920 | Strongly Agree |
| Reduction of Traffic Noise | 4.07 | 3.651 | Agree |

*Source: Author*

By evaluating and analysing the perceptual dimensions of visual attractiveness, mood improvement, shade provision, comfort, and security, we found that the visual attractiveness of the community was significantly enhanced through the beautification of the natural environment and greenery, while the green environment positively affected residents on a psychological level by providing a pleasant walking atmosphere. The shade provided by greenery and trees became a key factor in enhancing walking comfort in hot weather, while the presence of natural elements also provided psychological security for residents by reducing traffic noise and providing natural barriers.

As for community walkability, from the data collected, we found that respondents' walking behaviour was influenced by a variety of factors, including the natural environment and green status in the community. Walking behaviour not only includes the frequency and duration of walking, but also involves the preference of choosing walking paths, interactions during walking, and the main motivation for walking.

**Table 6:** Influence of Community Environment on Walking Behavior.

| Behavioural Dimension | Average Score | Standard Deviation | Interpretation |
|---|---|---|---|
| Walking Frequency | 4.06 | 3.694 | Frequent |
| Path Selection Preference | 3.67 | 3.773 | Diverse |
| Attractiveness of Natural Environment | 3.86 | 3.943 | Significant |
| Greenery's Role in Promoting Walking | 3.62 | 4.035 | Significant |

*Source: Author*

The analysis showed that the respondents generally believed that the natural environment and greenery of the community had a positive impact on their walking behavior. Among them, respondents who walked more frequently


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tended to choose paths with beautiful environments and sufficient green coverage for their daily walks. This finding underscores the important role of the natural environment and greenery in encouraging walking behaviour in the community, especially in terms of increasing residents' interest and satisfaction in walking.

Through statistical analyses exploring how natural environments and greenery are associated with community walkability, we found that the variables of weather factors, proximity, comfort/infrastructure, and greenery/shade had a significant positive impact on enhancing community walkability. The results of these analyses further confirm the positive role of natural environments and greenery in shaping residents' walking behaviours and perceptions, emphasizing the need to incorporate natural elements in future urban planning and community design.

**Table 7.** Impact of Natural Environment and Greenery on Community Walkability.

| Variable Name | Average Score | Standard Deviation | Evaluation |
|---|---|---|---|
| Weather Factors | 3.889 | 3.536 | Significant |
| Proximity | 3.625 | 3.308 | Significant |
| Comfort/Infrastructure | 3.625 | 3.240 | Significant |
| Greenery/Shade | 3.542 | 3.180 | Significant |
| Natural Environment and Greenery | 3.514 | 3.162 | Significant |
| Attractiveness of Location/Scenery | 3.472 | 3.109 | Significant |
| Connectivity/Accessibility | 3.458 | 3.122 | Significant |
| Safety Factors | 2.139 | 2.466 | Lower |

*Source: Author*

Taken together, this study reveals the significant impacts of the natural environment and greening on enhancing community walkability through systematic quantitative analysis. Also, this study emphasizes the importance of considering the needs of different populations and adopting diverse strategies in community planning and design to promote healthy lifestyles and sustainable community development.

## FINDINGS

This research delves into how natural environments and greenery influence the perception and actual behaviours of walking within communities, revealing their pivotal role in enhancing community walkability. Through comprehensive analysis, we found that natural environments and greenery not only significantly contribute to beautifying communities, uplifting residents' moods, and enhancing the pleasure of walking but also act through various mechanisms to significantly elevate the walking experience of residents and the overall walk-friendliness of

the community. These results offer new perspectives for urban planning and environmental design, particularly on how to effectively employ greening strategies to enhance urban sustainability and the quality of life for residents.

The first key finding of this study is that natural environments and greenery significantly boost the visual appeal of communities, producing profound psychological impacts on residents. This finding resonates with the study by Budiani et al. (2022), which highlighted visual appeal as an important factor influencing urban residents' willingness to walk. Our analysis further indicates that greenery, by providing a comfortable and pleasant walking environment, not only beautifies communities but also enhances the psychological pleasure of walking, promoting residents' walking activities. This underscores the importance of integrating green elements in urban planning to create liveable and walk-friendly environments.

The provision of shade was another key finding that enhances walking comfort. Ample shading can significantly reduce the negative impact of high temperatures on residents' walking experiences, aligning with the findings of Labdaoui et al. (2021), who discovered that shading is an effective measure to improve thermal comfort and encourage outdoor activities. Moreover, the presence of natural elements increased residents' psychological sense of safety, further improving walkability through reducing traffic noise and providing natural barriers. These findings emphasize the role of natural environments and greenery in enhancing residents' comfort and sense of safety while walking, with important implications for urban planning and community design.

These findings not only enrich the theoretical framework of urban walkability but also provide an empirical basis for urban planning and public policy. They suggest that by better utilizing natural elements in urban design, cities can be more sustainable, the quality of life for residents can be improved, and the development of healthy communities can be promoted. Furthermore, this study highlights the key role of greening strategies in achieving these objectives, offering concrete guidance for urban planners and designers.

## DISCUSSION

### Significance and Interpretation of Research Findings

This study conducted a thorough investigation into how natural environments and greenery affect walkability perceptions and behaviors in Malaysian communities. It demonstrates that well-maintained green spaces not only improve the visual aesthetics of communities but also positively influence residents' psychological inclination to walk, by enhancing the comfort and safety of walking experiences. Such findings introduce a novel angle to urban planning and highlight the significance of greenery in advancing urban sustainability and improving life quality.


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We've quantitatively explored the ways in which natural surroundings and greenery contribute to walkability perceptions, addressing not just aesthetic and comfort aspects but also safety and distance perceptions, thus broadening the understanding of greenery's role in promoting walkability.

The implications for urban planning are considerable, with our research underscoring the effectiveness of strategic green space design and maintenance in promoting walkability, thus supporting the integration of green infrastructure as a cornerstone for healthy and sustainable urban communities.

**Contributions to Empirical Research**

This study significantly extends the theoretical framework regarding the impact of natural environments and greenery on walkability, offering fresh insights into how these environmental elements shape people's walking behaviour and perceptions. By systematically assessing the specific role of natural environments and greenery in Malaysian communities, this research further reveals the nuanced mechanisms through which natural environments affect the psychological perception of walkability. In particular, this study underscores the mediating roles of visual appeal, psychological comfort, sense of safety, and the perception of walking distances in how natural environments enhance walkability, providing new dimensions of explanation for the complex interplay of natural environments on human behaviour.

From a practical standpoint, the findings of this study provide valuable guidance for urban planners and community designers, emphasizing the importance of integrating natural environments and greenery into community planning and urban design. The results indicate that enhancing the quality and accessibility of natural environments can significantly boost community walk-friendliness, thereby fostering healthy lifestyles among residents and the sustainable development of communities. Specifically, we suggest that urban planning and community design should consider the following aspects:

Optimizing Greenery Layout: Prioritize the layout of green spaces in community planning to ensure an equitable and ample distribution of green spaces that are easily accessible to residents.

Enhancing Greenery Quality: Increase the diversity of plant species to not only beautify community environments but also to raise biodiversity, enhancing residents' interactive experiences with nature.

Designing Walk-Friendly Pathways: Plan comfortable and safe walking paths in conjunction with natural environments and greenery to encourage walking, especially between commercial and residential areas.

Implementing Green Infrastructure Projects: Promote green roofs, rain gardens, and other green infrastructure projects to improve the ecological functions of the city and the walking experience of residents.

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In summary, this study not only theoretically enriches our understanding of the impact of natural environments and greenery on walkability but also provides an empirical foundation and concrete recommendations for urban planning and community design, indicating effective pathways for enhancing community walk-friendliness through the utilization of natural environments and greenery. These outcomes are expected to have a positive impact on promoting sustainable urban development, contributing to the creation of more liveable and healthier urban environments.

**Research Limitations and Suggestions for Future Studies**

This research utilized quantitative methods to analyse the impact of natural environments and greenery on the psychological perception of walkability among residents of Malaysian communities, revealing a significant positive role of natural spaces in promoting walkability. The study was limited by its sample size and regional scope, which may affect the generalizability of the results. Future studies should expand the sample and geographic scope and integrate objective measurement tools such as walkability audits and GIS to enhance the applicability and accuracy of the findings. Further research should also investigate the specific mechanisms by which natural environments and greenery impact walkability, providing guidance for urban planning across various cultural and geographical contexts.

**Implications for Policy Formulation**

This research provides clear evidence of the critical role natural environments and greenery play in promoting walkability in communities, offering new perspectives for urban planning and community development. Based on our findings, we recommend the following for policy formulation:

**Promote Green Infrastructure:** Prioritize green infrastructure in urban planning for sustainable community development, including parks, green streets, rain gardens, and green roofs, which enhance the environment and encourage walking.

**Develop Green Corridors:** Establish green corridors that connect residential, work, and recreational areas, considering walkability and environmental quality, ensuring pathways are comfortable and safe.

**Encourage Community Engagement:** Support community involvement in green projects through incentives, recognizing that participation can improve project success and foster a sense of environmental stewardship.


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**Strengthen Cross-Sectoral Collaboration:** Encourage collaboration across sectors to integrate greenery in urban planning effectively, considering the multifaceted benefits for environmental conservation, economic development, and social well-being.

**Monitor and Evaluate:** Implement a system to monitor and assess the impact of green policies, especially on walkability and health, to guide policy optimization for long-term sustainability goals.

By implementing these policies, communities can enhance walkability and achieve broader benefits, including improved air quality and urban resilience, contributing to residents' physical and mental health. Integrating natural environments and greenery is essential for sustainable urban development.

## CONCLUSIONS

This study comprehensively investigates the role of natural environments and greenery in enhancing community walkability in Malaysia. Key findings from our robust quantitative methods and data analysis enrich theoretical and practical understandings in urban planning and public health.

The primary contribution of this study is the positive psychological impact of natural environments and greenery on the public's walking experience and willingness to walk. By enhancing community appeal and comfort, natural elements significantly encourage walking behaviors.

Policymakers and urban planners should consider these elements essential in improving walkability and sustainable development. Integrating high-quality natural environments and creating interconnected green corridors should be central to urban planning efforts.

In summary, this study offers empirical evidence and guidance for creating healthier and more sustainable living environments. We anticipate further research to explore the potential of natural environments in enhancing walkability, inspiring policy and practice innovations.

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# SATISFACTION WITH KUALA LUMPUR CITY HALL SERVICES: A STUDY ON PUBLIC HOUSING SRI SABAH VIA CSMS MODEL

**Hairunnisa Mohamad Ibrahim[1], Malarvilly a/p Ramayah[2], R. Usha Devi C. Rajaratnam[3]**

[1]*School of Pre-University Studies,*
TAYLOR'S COLLEGE, MALAYSIA
[2]*School of Accounting and Finance, Faculty of Business and Law,*
TAYLOR'S UNIVERSITY, MALAYSIA
[3]*School of Diploma and Professional Studies,*
TAYLOR'S COLLEGE, MALAYSIA

## Abstract

This study focuses on the factors influencing the satisfaction of public services offered by the Kuala Lumpur City Hall, Malaysia. The area of study is the public housing at Sri Sabah, which is located in Kuala Lumpur, the capital of Malaysia. This quantitative study is based on data collected from a survey involving 343 Malaysian citizens who are currently residing in the Sri Sabah neighbourhood. CSMS research framework was employed and analysed utilizing PLS-SEM statistical tool for data analysis purposes. The findings strongly support the attainment of all three objectives outlined in this study. The first finding indicates that the relationship between the KL City Hall and Sri Sabah citizens has a significant influence on the respective community's quality of life. The next outcome is that the Sri Sabah citizens' attachment to the neighbourhood affects their quality of life significantly. Finally, the relationship between the KL City Hall and citizens, quality of life, and attachment to the neighbourhood have a significant influence on the satisfaction with public services that are provided by the KL City Hall of the city.

***Keywords***: satisfaction with public services, neighbourhood attachment, quality of life, relationship with KL City Hall.

