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AUSPICIOUS GREEN RETROFIT STRATEGIES IN TWO-STORY TERRACE HOUSES: CASE STUDY OF PETALING JAYA SELANGOR MALAYSIA

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Abstract

The surge of terrace house retrofitting practices has evoked sustainability concerns among the construction players. With the popularised means of upgrading the house condition, green retrofit becomes critical to achieving sustainable retrofitting among the existing residential building. Hence, this study aims to evaluate the potential application of green retrofit strategies in a two-story terrace house. The investigations were made concerning the Petaling Jaya District housing development. This thorough investigation involved analysing the retrofitting behaviour of over 2,946 cases leading to the key building components for applying the green retrofit approach. The outcome of the analysis shows that despite the common practice of retrofitting, the result mostly does not depict the implementation of a green approach in which the majority of upgraded works only reached the second degree – only 30% of improvements involved. The high rate of upgrading actions initiated depicts an immense potential for green retrofit strategies to be administered among the existing residential building stock, taking the measures towards more enforceable roles in pushing the country's low carbon movements forward.

Keywords: Green Retrofit, Terrace House, Existing Building Retrofit, Sustainable Building Development

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INTRODUCTION

As one of the countries with a high urbanisation rate, Malaysia developed a considerable amount of existing building stock. The growth of new construction only accounts for a limited percentage of development due to the dense urban landscape of cities. To begin with, most existing building stock was not built as energy-efficient buildings and calls upon the venture of green retrofit to achieve sustainable development (Jagarajan et al., 2017). The widespread adoption of green development for the past few decades has encouraged sustainable building practices among existing building stock. Besides, according to Masrom et al., (2017), building improvement of the 1960s and 1970s stock has become increasingly significant following their declining performance.

Retrofitting strategy is the current prospect to attain green in existing buildings as it has emanated as one of the key strategies for energy usage and carbon emission reduction. Despite that, the uptake among existing residential buildings remains limited and requires inclusive guidelines for successful implementation (Ramli et al. 2022). As the most popular housing typology, terrace house transformation is not a new norm in the Malaysian construction industry as the approach unlocks the potential for sustainable retrofitting while encouraging the revolutionization of green practices in existing residential buildings. Additionally, studies on Malaysian terrace houses drew more attention today regarding design and thermal comfort. Several studies (Abdul Rashid et al., 2016; Leng et al., 2021) have argued and asserted that the existing terrace houses in Malaysia did not sufficiently build to optimize thermal performance and are suited to the tropical climate context. It has further incited common modifications among this typology.

Hence, the objectives of this paper are (i) to analyse the retrofitting behaviour among the existing two-story terrace houses in Petaling Jaya, and (ii) to investigate the application of green retrofit strategies among the cases. In conclusion, this paper deliberates the application of green retrofit strategies in the upgraded works of two-storey terrace houses to achieve sustainability among existing residential buildings.

LITERATURE REVIEW

Retrofitting in Malaysian Terrace Houses

With about 6.02 million existing residential stock in Malaysia (Valuation and Property Services Department and Ministry of Finance Malaysia, 2022), terrace house is the most popular typology and homeowners are most likely to opt for retrofitting to improve the original condition of their houses. The residential building plays a critical role in promoting sustainability at the community level, considering the commitment can be entirely according to the homeowners' decision-making. Previous studies on Malaysian terrace houses covered a range of topics encompassing behavioural adaptation (Rahim & Hashim, 2012), changes and modifications of the design (Omar et al., 2017), and thermal comfort and performance (Leng et al., 2021; Othman et al., 2021; Tuck et al., 2020).

Green Retrofit Strategies to Achieve Sustainable Building Development

Retrofitting existing buildings presents a great platform for reducing energy consumption towards nearly zero energy levels (Ohene et al., 2022) and is regarded as one of the key strategies for bringing off sustainability to the built environment at a relatively low-cost (Ma et al., 2012). In addition to that, further suggestions for feasible application of green retrofit strategies in terrace house retrofitting are described in Table 1. The below-highlighted strategies are among the most common green improvements that have potential utilization in terrace house retrofitting.