[1] Corresponding Author Email: hairunnisa.mohamadibrahim@taylors.edu.my

## INTRODUCTION

The City Hall of a metropolitan is crucial in creating liveable neighbourhoods for its citizens. The characteristics of a city's neighbourhoods and the standard of living of its citizens heavily depend on how well the City Hall runs. Only when citizens and the City Hall collaborate will the city's future and the ability to be a safe and liveable place be possible. In urban public housing communities, the importance of the municipality is more obvious (Gendel-Guterman & Billig, 2021; Barreira et al., 2019). In this study Kuala Lumpur City Hall (KLCH), the local authority will fulfill the role of the municipality bearing in mind that Kuala Lumpur is a metropolitan city. In this discussion, KL City Hall will use the Malay abbreviation of Dewan Bandaraya Kuala Lumpur (DBKL), and interchangeably the term municipality will be used to indicate that KL City Hall/DBKL is the local authority as per literature reviews that discuss municipal services (CSMS).
Financial Stability Review (FSR) by Bank Negara Malaysia, which was released together with the 2021 annual report indicates that housing affordability is a significant concern for most Malaysians (Central Bank of Malaysia, 2021). The central bank's analysis reveals that many households perceive houses as "seriously unaffordable." This perception arises primarily due to inadequate income levels. Despite house prices growing at a moderate compound annual growth rate (CAGR) of 4.1% between 2014 and 2020, the pace of income growth has not kept up with these rising prices. The report emphasises that the limited affordability of houses poses a substantial obstacle for households, and as a result, broader reforms are necessary to address this issue. The central bank believes that enhancing housing affordability is crucial to preventing households from becoming excessively burdened with debt, aligning their financial commitments with their realistic means, and mitigating the potential risks of future financial distress. In a specific geographic context, the report highlights the situation in the Klang Valley, where around 2.25 million households are situated. Among these households, only approximately 25.8% (equivalent to just over 580,000) have the financial capacity to afford the median house price recorded in 2020, which amounted to RM310,000 in 2021. Hence, inspite of the government undertaking various housing programmes and initiatives to assist low-income earners in owning houses, there seems to be a challenge in terms of ownership This stark statistic underscores the severity of the affordability challenge in this area. Furthermore, the report highlights that even in Kuala Lumpur, which is the capital city of Malaysia, the number of households capable of affording the median house price is limited. Specifically, only around 129,000 households in Kuala Lumpur have the financial means to meet this affordability threshold. (Edge Markets, 2022). In conclusion, the 2021 Financial Stability Review and the Bank Negara Malaysia's annual report indicate that housing affordability is a pressing concern for Malaysians, with most finding houses seriously unaffordable due to income constraints. The report underscores the importance of comprehensive

reforms to enhance housing affordability, which in turn would help alleviate household debt burdens and minimize potential financial hardships in the future.

Anticipating population growth, projections indicate that Greater Kuala Lumpur's population will likely reach 11 million by 2050 and approximately 12 million by 2100, (Aziz, 2018). The Government of Malaysia defines houses priced under RM 300,000.00 as affordable housing. This perspective reflects the government's belief that such housing is within reach for a wider populace. This role becomes more prominent in the public housing neighbourhoods as these neighbourhoods were created by the government to support the urban poverty communities to have proper housing. The KL City Hall plays a vital role in ensuring that a city is liveable for all its inhabitants, regardless of their socio-economic status. In the case of the capital city Kuala Lumpur, KLCH plays an important role in creating liveable housing estates. In 2018, KLCH created the Department of Community Development and Urban Well-Being to provide more effective and efficient services to the citizens of Kuala Lumpur (DBKL, 2020). KLCH manages residential flats within 50 areas within the vicinity of Kuala Lumpur. These flats serve the B40 community, in elevating urban poor housing needs.

According to the OECD (2019) report, Malaysia must ensure public sector integrity in order to achieve the United Nations Sustainable Development Goals and enhance overall well-being. This report emphasised the actions taken by the Malaysian government to address the issues of rising living costs, particularly for lower-income group households, and ways to reduce income disparity. These actions include direct cash transfers to households with monthly incomes of MYR4,000 and below, an affordable housing programme for low-income households, as well as the provision of subsidies and price controls for some essential goods. However, the report noted that these steps were not enough to make up for the B40 households' relatively low income and the higher prices of essential goods (OECD, 2019).

Moreover, on July 25th, 2023, the Director of the Department of Community Development and Urban Well-Being at KLCH shared in her discussion that, up to that point, the department has yet to conduct a survey to gather B40 communities' interpretations of their interactions with KLCH and how their services had impacted their sense of neighbourhood attachment and quality of life. This discussion was shared with the members of Taylor's University's Urban Liveable Communities Impact Lab. The Director highlighted that information gathered from surveys reflecting citizens' viewpoints will be vital in enhancing the liveability of public housing neighbourhoods and in line with "the "Malaysia MADANI" concept. Hence, she proposed that Sri Sabah flats be the first public housing community to undergo this investigation. Following will be the research objectives of this study:


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1. To examine the influence of the relationship between the KL City Hall and Sri Sabah citizens on the respective community's quality of life.
2. To investigate the effect of Sri Sabah citizens' attachment to neighbourhood on their quality of life.
3. To inspect the effect of the relationship between the KL City Hall and citizens, quality of life, and attachment to neighbourhood on the satisfaction with public services.

## LITERATURE REVIEW

Citizens' satisfaction with municipal services (CSMS) model reflects city dwellers' overall perception of their city municipality (Gendel-Guterman & Billig, 2021). This model focuses on the general attitude of the city dwellers towards their municipality. The affiliation between relationship and quality of life (QoL). The extensive definition of QoL offered by the World Health Organisation is that it refers to "an individual's perception of his or her position in life in relation to goals, expectations, standards, and concerns within the context of the culture and value systems" (Gou et al., 2018). Marans (2015) further added that in terms of quality of life, it is crucial to incorporate residential environment from the perspective of satisfaction with the individual home or dwelling, satisfaction with the neighborhood where the home is situated and satisfaction with the community (city, town, village, or township) in which the neighborhood is placed. Rapid urbanisation has challenged city planners in providing investments in urban infrastructure, feasible businesses, and proper housing to improve the city dwellers living environment and enhance their quality of life (Turok, 2018; Hanlon & Miscio, 2017). Gendel-Guterman & Billig (2021) study revealed otherwise that absence of significant affiliation between relationships and quality of life. Therefore, this study assumed that citizens' relationships influence citizens' quality of life.

*H1: Citizens relationship with KL City Hall will affect the quality of life.*

Past studies revealed various factors that affect the citizens' overall satisfaction with municipality services. One of the crucial factors would be the relationship between citizens and municipality services (Gendel-Guterman & Billig, 2021; Barreira et al., 2019). The term "relationship" is used in this study in accordance with Belanche et al., (2016), whose work stated that relationship in the marketing perspective proposes that public managers must establish closer links between themselves and the citizens. Gendel-Guterman & Billig (2021) study revealed that there is a significant direct relationship between relationship and satisfaction with public services. Furthermore, Ochoa-Rico et al. (2024) found that following an experience with the service, the urban population's perception of the territorial planning and municipal service delivery quality is

improved. Additionally, Meirinhos et al. (2022) municipal executive recommendation is directly, favorably, and statistically significantly impacted by municipal satisfaction and loyalty dimensions. Thus, it is assumed that citizens' relationship with the KLCH is essential to enhance satisfaction with municipal services.

*H2: Citizens' relationship with KL City Hall/ DBKL will influence satisfaction with public services.*

The next factor influencing citizens overall satisfaction with municipality services will be quality of life (Westaway, 2009; Senasu & Singhapakdi, 2018; Gendel-Guterman & Billig, 2021). Quality of Life which reflects life satisfaction and feelings of fulfillment or contentment with one's experience of the world. An individual's and a society's efficient functioning depends on their subjective sense of satisfaction, which is a composite reflection of how people evaluate the many facets of their lives (Andereck & Nyaupane, 2011; Gou et al., 2018). To enhance societal conditions and maximise the realisation of human potential, it is crucial to monitor citizens' subjective feelings of happiness and life satisfaction (Diener et al., 2018). Moreover, the Gendel-Guterman & Billig (2021) study disclosed that quality of life has a positive direct effect on citizens' overall satisfaction. Thus, this study predicts positive relationships exist between these two variables.

*H3: Quality of life will influence satisfaction with public services.*

Another crucial determinant that influences citizens' overall satisfaction with a municipality would be neighbourhood attachment. (Zhang et al., 2020; Lu et al., 2018; Mouratidis, 2017). Neighbourhood attachment is developed based on the place attachment concept that was developed by Low & Altman (1992) utilising attachment theory which was established by Bowlby in 1969 (Bretherton, 1992). Neighbourhood attachment concept demonstrates the emotional bonding between the citizens and the place (Lewicka, 2010; Devine-Wright et al., 2020). Besides that, Kourtit et al., (2022) neighbourhood-specific analyses revealed that in a city the districts and neighbourhoods differ substantially in many physical and social-emotional aspects, and this proves the need for place-based policies and sub-local well-being initiatives.

*H4: Attachment to Neighbourhood will influence satisfaction with public services.*

Ramkissoon (2017) added that there is an affiliation between place attachment and quality of life. This has been concurred by Gendel-Guterman &


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Billig (2021) study by incorporating city attachment and quality of life in the CSMS model. Similarly, Ng et al. (2022) concluded that people who have a stronger sense of place display greater emotional well-being.Such strong relationship between living environment / space and quality of life was exhibited in studies related to indigenous communities in Malaysia (Ismail et al., 2024) and campus community in Malaysia (Abdullah et al., 2024).Hence these people with stronger affective and behavioural sense of place demonstrate greater social and psychological well-being in urban neighbourhoods. Casakin et al., (2021) also revealed similar outcome expressing people who perceived their neighborhood as high quality showed higher levels of attachment and residential well-being, which affects the development of cognitive-emotional place attachment in a city. The study revealed that city attachment has a large positive direct effect on quality of life.

*H5: Attachment to Neighbourhood will affect quality of life.*

The CSMS model will be appropriate for studying the relationship between Sri Sabah citizens and KLCH based on application spotting research gaps. Advocates of application spotting frequently assert that a particular body of literature needs to be expanded upon or supplemented in some way. It primarily looks for a dearth of a particular theory or viewpoint in a particular field of study (Sandberg & Alvesson, 2011). Application spotting due to lack of studies conducted from the perspective of public housing citizens and KLCH.

## RESEARCH METHODOLOGY

### Sample

It is a purposive sampling method as the investigation will be focused on Flat Sri Sabah citizens, and the subjects are Malaysian citizens of the same municipality. Purposive sampling is the method the researcher uses to choose the sample for this study (Campbell et al., 2020). Partial least squares structural equation modelling (SEM) was used to test the proposed relationship (PLS-SEM). This complete multivariate statistical analysis approach can simultaneously investigate all the interactions between variables in a conceptual model, including measurement and structural components. The "ten times rule" (Chin, 1998; Hair et al., 2011), which states that the minimum sample size must be 10 times the greatest number of routes in either the structural or formative measurement models, is another sampling guideline for PLS-SEM. Therefore, we can say with confidence that 343 was an appropriate sample size for this investigation.

### Questionnaire Design

The questionnaire of this study was constructed from critically reviewed relevant literature. Numerous previous researchers exploited questionnaires as an

instrument in studying attachment to a place (Plunkett et al., 2019; Song & Soopramanien, 2019), place satisfaction (Low et al., 2018; Zhan et al., 2018; Robert W. Marans, 2015) and quality of life (Mcarthur & Robin, 2019; Joseph Sirgy, 2019). This study investigates satisfaction with public service relationships, neighborhood attachment, quality of life, and relationships, while also examining demographic aspects. The items in this study will be measured through 5-point Likert scales ranges from (1= strongly disagree) to (5 = strongly agree). The survey will be undertaken using both hardcopy and Google links depending on the convenience of the citizens.

## DATA ANALYSIS

### Demographic Characteristics

This section presents the demographic characteristics of the respondents. From the total collected valid sample size of 343 respondents, 109 (31.8%) were male and 234 (68.2%) were female. Most of the respondents are in the age group of 18-29 years old, comprising 114 respondents (33.2%), followed by the above 60 years old group with 66 (19.2%), whereas 65 (19%) respondents were aged between 40-49 years. These results show that people aged between 18-29 years were the most popular group in responding. 190 respondents (55.4%) had secondary education while a minority of the respondents (1.5%) had no formal education. The result also showed the duration of the survey respondents' stay at their current residence, 30.3% had been there for 17 years. More than half of the 343 respondents in the valid sample size have income of less than RM1000.

### Model assessment using PLS-SEM

Table 1 presents PLS-SEM analysis of measurement model, following Hair, Hollingsworth, Randolph, and Chong's (2017) guidelines, indicating reliability with indicators greater than 0.70 and convergent validity with those below 0.40. The analysis shows that RL2 and AT3 have the highest and lowest values, indicating construct validity. It's recommended that the composite reliability (CR) and AVE values be above 0.70 and 0.50, respectively.


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**Table 1:** Measurement Model

| Construct | Loading | Cronbach α | CR | AVE |
|---|---|---|---|---|
| **Satisfaction with public services (S)** | | 0.811 | 0.888 | 0.730 |
| S1. Overall satisfaction with the municipality and its services | 0.924 | | | |
| S2. Overall satisfaction with the mayor's performance | 0.693 | | | |
| S3. Satisfaction with the management operations in town | 0.925 | | | |
| **Quality of life (QoL)** | | 0.759 | 0.859 | 0.672 |
| QoL1. Excellent quality of life in this place | 0.907 | | | |
| QoL2. The place is a good place to live. | 0.705 | | | |
| QoL3. A good feeling living in this place. | 0.835 | | | |
| **Attachment (AT)** | | 0.730 | 0.853 | 0.665 |
| AT1. Proud to be a citizen in this neighborhood. | 0.885 | | | |
| AT2. The neighborhood is part of my identity. | 0.906 | | | |
| AT3. My roots are in this neighborhood. | 0.624 | | | |
| **Relationship (RL)** | | 0.924 | 0.952 | 0.869 |
| RL1. A good general relationship with your municipality | 0.911 | | | |
| RL2. Getting all needed information from municipality | 0.953 | | | |
| RL3. Municipality pays attention to my views. | 0.931 | | | |

## Discriminant validity

The study utilized Fornell-Larcker's criterion and HTMT criterion to ensure discriminant validity in cross-loading measurement as shown in table 2 and table 3. The square root of AVE for value-added was larger than correlations, and none of the values exceeded thresholds of 0.90 (Kline, 2016; Hair et al., 2019).

**Table 2:** Fornell-Larcker's criterion

| | (AT) | (QoL) | (RL) | (S) |
|---|---|---|---|---|
| Attachment (AT) | 0.815 | | | |
| Quality Of Life (QoL) | 0.826 | 0.820 | | |
| Relationship (RL) | 0.622 | 0.704 | 0.932 | |
| Satisfaction (S) | 0.744 | 0.761 | 0.733 | 0.854 |

**Table 3**: Heterotrait-Monotrait ratio (HTMT)

| | (AT) | (QoL) | (RL) | (S) |
|---|---|---|---|---|
| Attachment (AT) | | | | |
| Quality Of Life (QoL) | 0.883 | | | |
| Relationship (RL) | 0.758 | 0.824 | | |
| Satisfaction (S) | 0.834 | 0.722 | 0.840 | |

## Structural Model Analysis

The path coefficients for the modelled relationships between the constructs are generated by PLS. The significance of these coefficients was determined using the bootstrap approach, which provided the t-values for each path estimate. The predictive power $R^2$ and predictive relevance were used to evaluate the model's ability to predict the outcome variables (Hair et al., 2021). According to Hair et al. (2019), R-Square levels of 0.67, 0.33, and 0.19 are considered strong, moderate, and weak, respectively. The R-squared values of the endogenous latent variables Satisfaction (S) and Quality of Life (QoL) are 74.2% and 68.7%, respectively, indicating a strong level of model fitness. The effect size for each relationship is reported in Table 4 and the interpretation of the $f^2$ is as follows: 0.02 (small), 0.15 (medium), and 0.35 (large).

As suggested by Hair et al. (2017), the problem of multicollinearity was assessed. All variance inflation factor (VIF) values for the two endogenous variables (Satisfaction and Quality of Life) were below the recommended value of 4, which does not indicate a collinearity problem. Next, model fit was assessed by evaluating the standardized root mean square residual (SRMR). Since the SRMR value for this research model was 0.07, which is below the threshold of 0.08, it can be concluded that the model is adequately fitted (Hair et al., 2021).

**Table 4** Hypotheses

| **Hypothesis** | **Path** | **Beta** | **T-statistic** | **P-value** | **Decision** | **$f^2$** |
|---|---|---|---|---|---|---|
| H1 | RL -> QoL | 0.309 | 6.971 | 0.000 | Supported | 0.227 |
| H2 | RL -> S | 0.366 | 10.046 | 0.000 | Supported | 0.214 |
| H3 | QoL -> S | 0.242 | 5.055 | 0.000 | Supported | 0.048 |
| H4 | AT -> S | 0.316 | 14.753 | 0.000 | Supported | 0.900 |
| H5 | AT-> QoL | 0.634 | 5.833 | 0.000 | Supported | 0.955 |

The structure model tested the hypotheses in the research framework via PLS regression analyses. Table 4 shows all path coefficients and explains variances for the model. Our analysis showed that Relationship presented a positive effect on Quality of Life ($\beta$=0.309, t=6.971, p value < 0.05) at significant level 0.05, and attachment showed a positive result on Quality of Life ($\beta$=-0.634, t=5.853, p value < 0.05), thus supported H1 and H5.


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The results for Hypotheses 2, 3 and 4 show that the path coefficients of Relationship (RL), Quality of Life (QoL) and Attachment on Satisfaction (S), are 0.366, 0.242 and 0.316, respectively. Therefore, the results of this study supported H2, H3 and H4.

## DISCUSSION

This study's first objective was to examine the influence of the relationship between KLCH and Sri Sabah residents on the respective community's quality of life. Thus, objective one was investigated under $H_1$. The outcome of this study disclosed that the citizens' close relationship with KLCH staff significantly affects their quality of life in the Sri Sabah neighbourhood. This result is consistent with past studies which emphasized the important role played by city planners in providing investments in urban infrastructure, feasible businesses, and proper housing to improve the city dwellers living environment and enhance their quality of life (Turok, 2018; Hanlon & Miscio, 2017). On the other hand, the findings of this study differ from Gendel-Guterman & Billig (2021) study which revealed otherwise by disclosing the absence of significant affiliation between relationship and quality of life. In this study the first objective was met because of the continued community engagement activities teaming up with private sectors undertaken by KLCH in Sri Sabah such as space for urban farming, community room, community furniture projects and computer room to enhance the resident's quality of life.

The next aim of this study was to investigate the effect of Sri Sabah citizens' attachment to the neighbourhood on their quality of life. This aim was addressed by $H_5$ through assessing if neighbourhood attachment affects quality of life. The findings of the study suggested that there is a significant positive relationship between neighbourhood attachment and quality of life among citizens who are residing in Sri Sabah neighbourhood. The outcome of this study indicates the higher satisfaction towards being proud of the neighbourhood and Sri Sabah being the identity of the citizens contributes to greater attachment towards this neighbourhood. Such strong relationship between neighbourhood attachment and quality of life were also declared by Casakin et al., (2021), Gendel-Guterman & Billig (2021) and Ng et al. (2022). These past studies also concluded that neighbourhood attachment among citizens is essential to enhance the quality of life in a particular neighbourhood. Additionally, a study by Somasundram, S., Ramayah, M. & Abd Rahman, R. (2023) also concluded that place attachment in the form of place identity was socially empowered, and this is essential for quality-of-life betterment.

The final objective of this study was to inspect the effect of the relationship between the KLCH and citizens, quality of life, and attachment to neighbourhood on the satisfaction with public services. This objective was addressed by $H_2$, $H_3$ and $H_4$. $H_2$ tested if the citizens' relationship with KLCH

will influence satisfaction with public services. The data collected revealed that this hypothesis was supported. Hence, the findings indicated that the citizens' relationship with KLCH has a significant positive influence on satisfaction with public services. The formation of a close relationship between KLCH and citizens of Sri Sabah was possible as some of the senior citizens are retirees from KLCH. Such an alliance had created a good avenue for the Sri Sabah citizens to build a good repo with the KLCH staff whom they dealt with. This is consistent with past studies which disclosed that urban population experience with the municipality public service improves the perception of the territorial planning and municipal service delivery quality (Ochoa-Rico et al. ,2024; Meirinhos et al.,2022). On the other hand, $H_3$ tested quality of life influence on the satisfaction with public services and the findings disclosed a significant positive relationship between these two variables. Thus, the study outcome proposed that Sri Sabah citizens who have a better quality of life in the neighbourhood were more satisfied with the public services that were provided by KLCH. In terms of quality of life among Sri Sabah citizens, a sense of a good place to live and having a good feeling living in this residence are crucial in forming satisfaction and thus played a crucial element in forming the satisfaction on public services that were provided by KLCH. The outcome of this study is consistent with Gendel-Guterman & Billig (2021) study which also related that quality of life has a positive direct effect on citizens' overall satisfaction. The last hypothesis under this research objective which is $H_4$ assessed neighbourhood attachment influence on the satisfaction with public services. The data analysed exposed the existence of a significant positive relationship between neighbourhood attachment and satisfaction with the public services provided by KLCH. The result concluded that the more Sri Sabah citizens are attached to their neighbourhood, the higher their satisfaction towards the public services that were provided by KLCH. This study's finding has similarity with Kourtit et al., (2022) study which revealed that city neighbourhood differs substantially in many physical and social-emotional aspects, and there is a need for place-based policies to enhance the citizens subjective well-being. This study has further enhanced the CSMS model by replacing attachment to city variable with neighbourhood attachment variable to narrow down the search to specific neighbourhood in the city. This is because the city is comprised of citizens from different socio-economic statuses. Hence, it is essential for KLCH, the local city authority to be aware of the needs of different groups of city dwellers who reside in different neighbourhood. Knowing the neighbourhood in the city will be a crucial element in creating place-based services which will enhance the respective city dwellers' quality of life. This study contrasted Gendel-Guterman & Billig (2021) discovery that attachment to a place doesn't affect directly CSMS. Hence, the modification of variables from attachment to city to neighbourhood attachment has significantly contributed to this model.


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## CONCLUSION

Investigation at neighbourhood level to identify the needs from the perspective of citizens is essential. Knowing the citizens at neighbourhood level is important for the municipality staff. Such bonding will ensure city planning will be undertaken to align with the needs of city citizens. When municipality successfully tackles issues at neighbourhood level, it enhances the satisfaction towards municipality, neighbourhood attachment, and quality of life. This is very crucial, especially for low-income groups who are residing in low-income housing areas. Future researchers may incorporate a mediator and moderator to enhance this model further.

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## DISCLOSURE STATEMENT / ETHICAL STATEMENT

Taylor's University Human Ethics Committee concluded that this study poses no ethical issues of concern. This approval is valid until the project end date of December 2023.

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# FACTORS INFLUENCING BRUNEIANS' ADOPTION OF STRATA TITLE LIVING

**Mohd Don Omar[1], Rosli Said[2], Rohayu Ab Majid[3], Nurdiana Wahid[4]**

[1,2]*Department of Real Estate, Faculty of Built Environment,*
UNIVERSITI MALAYA, MALAYSIA
[3]*College of Built Environment,*
*Faculty of Architecture, Planning and Surveying,*
UNIVERSITI TEKNOLOGI MARA (UITM), MALAYSIA
[4]*M.D Associates*,
BRUNEI DARUSSALAM

## Abstract

Strata ownership presents a promising housing option characterised by shared amenities within a single building or complex, offering diverse advantages to its residents. Despite its potential, the adoption of this housing concept in Brunei remains relatively novel, significantly influencing the acceptance of strata living. This paper aims to assess the extent of Bruneians' embrace of strata living and identify factors influencing their acceptance of Strata Title Living (STL) in Brunei. Seven factors related to strata living acceptability – including cost savings, provision of facilities, house design, legal framework, housing environment, political context, and government support – were examined to determine their impact on Bruneians' acceptability. Data were collected from 241 Brunei residents via surveys, and both descriptive and inferential analyses were conducted to assess Bruneians' acceptance factors regarding strata title living. Results reveal a notably low level of acceptance among Bruneians toward STL and underscore the most influential factor shaping Bruneians' acceptability of STL within Brunei Darussalam.

***Keywords***: Acceptance, Strata Title Living, Bruneian, Strata concept

[2] Corresponding author. Email: rosli_alambina@um.edu.my

## INTRODUCTION

Strata title (ST) partitions common property into multiple units, allowing individuals to own a fraction of it with shared access and maintenance duties (Bailey and Robertson, 1997). This concept is gaining traction in real estate development, offering varied designs that enhance residents' quality of life (Dredge & Coiacetto, 2011). By providing shared amenities, strata residences reduce expenses and attract investors, capitalising on market trends (Dredge & Coiacetto, 2011). The adaptable nature of ST meets diverse societal needs, providing legal and economic opportunities for homeowners and investors alike (Troy et al., 2016). However, adoption remains uneven, with regions like Brunei still in the experimental phase despite clear demand (Brudirect, 2016). This study explores Bruneians' acceptance of strata living and identifies key factors influencing their decision-making.