Table 1: Potential retrofit strategies for thermal performance

Elements	Retrofit strategies for thermal performance	References
Internal Wall	Apply phase change materials (PCMs) layer below the internal finishing of the wall	Al-Absi et al. (2021)
External Wall	Repaint with lighter-coloured paints Use of insulation on the vertical wall Use aerated lightweight concrete wall Add effective shading devices like awnings Use light shelves or exterior shelves	Hong et al. (2019) Shukri et al. (2020) Hong et al. (2019) Nadiar & Nusantara (2021) Hong et al. (2019)
Window / Door	Replace double or triple-glazing windows Use low-E glass for insulated window Install reflective tint on the window	Rabani et al. (2017) Hong et al. (2019) Y. Hong et al. (2019)
HVAC	Use new and highly efficient air-conditioners Use heat pumps and evaporative coolers Ensure adequate ventilation measures	Leung (2018) Y. Hong et al. (2019)
Electrical system	Replace lighting with LED fixtures Replace low energy saving lamps T5 fluorescent Use energy-saving motion sensors	Leung (2018) Haq et al. (2013) Leung (2018)
Water & Appliances	Replace water fittings with highly efficient ones Replace energy-efficient water heating system	Leung (2018)
Roof / Skylight	Use high-density polyethene nets as roof covers Use polyurethane insulation on the roof Install rooftop solar PV Install green roof	Tuck et al. (2020) Shukri et al. (2020) Florez & Ghazali (2020) Azis et al. (2021)

Ayodele et al., (2020) assert the key indicators for an effective retrofit strategy include minimization of energy consumption while conserving thermal comfort, upgrading architectural quality, acquiring a controlled impact of carbon emission, and making the expected cost of a retrofit intervention significant. The study further suggests that the building envelope is a critical factor influencing the amount of energy usage in a building. Several elements are forming the building envelope, like walls and thermal mass, roof, and windows. Table 2 presents building elements that contribute to reducing energy consumption in buildings and achieving the optimum thermal performance of terrace houses.

Table 2: Summary of building envelope elements of cases in Malaysian terrace houses.

Elements	Authors	Studies
Wall and Thermal Mass	Othman et al. (2021)	The influence of a higher window-to-wall ratio (WWR) in the living room of a terrace house will result in the lowest thermal comfort level
Roof	Tuck et al. (2020)	Roof cover maintained a consistent surface temperature at roof tiles and reduced the convective heat flux by approximately 70-80% in the attic and 88% in the room. Encourage use of active cooling with a ceiling fan is required to achieve a comfortable indoor temperature
Window	Othman et al. (2021) Leng et al. (2021)	Window placements and shading devices help in reducing sun exposure to the frontage of a building The current Uniform Building By-Law 1984 on a minimum of 10% openings of the total floor area because it does not effectively provide good thermal performance.

Hence, implementing green retrofit strategies during retrofitting works by highlighting the above building elements seems like a critical resort to achieve energy efficiency in residential buildings. This way, the green mandate for the building typology can be secured for sustainable building development. The above summary of studies on Malaysian terrace houses has further signified the urgency of devising a comprehensive green retrofit framework for residential buildings.

RESEARCH METHODOLOGY

This study employs qualitative case study research and observational data from multiple cases of two-storey terrace houses in Petaling Jaya (PJ). The data gathered during the field observation covered four (4) neighbourhoods in PJ, in which the case selection is designated from previous studies on PJ (Ju et al., 2011). Figure 1 below shows the selection of cases based on data collected among intermediate two-storey terrace houses in the city focusing on Section 17, Damansara Jaya (SS22), Kelana Jaya (SS5) and Kota Damansara (Section 6 PJU5). The selection of PJ is based on the previous extensive research suggested study by Ramli et al. (2022) to promote sustainability among residential buildings. The rise of new residential buildings in the city is becoming restricted due to limited land available which further encourages modifications (Ramli & Yunus, 2022). Derived from the objectives formulated, the observational process among 2,946 samples built throughout the 1960s to 1990s in the city was studied and observed.