## LITERATURE REVIEW

Living under a strata title provides numerous benefits to residents, extending beyond high-rise buildings to include landed residential properties (Troy et al., 2017). This expansion reflects the global recognition of advantages such as shared facilities and effective management systems (Easthope & Randolph, 2009). Strata living encompasses cost savings, shared facilities, diverse housing options, legal protection, pleasant environments, political stability, and governmental support, appealing to individuals and families (Levin & Artherson, 2020; Altmann, 2016).

The definitions and perspectives of strata title (ST) vary by country, shaped by encrypted land and property laws to align with socioeconomic, cultural, and property market dynamics (NSW Fair Trading New South Wales Department of Fair Trading, 2009). However, a common feature of ST schemes is the shared facilities and responsibilities among ST owners (NSW Fair Trading New South Wales Department of Fair Trading, 2009). Generally, ST operates with owners purchasing units on land/buildings, accessing common facilities such as lifts, car parks, and recreational amenities, while sharing maintenance and management costs (Dredge and Coiacetto, 2011). Yet, legal, regulatory, and management issues have recently emerged, challenging the modern implementation of the ST concept (Hussain, 1994; Christudason, 2004).

The modern evolution of strata title (ST) signifies a significant transformation in the property market, driven by shifts in economic, social, lifestyle, and perceptual attitudes towards strata living (Leshinsky et al., 2018; Brugman, 2020). This evolution responds to increasing residential density globally and contemporary changes in modern living. Extensive literature emphasizes the intertwined nature of facilities, design, and underlying features of properties, influencing residents' perceptions and interactions (Burton, 2000; Bramley and Power, 2009). ST addresses demand and supply gaps, offering

economic opportunities for property ownership (Easthope, 2019), while responding to urbanisation and housing crises (Allatt, 2020). It supports metropolitan planning for sustainable development (Dredge and Coiacetto, 2011), ensuring enhanced living experiences through centralised governance (Liat Mehmood et al., 2022). Quality of life indicators now incorporate economic and social aspects (Kern, 2014; Said and Martin, 2013), recognizing houses as a blend of physical, economic, and social components (Hashim, 2003). Given this paradigm shift, understanding the motivating factors behind ST's living choices is paramount.

Normative studies suggest that geographic displacement often prompts consideration of relocating to strata-based housing for improved services, facilities, and economic, social, functional, and psychological opportunities (Kearns and Mason, 2013; Crommelin et al., 2020). Strata title (ST) homes ensure residents' health by providing essential facilities and community spaces, a crucial factor driving preference for ST living (Kim et al., 2005; Levin and Arthurson, 2020). In high-density environments, social interaction can be challenging, but amenities like sports facilities, parks, libraries, and cultural centres, along with involvement in governance, foster positive social interactions among ST residents (Thompson et al., 2022; Kathitasapathy et al, 2023). Furthermore, the legal ownership of valuable property in ST homes serves as a personal achievement, enhancing residents' perception and acceptance of ST living (Mohit and Raja, 2014; Troy et al., 2016).

Complexities in the structure, management, and maintenance of strata title (ST) properties can diminish residents' acceptance. Past studies link ineffective procedures and high maintenance costs to reduced acceptance (Sherwin, 2000; Vanier, 2001). Outdated maintenance strategies have led residents to seek alternative housing (Jones and Sharp, 2007), while a lack of clarity on responsibilities hampers understanding (Easthope et al., 2009). Safety and design issues, including non-compliance with regulations, pose barriers to acceptance (Yang et al., 2022). Concerns about management's approach to climate change also affect residents' perceptions (Guilding et al., 2015). Ethnic and social distribution strategies, residential disputes, neighbour attitudes, and vandalism are additional barriers noted in emerging studies (Web and Webber, 2017; Easthope et al., 2012; Buys et al., 2013; Shim and Kang, 1996; Kan et al., 2022).

Overall, the strata housing scheme offers appealing features that encourage acceptance of this innovative residential concept. However, Bruneians' inclination towards strata living is influenced by diverse factors, necessitating examination to identify predominant ones to reinforce and weaker ones to address, thereby fostering a favourable reception of the concept among the Bruneian populace.


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**1. Living Cost Saving**

Strata living often yields cost-saving benefits compared to traditional housing setups, with shared expenses for maintenance, security, and amenities leading to lower overall living costs (Susilawati & Yakobus, 2010). However, challenges arise in establishing affordable strata title housing in prime locations due to factors like land availability, high construction costs, cultural barriers, and risks with lower returns (Susilawati & Yakobus, 2010). Similarly, in Malaysia, urban centres face a severe shortage of affordable housing, driven by population growth outpacing supply (Tan et al., 2017). Bakhtyar et al. (2012) found that increased density can benefit developers, allowing for the provision of affordable quality housing through projects like the Malaysian Smart Growth's Affordable Quality Housing initiative. Cyrus (2015) highlights affordability and the opportunity to own a quality house with complimentary facilities as primary motivational factors for accepting strata title homes.

**2. Provision of Facilities**

Strata living offers access to shared facilities such as swimming pools, gyms, and parking spaces, relieving residents of individual maintenance responsibilities and attracting investors (Dredge & Coiacetto, 201; Shuhaimi et al, 2024). However, residents often oppose commercialising these facilities due to security and privacy concerns, despite acknowledging the potential financial benefits (Samad et al., 2018). Multi-owned developments present shared ownership as both attractive and burdensome, with a study in New South Wales, Australia, highlighting the mismatch between owners' responsibilities and their awareness and acceptance of these obligations (Easthope et al., 2018).

**3. House Design**

Strata developments offer diverse housing designs, including high-rise apartments, townhouses, and detached homes within gated communities, catering to various preferences and lifestyles. Innovation in building design and technology, as highlighted by Higgins (2015), enables thinner and higher infill redevelopment, while Leshinsky et al. (2018) suggest that smart sustainable materials and design can mitigate urban stressors like climate change and population growth. Structural issues in the design and facilities of strata title (ST) properties, identified by Celine (2015), Sajan (2015), Sia et al. (2018), and Olanrewaju et al. (2021), impact ST planning and property market development. Burton (2000) and Bramley and Power (2009) emphasise the role of property features in shaping resident perceptions, while Yang et al. (2022) highlight safety and design as key barriers to ST acceptance due to non-compliance with regulatory requirements."

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**4. Law & Regulation**

Strata living operates within a legal framework governed by specific laws and regulations, dictating rights and responsibilities for residents and management bodies (Troy et al., 2016). However, legal, regulatory, and governance complexities may hinder future growth and the creation of sustainable property markets (Christudason, 2008, 2009, 2010; Easthope and Randolph, 2009; Crommelin et al., 2020). Mohit and Raja (2014) highlight the positive perception of legally owning valuable property among residents, guiding acceptance of strata title (ST) homes. Governance and dispute resolution processes in Victoria's strata system have been criticized for lack of representation of resident needs, prompting reform proposals (Leshinsky et al., 2012). Strata title laws vary across jurisdictions, with reforms underway in regions like NSW, Western Australia, Ontario, and Vancouver, aimed at addressing governance issues and facilitating urban regeneration (Easthope, 2013). The legal framework creates enforceable rights, responsibilities, and restrictions between owners, with each state and territory in Australia having its own strata legislation (Weir, 2018; Sherry, 2009; Blandy, 2010; Everton-Moore et al, 2006). However, differences in property law between jurisdictions pose challenges for developers, impacting the morality and legitimacy of modern property law (Sherry, 2008; Radha & Razali (2023).

**5. Housing Environment**

The overall environment of a strata development significantly impacts residents' quality of life, with factors like cleanliness, landscaping, noise levels, safety, and community atmosphere playing crucial roles (Dredge & Coaicetto, 2011). Developers and strata managers have a corporate social responsibility to address these issues proactively, aiming to create vibrant and well-maintained neighbourhoods (Leshinsky et al., 2018). Strata living is positioned to be an effective planning and property tool, particularly in working with greyfields, to bring about real change (Leshinsky et al., 2018).

**6. Political Situation**

The political climate indirectly affects strata living through its influence on economic stability, property regulations, and infrastructure development, with a stable environment fostering confidence in the real estate market and encouraging investment in strata developments. Urban governance has garnered attention, reflecting changes in cities' roles in the global economy and political ideals (Easthope & Randolph, 2008). Malaysia's rapid growth is attributed to its long-standing social and political stability, enabling attention to various planning aspects and sustainability issues (Radha & Razali, 2023). The property's legal structure mirrors societal norms and values beyond market value considerations (Weir, 2018). Global urbanisation and the need for consolidation pose


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multifaceted economic, political, environmental, and social challenges (Easthope & Randolph, 2008).

**7. Government Support**

Government policies and support initiatives are pivotal in promoting and regulating strata living, encompassing incentives for developers, subsidies for affordable housing projects, tax breaks, and legislative measures to enhance strata management practices and resident welfare (Dredge & Coiacetto, 2011). The shift in residents' perceptions towards viewing houses as a blend of physical, economic, and social components underscores the importance of government initiatives in fostering quality living conditions (Kern, 2014; Said & Martin, 2013; Hashim, 2003, Thompson et al, 2022). Studies have shown that geographic displacement can drive individuals towards strata-based housing for better services and economic opportunities (Kearns & Mason, 2013; Crommelin et al., 2020), with a focus on residents' health and provision of community spaces also influencing preferences for strata living (Kim et al., 2005; Levin & Arthurson, 2020). Recognizing legally owned valuable properties and the affordability of quality homes with complimentary facilities further motivate acceptance of strata living (Mohit and Raja, 2014; Troy et al., 2016; Cyrus, 2015). Conversely, challenges in structure, management, and maintenance, along with inadequate strategies for addressing climate change concerns and social issues, pose barriers to strata living acceptance (Sherwin, 2000; Vanier, 2001; Yang et al., 2022; Guilding et al., 2015; Web and Webber, 2017; Easthope et al., 2012; Buys et al., 2013; Shim & Kang, 1996; Kan et al., 2022).

## RESEARCH METHODOLOGY

The literature review of previous studies, as discussed earlier, has unveiled distinct characteristics typically observed in strata-concept dwellings. These characteristics have informed the construction of a questionnaire, serving as the primary research instrument. The questionnaire consists of two sections: one dedicated to gathering demographic profiles and the other focusing on the seven elements of Strata Title Living (STL). Thus, the theoretical framework illustrated in Figure 1 serves as a foundation for this research endeavour.

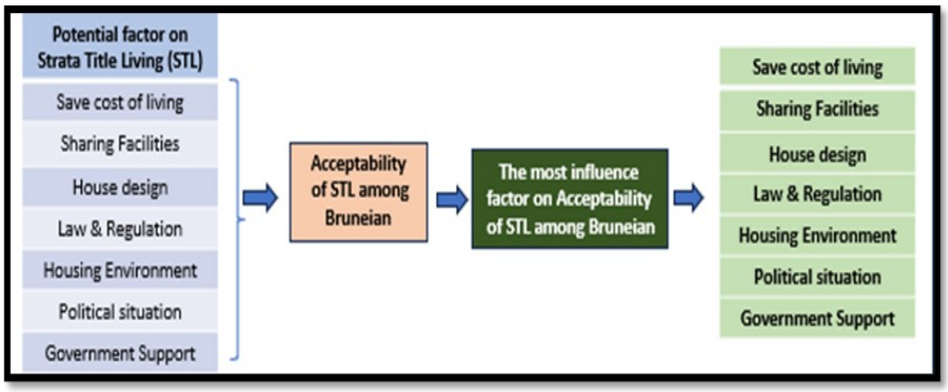


**Figure 1**: Theoretical Framework

In this research endeavour, a meticulous approach was undertaken to gather insights into the acceptance and perceptions of Strata Title (ST) living among Bruneians. A sample of 241 individuals was meticulously drawn from a substantial pool of 22,000 applicants of the National Housing Scheme (NHS) in Brunei. These applicants were deemed an ideal population for examination, as they provided a diverse cross-section of the community, enabling a comprehensive assessment of expectations, preferences, and attitudes towards ST homes. The design of a psychometrically sound survey instrument was of paramount importance, ensuring the collection of reliable and valid data to meet the research objectives effectively.

Upon completion of data collection, sophisticated analytical techniques were employed to discern patterns and relationships within the dataset. Correlation analysis was utilized to explore the significance of various factors influencing Bruneians' acceptance of Strata Title Living (STL). Factors exhibiting a p-value below $<0.05$ were identified as pivotal contributors to the acceptability of STL among the populace. Furthermore, the correlation coefficient unveiled significant linear relationships between these factors and Bruneians' decision-making processes regarding STL adoption. Subsequent regression analysis was then conducted to construct an acceptance model elucidating the nuanced dynamics shaping Bruneians' attitudes towards ST homes. This comprehensive methodology aimed to provide valuable insights into the factors driving or impeding the embrace of ST living arrangements within the Bruneian context, thus informing future policy initiatives and urban development strategies.

## RESULTS

Overall, the study findings underscore a limited understanding among Bruneians regarding strata housing. The analysis (Figure 2) suggests that merely 22.8%


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perceive strata residences as a feasible alternative to their existing housing arrangements. Conversely, 39.4% strongly oppose the notion of strata housing as a viable option. Moreover, a substantial segment comprising 37.8% of respondents exhibits indifference towards strata housing as an alternative lifestyle choice.

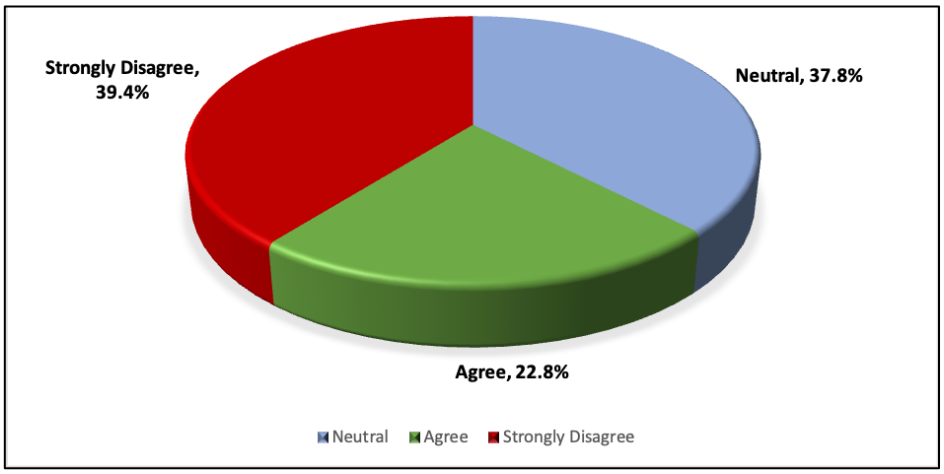


**Figure 2**: Acceptability score among Bruneians on Strata Title living as an alternative for current housing development

Table 1 presents a crosstab analysis examining the relationship between respondents' demographic profiles and their acceptance scores towards Strata Title Living (STL). Among the gender profiles, 20.7% of males expressed disagreement with the concept of strata, while 14.5% of females shared the same sentiment. In terms of age groups, 14.5% of Bruneians aged between 30-39 and those aged 50 years and above indicated agreement with the strata housing scheme. Additionally, 5% of individuals in the income group earning between 3,501 to 4,500 BND per month exhibited the highest rate of agreement with strata housing, compared to other income brackets ranging from 2,500 to 3,500 and incomes above 5,000 BND per month.

**Table 1**: Crosstab Analysis

| **Category** | **Demographic Profile** | **B7. / Strata Title Living fits well with the way I like to have my home** | | | **Total (%)** | **Total sample** |
|---|---|---|---|---|---|---|
| | | Strongly Disagree (%) | Neutral (%) | Agree (%) | | |
| **Gender** | Male | 24.9 | 20.7 | 13.7 | 59.3 | **100** |
| | Female | 14.5 | 17 | 8.3 | 40.7 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Nationality** | Non-Bruneian | 1.7 | 1.7 | 2.5 | 5.8 | **100** |
| | Bruneian | 37.8 | 36.1 | 20.3 | 94.2 | |
| **Age** | Between 18-29 | 4.1 | 4.1 | 2.9 | 11.2 | **100** |
| | Between 30-39 | 8.3 | 6.6 | 7.5 | 22.4 | |
| | Between 40-49 | 11.2 | 10 | 5.4 | 26.6 | |
| | 50 and above | 15.8 | 17 | 7.1 | 39.8 | |
| **Marital Status** | Single | 6.6 | 9.1 | 6.6 | 22.4 | **100** |
| | Divorced | 1.2 | 0.4 | 1.2 | 2.9 | |
| | Married | 31.1 | 28.2 | 14.9 | 74.3 | |
| | Others | 0.4 | 0 | 0 | 0.4 | |
| **Monthly Income (BND)** | Below 500 | 0.8 | 2.1 | 2.9 | 5.8 | **100** |
| | 500-1,500 | 3.3 | 5.8 | 2.5 | 11.6 | |
| | 1,501-2,500 | 7.1 | 4.6 | 2.5 | 14.1 | |
| | 2,501-3,500 | 7.1 | 7.1 | 4.6 | 18.7 | |
| | 3,501-4,500 | 8.3 | 5.8 | 5 | 18.7 | |
| | 4,501-5,500 | 5 | 5.8 | 2.1 | 12.9 | |
| | Above 5,500 | 7.9 | 6.6 | 3.7 | 18.3 | |
| **Total** | | **39.4** | **37.8** | **22.8** | **100.0** | |

Table 2 presents five out of the seven factors studied that exhibited a significant status with a p-value below < 0.05. Specifically, Facilities, Housing Environment, and Political Situation demonstrated a highly significant value of 0.00, while House Design and Cost of Living Savings indicated p-values of 0.012 and 0.008, respectively. These five significant factors were further subjected to correlation analysis to assess their impact on the acceptance score of Bruneians towards Strata Title Living (STL). The correlation coefficients for these factors ranged from 0.146 (Cost of Living Savings) to 0.259 (Housing Environment), indicating the extent to which each factor influences Bruneians' acceptance of STL.

**Table 2**: The significant status of potential factors influencing Bruneian's acceptability of STL

| **Influence Factor on STL Acceptability** | **P Value** | **Correlation Coefficient** |
|---|---|---|
| B4. Save cost of living | 0.012 | 0.146 |
| B13. Facilities | 0 | 0.253 |
| B18. House design | 0.008 | 0.156 |
| B19. Law & Regulation | 0.109 | - |
| B20. Housing Environment | 0 | 0.259 |
| B21. Political situation | 0 | 0.224 |
| B23. Government support | 0.167 | - |


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Table 3 presents a summary model for Bruneians' acceptance of STL, derived from regression analysis involving the five significant factors. The adjusted R-squared value of 0.107 indicates that these factors collectively contribute to 10.7% of the variance in Bruneians' acceptance of STL. Each of the five factors exhibited contributions ranging from 0.034 to 0.206, demonstrating their impact on Bruneians' decision to embrace the concept of STL in their housing. Notably, the facility aspect within STL exerted the greatest influence on Bruneians' scores, with a standardised coefficient value of 0.185. Despite the influence of these factors, the overall acceptance rate remains relatively low, as indicated by the summary model.

**Table 3**: Model summary of Bruneian's Acceptability toward Strata Title Living

Model Summary[b]

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change | |
| **1** | 0.355 | 0.126 | 0.107 | 1.644 | 0.126 | 6.774 | 5 | 235 | <.001 | 1.861 |

a. Predictors: (Constant), B4. Save cost of living, B13. Facilities, B1 8. House design, B20. Housing Environment, B21. Political situation

b. Dependent Variable: B3. Bruneian Acceptability on Strata Title Living

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Correlation | | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Zero-order | Partial | Part | Tolerance | VIF |
| **1** | (Constant) | 1.291 | 0.323 | | 4.003 | 0.001 | | | | | |
| | B4. Save cost of living | 0.062 | 0.065 | 0.06 | 0.947 | 0.345 | 0.147 | 0.058 | 0.057 | 0.921 | 1.086 |
| | B13. Facilities | 0.206 | 0.071 | 0.185 | 2.918 | 0.004 | 0.243 | 0.187 | 0.178 | 0.926 | 1.08 |
| | B18. House design | 0.034 | 0.072 | 0.032 | 0.48 | 0.632 | 0.155 | 0.031 | 0.029 | 0.849 | 1.178 |
| | B20. Housing Environment | 0.158 | 0.076 | 0.153 | 2.084 | 0.038 | 0.26 | 0.135 | 0.127 | 0.692 | 1.445 |
| | B21. Political situation | 0.118 | 0.07 | 0.117 | 1.697 | 0.091 | 0.235 | 0.11 | 0.103 | 0.777 | 1.287 |
| | (Constant) | 1.291 | 0.323 | | 4.003 | 0.001 | 0.147 | 0.058 | 0.057 | 0.921 | 1.086 |

b. Dependent Variable: B3. Bruneian Acceptability on Strata Title Living

## CONCLUSION

ST living represents an innovative housing concept proposed as an integrated solution to address various social, economic, and developmental challenges impacting sustainable living. However, there remains a scarcity of information regarding the factors contributing to its acceptance, particularly in developing countries like Brunei. The findings suggest that different features and aspects of ST living can both positively and negatively influence residents' perceptions, thereby affecting its acceptance. Specifically, factors such as resource facilitation, including legal and regulatory support, alongside relative advantages in terms of economic, financial, and social benefits, may significantly impact the acceptance of ST living. Conversely, enhancing the simultaneous living experience could involve the integration of essential and complementary facilities, improved management, and governance, thereby fostering positive perceptions about ST living and ultimately enhancing its acceptance.

The study contributes to housing and sustainable living literature by presenting ST living as an innovative solution, highlighting seven influencing factors and enriching future research. It also aids Brunei's housing market transition, suggesting ST living as a dynamic option for property market development. The findings have practical implications for regulators, policymakers, practitioners, property consultants, and the public. Regulators should enhance legal infrastructure, policymakers can propose guidelines, practitioners address governance complexities, and property consultants recommend customer-oriented market strategies for ST developers.

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# DRIVERS, CAPABILITIES, AND CHALLENGES FOR ADOPTING DIGITAL TWIN IN FACILITY MANAGEMENT: A PROFOUND QUALITATIVE INVESTIGATION

**Asraf M. Shuhaimi[1], Liyana Mohamed Yusof[2], Rahimi A. Rahman[3]**

[1,2,3]*Faculty of Civil Engineering Technology,*
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH
[3]*Faculty of Graduate Studies,*
DAFFODIL INTERNATIONAL UNIVERSITY

## Abstract

Digital Twin (DT) adoption in Built Environment (BE) industry especially facility management (FM) is still slow. DT in FM can offer accurate time information for asset management and building maintenance systems and provide a supporting decision-making process. However, the current FM industry still practices the traditional way of building operation and maintenance, which is inefficient and the principal cause of loss of information due to the lack of digitalization processes and making data inaccessible. Compare to other industries that has effectively applied DT, FM still in infancy due to the ambiguous concept. Therefore, this study aims to profoundly investigate the drivers, capabilities, and challenges for adopting DT in FM. An explorative qualitative approach was employed through semi-structured interviews with eighteen FM professionals to achieve the study objectives. The interview data were analysed using the thematic analysis approach. The study findings suggest that legislation, technology, organization, streamlining operations and stakeholder value are the drivers for adopting DT in FM. Furthermore, findings show that the capabilities needed for adopting DT in FM are manpower, infrastructure, knowledge, and budget. Lastly, the challenges for adopting DT in FM are cost, people, and technology. In conclusion, the study findings provide valuable insights and understanding for the FM industry to motivate further and take action to use DT.

***Keywords***: Digital Twin, Emerging Technology, Facility Management, Operation, and Maintenance

[2] Senior lecturer. Email: liyanam@umpsa.edu.my

## INTRODUCTION

Building Information Modelling (BIM) is a 3D-digital representation of the physical and functional parameters of the facility, based on the knowledge exchange of information and resources, to form a valid basis for decision-making over its life cycle. (Aripin et al., 2019). In addition, BIM also offers continuous and organized views and representations of the 3D model along with accurate data such as costing (4D) and the construction schedule (5D). The rich underlying data and three-dimensional (3D) models enable a variety of trades to interact and coordinate the information with one another to boost productivity and raise the return on investment (ROI) associated with proactive problem-solving methods and virtual modelling (Shen et al., 2016). Today, BIM could also be modelled up to 6D and 7D, which provide sustainability, facilities management, and asset management (CREAM, 2014).