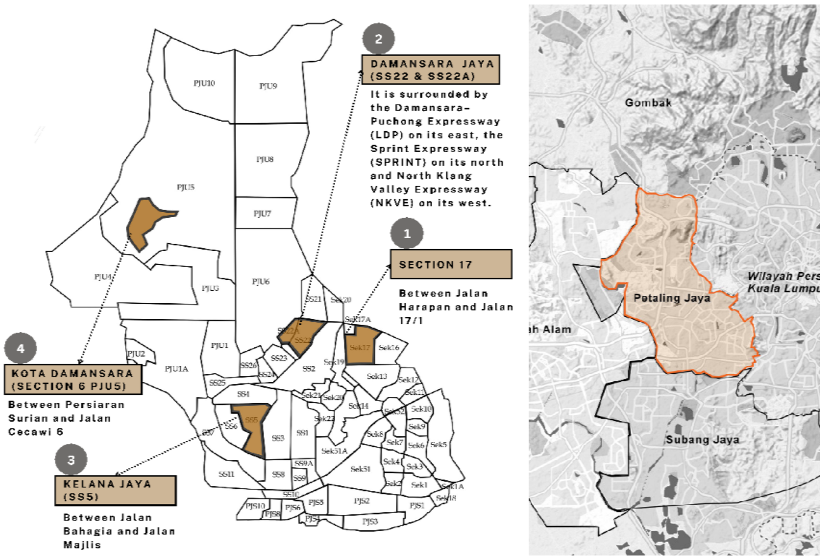
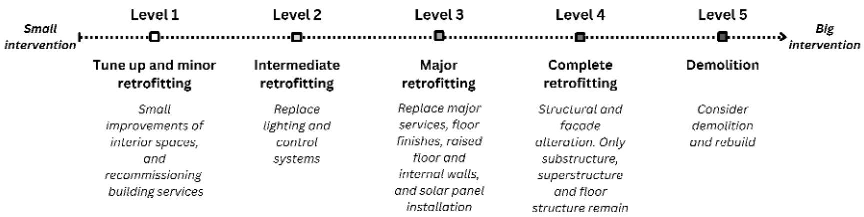


Figure 1: The selection of cases in four different districts of Petaling Jaya

This study utilises a conventional content analysis method in which codes are derived from data. The first part of the data range is a referral from Building and Construction Authority, (2010) should reflect the extent of upgraded works done among the cases as well as actions entailed during each of the designated works (Figure 2). The result will review the state of retrofitting behavioural data and further analyse whether green initiatives were adopted by the residents as well as whether each upgraded work is enough to reflect the drive towards sustainability.

Figure 2: Retrofit level in buildings



Source: Building and Construction Authority, (2010)

Then, the analysis part confers the retrofitting behavioural data with frequency provided within the relevant data. The analysis discloses the conduct of retrofit level among the housing typology and key building components for each level of retrofits to determine the best suitable green retrofit strategies. The cause also presents the retrofitting rate among the cases of two-storey terrace houses in PJ. Consequently, the outcome of this analysis is expected to facilitate the study during the next stage of research in devising the green strategies for each building component that ensued from this remark. Table 3 summarizes key findings of the data collected from PJ observational studies on socio-demographics, housing characteristics, retrofit behavioural and strategies for retrofitting works.

Table 3: Summary of main findings from observational studies.

Observational studies on	Main findings
Socio-demographic characteristics of the case	The characteristics of the cases such as development year, age, population, location and the total number of houses associated with the area
Housing characteristics	Type of the housing (intermediate two-storey terrace house), spatial arrangement of the spaces, building frontage facade of the housing unit as well as materials used
Behavioural characteristics of the retrofitting	The extent of retrofitting done to the cases from Level 1 to Level 5 that covers minor retrofit to complete demolition as well as the houses that remain in the original condition
Strategies of retrofitting	Residents conduct retrofitting differently according to their needs. The majority of retrofitting works were done without considering initiatives toward green

ANALYSIS AND DISCUSSION

From the case study of two-storey terrace houses in the PJ area, the extent of retrofitting works carried out in the area along with the additional information on the cases is included in Table 4. The cases of Section 17, Damansara Jaya, Kelana Jaya (SS5), and Kota Damansara (Section 6 PJU5) are defined as Cases 1, 2, 3, and 4 respectively. The scope of the study is limited to intermediate two-storey terrace houses due to the high numbers of the typology and restricted options for modification. From the cases, it is concluded that the majority of residents have conducted level 1 and 2 retrofitting works in which about 1,132 units had done cosmetic repairs on the building façade. Following that, about 823 units with a major retrofit, and, 535 units conducted complete retrofit. It is a positive note that no cases of demolition were spotted during the observation, as demolition and disposal of the whole original structure to build a total replacement will result in an increased carbon footprint (Building Research Establishment (BRE), 2016).

Table 4: Number of interventions acted among the cases.

Area	Case 1	Case 2	Case 3	Case 4	Total
Year	1965	1975	1984	1992	Between 31 - 58 years old
Household	3072	1932	2536	2683	Total household of 10,223
Total Houses	712	1260	400	574	Selected 2946 units
Original Design	136	141	86	93	456 units remain intact
Levels 1 & 2	301	488	103	240	1,132

Area	Case 1	Case 2	Case 3	Case 4	Total
Level 3	193	421	93	116	823
Level 4	82	210	118	125	535
Level 5	-	-	-	-	No cases observed

Source: Ju et al. (2011) *and Author's Observation*

For the first part of the retrofitting level, it is observed that many of the cases indicate improvements in building services that are – the additional air-conditioning. The upgrade automatically differs the extent of retrofitting between minor (Level 1) and intermediate (Level 2) in which the latter highlights the usage of HVAC among the cases. Major modification project (Level 3) involves works of both minor and intermediate with the replacement of major building services, plus the possible addition of solar panel components. Meanwhile, complete retrofitting manifests major structural changes in the substructure, superstructure, and floor that completely alter the façade of the building.