The concept of Digital Twin (DT) was first proposed in 1991, with the idea that by sharing information and data, a digital equivalent to a physical system could be created. The idea of a DT is built around the role of a virtual copy of a target physical entity that is used to conduct experiments or simulations and predict future behaviours to help decision-makers make up their minds or to help automated decision systems determine appropriate solutions to the expected problems (Salem & Dragomir, 2022). During its space exploration missions in the 1960s, the National Aeronautics and Space Administration (NASA) was the first to use DT as the core idea and means of understanding a physical object. NASA used DT models to control and simulate their spacecraft for accurate mapping (Kit, 2022). In 2010, NASA reintroduced the concept of DT as an integrated Multiphysics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physical model, sensor updates, fleet history, and other technologies to mirror the life of its corresponding flying twin (El Jazzar et al., 2020).

DT can be equipped with sensors, gauges, measuring machines, lasers, vision systems, and white light scanning that can sense the physical asset's real-life experience information. DT can accurately predict potential failures, feed information back to the system, and react in response to stimuli. It also allows the collection of information about a physical asset throughout its life cycle and continuously monitors all project processes (Ozturk, 2021). In contrast, design visualizations, quick design choices creation, automated model reliability analysis, report generation, and asset performance forecasting are all made possible by BIM (Radzi et al., 2023). In other words, DT and BIM can resolve several challenges during construction projects and improve project effectiveness (Radzi et al., 2023). However, there are still misconceptions about the connection between DT and BIM. Practitioners are reluctant to investigate DT if BIM is already present in their building projects due to these misconceptions. While

there's growing interest in DT within the BE industry, the concept remains unclear for many professionals and researchers. Compared to established applications in automotive, aerospace, logistics, and oil & gas, DT research and use in BE is in its early stages (AlBalkhy et al., 2024). Thus, this study aims to profoundly investigate the drivers, capabilities, and challenges for adopting DT in facility management (FM). To achieve the research objectives, a qualitative approach was utilized, employing interviews with FM industry players. This study adds to the detailed understanding of the factors, including the drivers, capabilities, and challenges that affect DT adoption in FM. This study benefits FM organizations as the outcomes can help FM organizations choose the best practices for successful DT adoption.

## LITERATURE REVIEW

### Building Information Modelling, Digital Twin, and Facility Management

A BIM model represents the parts used in the construction process to construct a building. It includes geometry, spatial relationships, geographical information, the number and nature of the building components, cost estimating, project schedule, and material inventory. The life cycle of a building can also be replicated using BIM, beginning with from construction phase and ending with the operation phase (Abdullah et al., 2015). In other words, BIM is a project simulation that consists of 3D models of the project components linked to all the necessary information related to the project planning, design, construction, or operation as portrayed. From the FM context, BIM can be defined as a dynamic document collecting instrument in archives used to accurately manage and regulate building data throughout the life cycle, which owners can use to manage facilities during the FM phase (Samsuddin & Zaini, 2022). The advantages of using BIM for facility operations are transparent. Additionally, BIM data and models can be viewed on different platforms and integrated with various digital devices. However, BIM adoption in FM lags behind that of the design and construction phases. The life cycle of construction projects should be considered when employing BIM, which now primarily extends to the design and construction phases (Liu & Issa, 2013). In addition, BIM FM is known to enhance a facility's operation and the operation of facilities management (Ikediashi et al., 2022). According to Samsuddin and Zaini (2022), facility managers have access to facility data using BIM FM, mainly geometric BIM data, which provides essential information such as equipment position, maintainability, and accessibility. Thus, BIM is set to offer a new level of functionality for the FM of a building as well as the physical assets in it.


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**Digital Twin in Facility Management**

A DT is a digital replica of the physical environment, states, and processes. A DT can be used to evaluate the present status and possibly estimate the future state of a digital replica of the built environment. In contrast, a BIM model comprises as-is and historical data (Stojanovic et al., 2018). DT also combines Artificial Intelligence, Machine Learning, and Big Data Analytics to develop dynamic models that can learn and update the status of the physical counterpart from numerous heterogeneous data sources (Hosamo et al., 2022). Changes in the built environment that affect the operating state of the workplace must be noted and handled for FM practices. Operation and Maintenance (O&M) processes are now documented using duplicate, frequently out-of-date information that is typically only available in paper format (Stojanovic et al., 2018). According to Hosamo et al. (2022), DT promotes improvement in AEC-FM operations by enhancing data management and processing using large-scale data, information, knowledge integration, and synchronization. It accomplishes this by continuously integrating data and information during the life of an asset. The work added that real-time data from the Internet of Things (IoT) sensors and devices is integrated into the physical system to improve adaptive updating and provide information for further machine learning and artificial intelligence integration to coordinate and automate the physical counterpart of the digital model after operational changes. Combining a virtual information model with real-time data could considerably improve decision-making during the lifetime of the building (Hosamo et al., 2022). However, due to the industry's delayed technological growth, complicated manufacturing and procurement procedures, disorganized supply chains, timetable constraints, and financial hardship, adopting DT in FM may take more than a decade (Ozturk, 2021). The primary obstacles facing the sector include digital transformation, technological infrastructure, interoperability, systems integration, security, stakeholder concerns, legal issues, a lack of experts, and many others. The restrictions listed above are comparable to the barriers to BIM adoption in the AEC sector. In other words, addressing the barriers to adopting BIM will facilitate DT adoption in the industry (Ozturk, 2021).

**Digital Twin applications in Malaysia**

BIM adoption in Malaysia has grown with 49% industry players has started using it but still below government’s goals which target 70% adoption rate for public and private projects by 2021 (Omar & Mohd Fateh, 2023). The government of Malaysia in 2014 announced the new toll-free Pan Borneo Highway that stretches 1,060 kilometers. Once completed, the highway shall be the backbone of Borneo transportation that plays a major role in opening economic corridors in the region (Bentley, 2020). The project delivery partner, Lebuhraya Borneo Utara (LBU) initiated the first Malaysia BIM workflows for road and highway project. LBU

leverage Bentley's ProjectWise to create an open, connected data environment to support the implementation and integration of BIM, GIS, and reality modelling processes. In addition, LBU also leveraging Bentley's ContextCapture by image captured using unmanned aerial vehicles (UAV) to accurately record the entire 1,060 kilometers asset information (Bentley, 2020). Another infrastructure project, Mass Rapid Transit Corporation (MRT Corp) having identified several challenges in construction management and handover of digital as-built information to operations of its first Sungai Buloh-Kajang line, MRT Corp decided to advance its BIM workflows by adopting digital twins using Bentley solutions such AssetWise and iModels for their Sungai Buloh-Serdang-Putrajaya Line (IES, 2020). By using Bentley's AssetWise, MRT Corp manage its data through a custom classification system specifically the KVMRT Classification System to capture all the relevant information related to assets and equipment, in which used by the operations and maintenance teams throughout the railway operational life. Regarding iModels, MRT Corp able to visualise and locate an asset in the 3D model and to gain better understanding of the connected or related assets and equipment (IES, 2020). In conclusion, digital twin has been applied in Malaysia predominantly in mega Infrastructure projects such as the Pan Borneo Highway and Mass Rapid Transit.

## RESEARCH METHODOLOGY

The data collection for this study involves acquiring qualitative data from individual interviews with FM personnel with experience in dealing with DT and FM. The interview questions were designed through literature reviews to address and identify the study aims. The questions have gone several testings to ensure the questions are relevant and easy to understand. In addition, one pilot interview session was conducted to test the interview questions and estimate the interview durations. The qualitative data were then analysed using the thematic analysis method. Data collected for the study presented here is used to profoundly investigate the drivers, capabilities, and challenges of adopting DT in FM. The subsequent subsections describe this study's data collection and analysis approaches.

### Data Collection

The interview sessions were conducted with FM professionals with experience in dealing with DT in FM. The main reason for conducting the interview is to understand the actual practice in the industry. Also, the target population can provide the relevant information as needed. Open-ended questions were provided to the participants as it enabled the researcher to follow up by asking pointed questions and also enabling the participants to provide as much in-depth information (Turner, 2010). Three main interview questions were asked: 1) What


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are the drivers for your organization to use DT for FM? 2) What are the capabilities needed for your organization to use DT for FM? and 3) What are the challenges that your organization faces to use DT for FM?. Question 1 aims to obtain what motivates FM organizations to adopt DT in their organization. Question 2 of the interview aims to obtain the ability needed for FM organizations to adopt DT. Question 3 of the interview instead aims to obtain the challenges that hinder FM organizations from adopting DT. The open-ended questions were used to encourage as much detailed information as desired. The data collection involves eighteen interviewees. Respondents from different FM companies are required to acquire different perspectives on the subject matter. After each interview session, a summary of responses was made and sent to participants for validation. The interview process was conducted from the fourth quarter of 2022 until the first quarter of 2023. The sampling method use in this study is purposive sampling where interviewees were found via the professional networking platform LinkedIn. Job titles, industries, and relevant phrases were utilised as search filters to locate individuals who possessed the desired attributes and experience required to give significant insights to the research objectives. Purposive sampling were used to select appropriate participants that are more likely to give useful information and different people have different views and ideas. (Campbell et al., 2020). Once possible respondents have been identified, personalised connection requests and messages explaining the objective of the study and requesting them to participate will be issued. This method not only allows for the recruitment of a tailored and relevant sample, but it also takes advantage of the convenience and accessibility of online networking platforms to quickly engage potential participants. Furthermore, the researcher obtained new respondents through contacts and networking with previously interviewed respondents. Lastly, data saturations of the interviews were achieved when there is no new significant insight and ideas gathered. Table 1 below shows the respondent profile of the interviewees. Most respondents are FM executives, DT-FM executives, and FM Managers.

**Data Analysis**

Thematic analysis is used in the data analysis to extract patterns from the interview data, as this method can help interpret qualitative data (Braun & Clarke, 2006). The thematic analysis was conducted based on the six phases described in Braun and Clarke (2006): (1) data familiarization; (2) initial coding; (3) themes coding; (4) themes review; (5) defining themes; and (6) output report. The first phase of the data analysis is to familiarize authors with the data obtained. The authors reviewed, reread, and took notes on the initial ideas after transcribing the interview data. The second phase is generating initial codes. The authors coded the data for potential themes and patterns as many as possible. The authors then

reviewed, discussed, and agreed on any additional changes to the coding. The third phase of the data analysis is to search for themes based on the initial codes. The authors regularly examined the codes from the second phase and the original data from the first phase when developing the themes. The fourth phase is to go over the themes. To achieve data saturation, the authors evaluated the subthemes regularly, defined and polished them, tested if the themes worked with the coded extracts and the complete data set, and reviewed data to look for additional themes. The fifth phase is to define the themes. The authors continually went back and forth between the themes, codes, and interview transcription to ensure that the themes were true to the independently coded responses. The final phase, the sixth phase, is to report the output of the analysis.

**Table 1.** Respondent profile

| Respondent | Position | Background | Years of Experience |
|---|---|---|---|
| **R1** | FM Project Manager | Contractor | 3 years |
| **R2** | Chief Executive Officer | Consultant | 20 years |
| **R3** | Operational Executive | Contractor | 13 years |
| **R4** | Technical Manager | Contractor | 20 years |
| **R5** | FM Manager | Building owner | 13 years |
| **R6** | FM Manager | Consultant | 11 years |
| **R7** | Architect | Consultant | 2 years |
| **R8** | Managing Director | Consultant | 23 years |
| **R9** | Consultant Engineer | Consultant | 4 years |
| **R10** | Verifier | Contractor | 11 years |
| **R11** | FM Manager | Building owner | 9 years |
| **R12** | Assistant Manager | Building owner | 13 years |
| **R13** | BIM FM Executive | Contractor | 5 years |
| **R14** | Assistant Verifier | Contractor | 10 years |
| **R15** | FM Manager | Contractor | 14 years |
| **R16** | BIM FM Executive | Contractor | 11 years |
| **R17** | BIM FM Executive | Contractor | 4 years |
| **R18** | Manager | Building owner | 8 years |

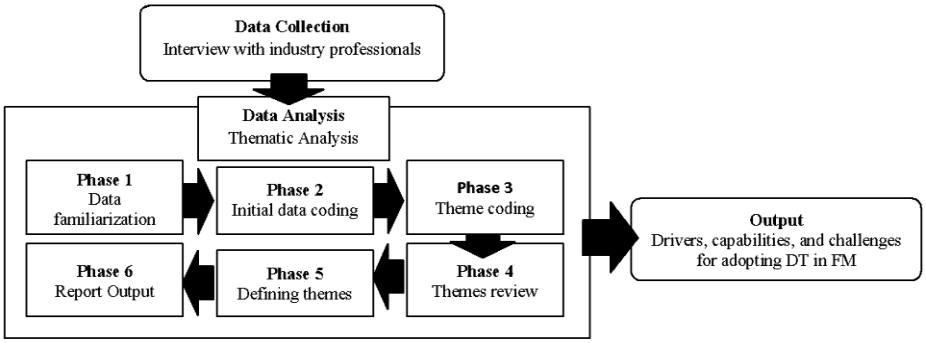


**Figure 1.** Overview of the research methodology (A R Radzi et al., 2020)


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## RESULTS AND DISCUSSION

Figure 2 shows the themes of the drivers, capabilities, and challenges for adopting DT in FM. This study has discovered twelve themes with thirty-six subthemes in total (subthemes are shown in subsequent figures). Five themes were identified under drivers: streamlining operational efficiency, legislation, technology, stakeholder value, and organization efficiency. In addition, four themes were identified for capabilities which are manpower, infrastructure, knowledge, and budget. Lastly, three themes that were identified under the challenges are cost, technology, and people. The details of each element are discussed in the subsequent subsections.

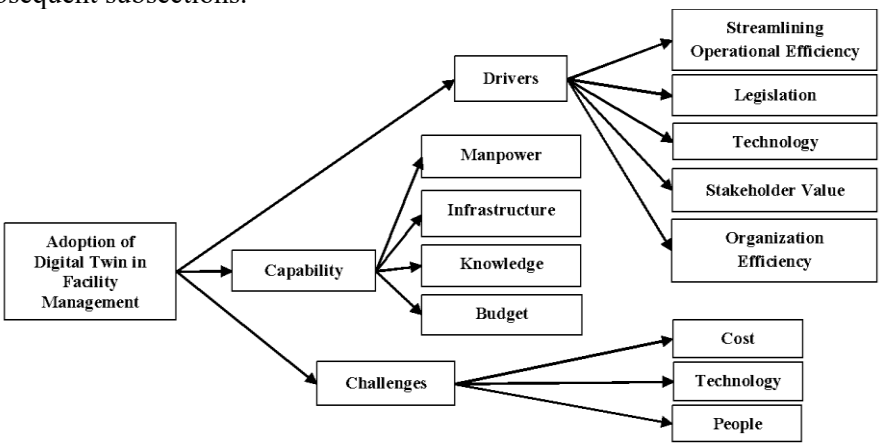


**Figure 2.** Overview of drives, capabilities, and challenges for adopting DT in FM

### Drivers for Adopting Digital Twin in Facility Management

Figure 3 summarizes the themes and subthemes for the drivers for adopting DT in FM. Twelve subthemes were identified, then grouped into five themes: streamlining operational efficiency, legislation, technology, stakeholder value, and organization efficiency. The details of themes and subthemes are discussed in the subsequent subsections.

#### *Streamlining operational efficiency*

According to the interview results, one of the themes that drive an organization to adopt DT is the streamlining of operational efficiency. Streamlining operational efficiency is a paramount goal for organizations, enhancing productivity and maximizing resources. Two subthemes, ease of maintenance procedures and ease of processes, stand out as essential contributors to this overarching topic. DT can aid FM organizations in minimizing downtime and disruptions by using proactive maintenance techniques, such as routine inspections and preventative actions. The ease of procedures subtheme also

strongly emphasizes streamlining and automating workflows, getting rid of pointless steps, and minimizing manual errors. By adopting DT, FM organizations can be more organized and reduce mistakes.

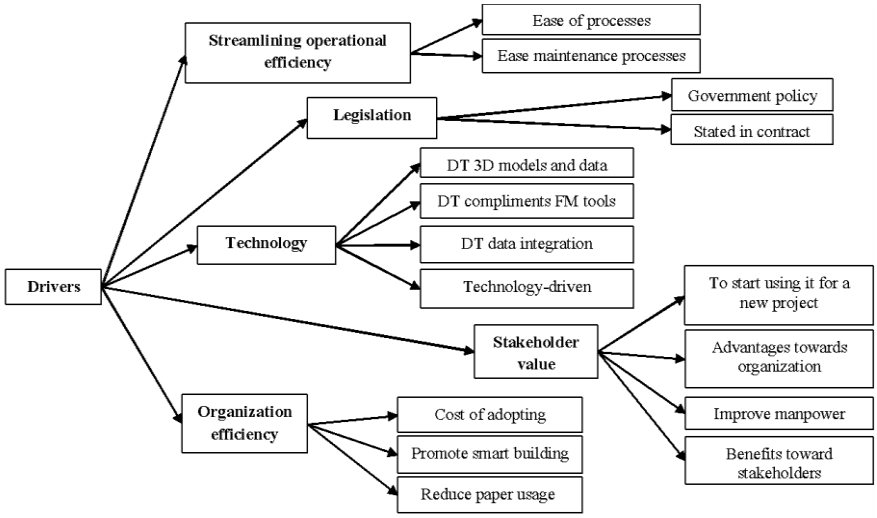


**Figure 3.** Overview of drivers for adopting DT in FM

### *Legislation*

When examining the theme of legislation, two significant subthemes emerge: "stated in the contract" and "government policy." The subtheme of "stated in the contract" emphasizes the importance of legislative provisions explicitly outlined within contractual agreements. From the interviews, DT was used as the building owner mandated it and stated in the contract to use DT. In addition, it is one of the government policies for public projects that cost more than MYR100 million to use DT. Government policies influenced by legislation also aim to address emerging challenges, adapt to changing societal needs, and promote the overall well-being of the nation.

### *Technology*

When it comes to FM, technology encompasses many subthemes that are rapidly altering the industry. The integration of DT, which enhances existing FM tools and software, is crucial. DT can improve FM processes by utilizing the capabilities of digital models and data, resulting in more effective operations and maintenance. The management of the built environment, accurate data, and visual representation of physical structure are all made possible by using DT-FM 3D model data. Additionally, DT in FM offers seamless data integration, facilitating information transmission across different systems and stakeholders, leading to


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increased cooperation and decision-making. Lastly, the overall evolution of technology within FM is driven by the constant advancements in software, sensors, and automation, making facilities more intelligent and responsive to the changing needs of occupants and owners. Integrating these technological innovations in FM ensures improved efficiency, sustainability, and performance of buildings and infrastructure in the digital age.

***Stakeholder value***

DTs are transformative technologies that can potentially enhance stakeholder value in different aspects of the construction industry. One of the subthemes is the usage of DT for new projects. By adopting DT at the early stages of project development, stakeholders can benefit from improved visualization, coordination, and communication. It is much easier to adopt DT at an early stage rather than applying it to existing buildings. Another subtheme is the advantages of DT for FM organizations. Using DT allows an opportunity and empowers an organization. Furthermore, DT has the potential to improve manpower usage in the construction industry significantly. These technologies enable stakeholders to streamline workflows, automate repetitive tasks, and enhance productivity. For instance, DT further enhances efficiency by enabling remote monitoring, maintenance, and troubleshooting of assets, reducing the need for physical interventions and on-site manpower. Overall, the adoption of DT provides several benefits to FM sector players. These technologies allow for better project outputs, more effective FM, more efficient workforce usage, and, ultimately, more stakeholder value.

***Organization efficiency***

DT is critical in improving organizational efficiency in the FM industry. Although the early costs of adopting DT can be substantial, the long-term advantages surpass the initial costs. DT promotes smart building practices by merging virtual models with real-time data, resulting in a longer life cycle for buildings. Furthermore, the use of DT saves paper consumption dramatically because these technologies enable the digitization of architectural drawings, project documentation, and collaboration processes. This not only speeds up operations but also adds to more sustainable practices by reducing paper waste and fostering a greener atmosphere.

***Summary***

To summarize the findings for drivers for adopting DT in FM, the theme streamlining operational efficiency shows that DT helps drive FM organizations in minimizing downtime and errors through proactive maintenance and automation. Next, legislation also drives FM organizations to fulfil contractual

obligations and comply with government policies that promote efficient building management through DT. In addition, the theme technology allows DT to integrate with FM tools and software by providing 3D modelling, seamless data, and to improve decision-making. Other than that, the theme stakeholder value shows that stakeholder can benefit from DT by improved the communication and workforce efficiency. Lastly, the theme organization efficiency can drive organization to promotes smart building practices, extends building lifespans, and reduces paper consumption for a more sustainable operation through DT. A similar study was done by Ghansah (2024) through his systematic literature reviews shows similar results where the application of DT in FM allows efficient operation and service monitoring of a building.

**Capabilities Needed for Adopting Digital Twin in Facility Management**

Figure 4 shows the themes and subthemes for the capabilities for adopting DT in FM. Ten subthemes were identified, which were then grouped into four themes which are manpower, infrastructure, knowledge, and budget. The details of themes and subthemes are discussed in the subsequent subsections.

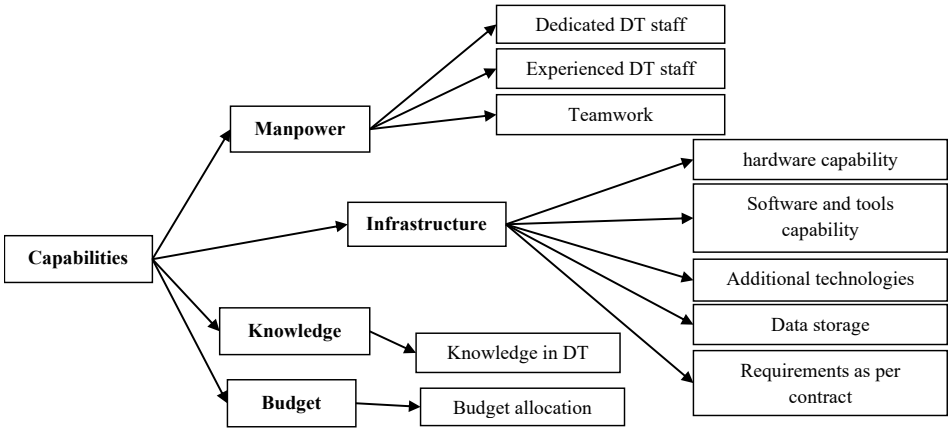


**Figure 4.** Overview of the capabilities for adopting DT in FM

***Manpower***

One of the capabilities needed for adopting DT is manpower capability. One critical component is the allocation of dedicated DT personnel. These specialized professionals may be able to handle and operate DT models and data entry successfully. Furthermore, competent individuals proficient in using DT tools are critical in realizing the full potential of these technologies. They must be well-versed, capable of reading 2D and 3D drawings, and multidisciplinary. Furthermore, cooperation is critical in maximizing the capabilities of DT. The potential of these technologies can be fully realized by developing a collaborative


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environment in which multiple stakeholders collaborate, exchanging insights and expertise.

***Infrastructure***

Another critical quality for adopting DT is the infrastructure capability. To begin with, hardware capabilities are critical in enabling the application of DT. To render sophisticated 3D models, cutting-edge gear and computers are required. Furthermore, software and tool capabilities are required for successful DT adoption. For smooth data integration, DT platforms provide intuitive interfaces and a stable internet connection. Furthermore, the incorporation of modern sensors, IoT devices, and artificial intelligence (AI) improves the usage of DT. In terms of data storage, cloud-based storage ensures that DT data are ready to use, and that the data can be handled.

***Knowledge***

Knowledge of DT is one of the capabilities needed for FM organizations to use these technologies. Such knowledge in DT is understanding standard technical terms and the basic knowledge to handle DT. FM personnel need to be experts in using 3D software and upskill and reskill themselves.

***Budget***

Finally, FM organizations with financial resources can take advantage of DT advantages by setting aside adequate funds for their adoption and understanding the long-term benefits of these technologies. Additionally, FM organizations can ensure that enough resources, including hardware, software, and qualified employees, are devoted to its deployment. Furthermore, a special allocation for experts and consultants with expertise in DT for engaging skilled professionals to ensure the successful integration of these technologies. Organizations can use the capabilities of DT to optimize financial resources, generate cost reductions, and maximize overall value by carefully allocating funds and taking the ROI into account.

***Summary***

To conclude, four capabilities for adopting DT in FM were identified. The theme manpower shows that dedicated personnel, skilled users, and collaborative environment are needed for a FM organization. The theme infrastructure shows that FM organizations need the capabilities to have relevant hardware, software, sensors, and cloud storage. In addition, FM organizations must have the knowledge to understanding DT, 3D software expertise, and continuous learning. Lastly, FM organizations must be capable of having budget for DT such as the financial resources for DT adoption, manpower, and consultants, with a focus on

ROI. According to Ghansah (2024) in his study, knowledge building constitutes the ability to gain new knowledge by using DT and, upskilling and reskilling current manpower can generate better understanding of DT.

**Challenges for Adopting Digital Twin in Facility Management**

Figure 5 shows the themes and subthemes for the challenges of adopting DT in FM. Eleven subthemes were identified, which were then grouped into three themes cost, technology, and people. The details of themes and subthemes are discussed in the subsequent subsections.

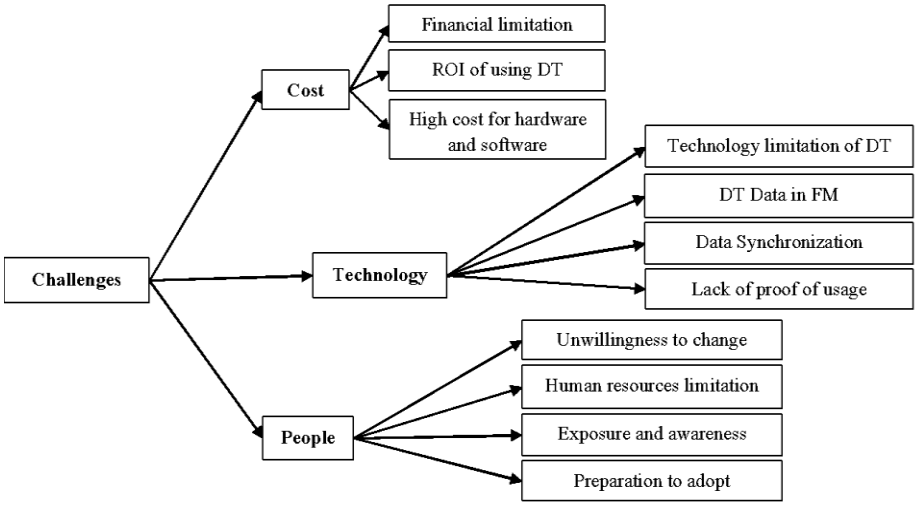


**Figure 5.** Overview of the challenges for adopting DT in FM

***Cost***

According to the interview findings, some significant challenges prevent DT adoption in FM. Financial constraints hamper widespread adoption, the requirement to demonstrate an ROI for DT, and the high costs of software and hardware acquisition. Lack of funding may prevent businesses, especially small and medium-sized ones (SMEs), from adopting DT.

***Technology***

Technology is also one of the challenges to adopting DT in FM that needs to be addressed. Firstly, technology limitations pose a significant hurdle. This can be due to a lack of proper infrastructure, such as hardware and software, to run DT. Secondly, ensuring effective integration between DT data for FM purposes can be challenging. The synchronization of data of DT also takes time and requires careful attention to prevent data clashing. Thirdly, the lack of proven usage and


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practical adoption examples of DT can impede adoption. Organizations may hesitate to invest in DT without concrete evidence of its benefits, hindering widespread adoption.

***People***

The findings also show that people or human factor is one of the themes for the challenges in adopting DT in FM. Unwillingness to change and resistance to adopting new technologies can hinder the widespread adoption of DT. Individuals such as top management within organizations may be hesitant to embrace these transformative technologies. Additionally, there may be a limitation in the availability of skilled human resources with the necessary expertise to adopt DT systems effectively. Upskilling existing employees or recruiting new talent can help address this challenge. Furthermore, the exposure and awareness of DT benefits and capabilities among key stakeholders may be limited. This can be due to the wrong perception of using DT from the FM industry perspective. Lastly, adequate preparation is crucial for successful adoption. Organizations need to assess their readiness to adopt DT, which takes time to adopt new trends, evaluate existing workflows, and prepare adequate infrastructure.

***Summary***

In conclusion, five themes were identified for challenges faced by FM organizations for adopting DT. The first challenge was cost where it involved financial constraints, difficulty demonstrating ROI, and high software and hardware costs. Next, technology limitations such as infrastructure, data integration challenges, and the lack of proven use cases. The last challenge faced by FM organizations are people management where there is resistance to change, limited skilled workforce, low awareness on DT, and inadequate preparation. These findings are in line with Ghansah (2024) where challenges associated with DT in FM is the social and technical issues. Ghansah (2024) added that social issues such as high cost of involving technologies and technical issues being that lack of a systematic and comprehensive reference model.

## STUDY IMPLICATION

This study contributes to understanding the drivers, capabilities, and challenges of adopting DT in FM organizations. From the findings, future research can develop frameworks and strategies to increase the awareness and adoption of DT in FM. Other than that, future research should seek a larger sample size that can represent the local industry to acquire more generalizable findings. In addition, the study findings could help policymakers and FM organizations to work together and develop suitable plans and blueprints for adopting DT. The drivers

of adopting DT in FM organizations can be a pathway that helps other players in the architecture, engineering, construction, and operation (AECO) industry to adopt DT in their organizations. Furthermore, the capabilities for DT adoption can help AECO industry players to measure themselves in preparedness to adopt DT. In the context of managerial level implication, the study findings could help FM managers on increasing awareness among their teams about the benefits and potential of using DT in FM. This could involve organizing training sessions or workshops to educate FM personnels about the benefits of adopting DT. Besides, FM managers can establish awareness campaigns within their organisations to convey the benefits and possibilities of DT adoption. This could include providing case studies, success stories, and tangible instances of how DT has positively impacted other FM organisations. On top of that, collaboration among other players in AECO industry to share insights and experiences related to DT adoption can be good collaborative approach by FM managers. Along with that FM managers as well as FM organizations should work actively with policymakers to build plans and blueprints that support DT adoption. Policymakers and FM experts can collaborate to establish a favourable environment for DT adoption through supportive rules, incentives, and resource allocation. Lastly, the challenges of adopting DT can prepare FM organizations and other industry practitioners to be aware of the potential challenges. Accordingly, the findings will enhance the awareness of DT and its benefits of adopting it, such as enabling AECO organizations to assess and monitor infrastructure performance in real-time and operate efficiently. In conclusion, this study provides researchers and industry practitioners with a set of variables that influence the adoption of DT in FM.

## LIMITATION

The limitations of the findings are as follows. Firstly, this study investigated the drivers, capabilities, and challenges of adopting DT from FM organization perspective. Secondly, the interview sessions were conducted via online virtual platform. Thirdly, this study focused on respondents from a single country, specifically from FM organisations background. Lastly, full usage of DT in FM is still lacking globally. Despite these limitations, the study objectives are still achieved successfully. Therefore, the study findings could be adopted and modified to be use by other nations. Future research can also further access the variables via quantitative approaches.

## CONCLUSION

In conclusion, this study sheds light on the growing interest in DT and FM. By exploring the relationship between DT and FM, this study highlights the potential benefits for the FM industry. Therefore, this study aimed to profoundly


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investigate the drivers, capabilities, and challenges of adopting DT in FM. The study involved conducting interviews with 18 industry professionals. The findings indicate that the drivers for adopting DT in FM encompass several crucial factors, including streamlining operational efficiency, compliance with legislation, leveraging technological advancements, enhancing stakeholder value, and improving organizational efficiency. In contrast, the capabilities needed to adopt DT in FM revolve around having adequate manpower, appropriate infrastructure, knowledge of DT, and sufficient budgetary resources. Additionally, the study identified the challenges faced when adopting DT in FM, which include the cost of adopting DT, technological constraints, and the human factor. These challenges must be carefully addressed and overcome to ensure the successful integration of DT in FM practices. Therefore, the aims of this study to investigate the drives, capabilities, and challenges for adopting DT in FM have been achieved. Overall, this study adds to the current FM body of knowledge by offering unique insights into the drivers, capabilities, and challenges connected with DT adoption. The study findings can be a significant resource for FM practitioners looking to leverage DT. By efficiently integrating DT, the FM industry may capitalize on its benefits and alter its operations more efficiently and sustainably.

## ACKNOWLEDGEMENT

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**PLANNING MALAYSIA**
Journal of the Malaysian Institute of Planners
B-01-02, Jalan SS7/13B, Aman Seri, Kelana Jaya,
47301, Petaling Jaya, Selangor Darul Ehsan, MALAYSIA
Tel: +603 78770637 Fax: +603 78779636
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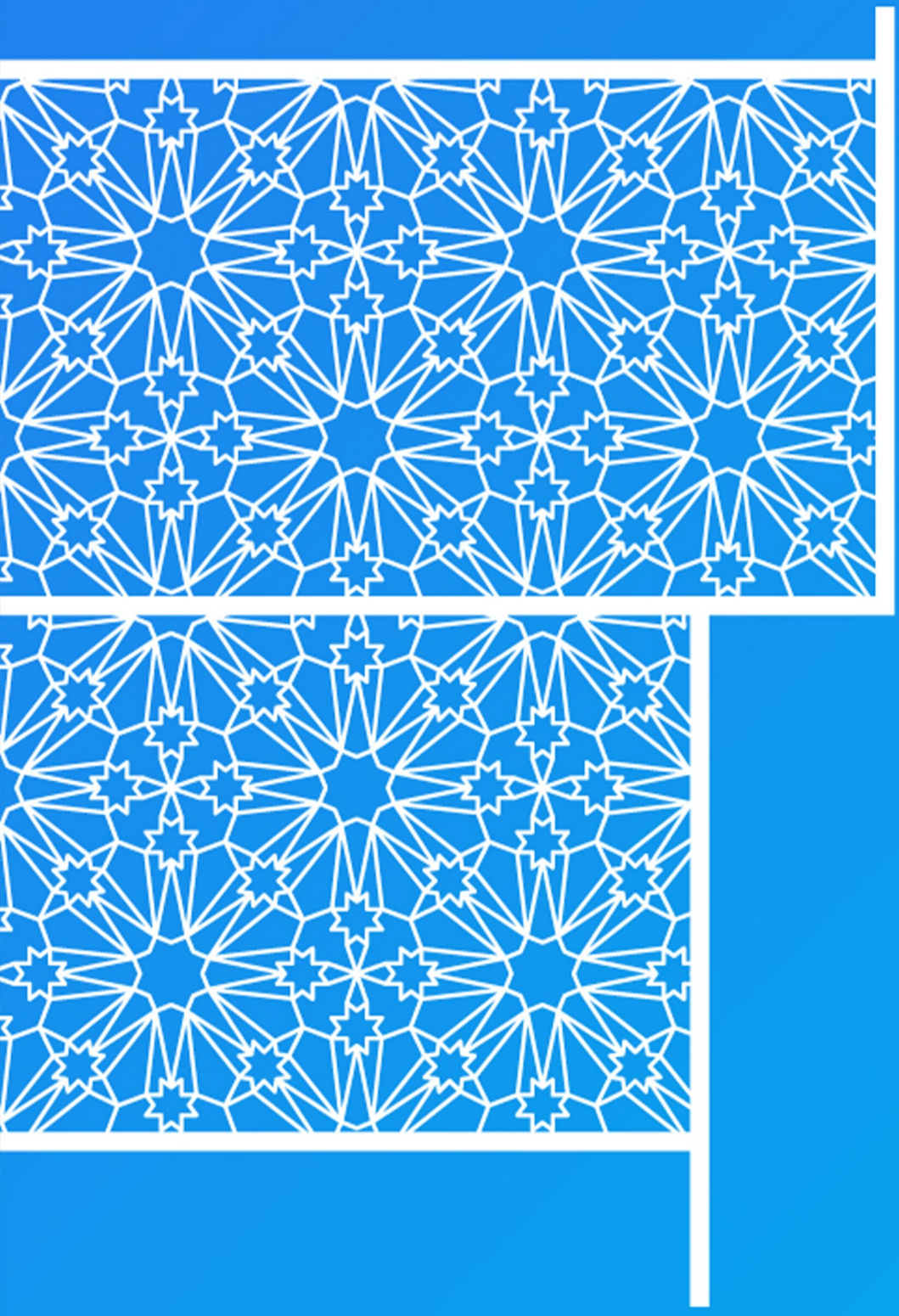

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47301, Petaling Jaya, Selangor Darul Ehsan, MALAYSIA
Tel: +603 78770637 Fax: +603 78779636
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