Apart from that, it is noted that out of 2,946 units surveyed, about 456 units have remained with the original façade of the building without any upgrade works implying that despite the ageing condition of the building, several houses remain unchanged without any improvements. By looking at the trend, and the increasing land price in the cities, the decision for improvements eventually will be made by the homeowners sooner or later.

On top of that, the study also identified several distinct retrofitting behaviours involved in all intervention levels. With a reference to the existing guideline of retrofitting level, this paper came up with a detailed action of several typical modification works of the cases during retrofitting. Table 5 below describes the designated behaviour among the cases of two-storey terrace houses with each of the building components involved in the process identified. In the end, overall remarks on the retrofitting behaviour for each of the cases are incorporated.

Table 5: Analysis of retrofitting behaviours conducted among PJ cases

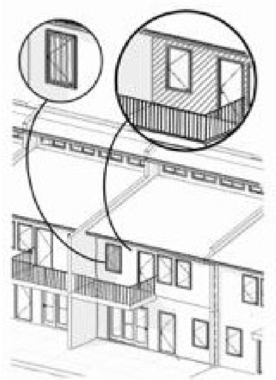
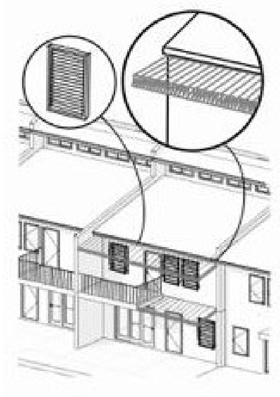
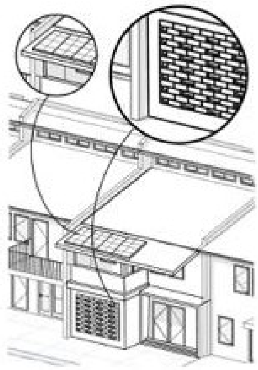
Retrofit	Conventional behaviours in retrofitting	Element	Remarks
Level 1	***Tune Up and Minor Retrofitting***		
	Install modern blinds/use curtain Revise layout to upgrade daylight, flexibility Repaint the interior & exterior of the building Replace energy-saving equipment (washing machine, refrigerator, oven, etc.) Ensure internal equipment is repaired and upgraded	Windows, Walls, Interior	Almost 70% of the cases consist of terrace houses from the year 1960 – 1970
Level 2	***Intermediate Retrofitting***		
	All of the above strategies in Level 1 Replace the old lighting system Install air-conditioning system Replace the automatic gated system Add a tinted/laminated/glazing system to the window	Electrical, Façade, Fence, Windows	

	Add temporary lightweight shading devices		
Level 3	***Major Retrofitting***		
	All of the above strategies in Level 2 Rearrange the interior spaces layout (replace services, floor finishes, raised floor, walls) Expand spaces from the original building Convert the balcony into a new space Install solar control system Add extended structural element (porch)	Façade, Balcony, Walls, Windows Roof	Terrace houses of the 1970s made up 51% of the cases
Level 4	***Complete Retrofitting***		
	All of the above strategies in Level 3 Made major alterations to the existing façade aesthetic and features Add major structural elements that completely change the original facade Possible relocation of stairs Replace roof structure and finishes	Interior, Windows, Walls, Façade, Structural, Roof	About 68% includes 1970 – 1980s terrace houses
Level 5	***Consider demolition and rebuild***		
	Remove all major elements of the building with the remaining structures only	All elements	No cases observed

The current retrofitting behaviour among the two-story terrace houses in PJ shows that a high number of upgraded works commonly conduct improvements from minor repairs to intermediate retrofitting which is insufficient to achieve high energy savings. Among the conventional strategies of retrofitting, despite the same building elements being used, the application of green technologies is not absolute. According to Global Buildings Performance Networks, GBPN (2013), despite the energy renovation of a building can reduce energy consumption by more than 75% in many cases, a standard retrofit work will often achieve energy savings in the range of 20 – 30%, sometimes even less. The most common practices of terrace houses in PJ reflect this phenomenon which can result in energy savings achievement by up to 30%. In the case of the European Union, the country has shifted to placing more critical actions of reducing GHG emissions by targeting 70% of renovations taking place should be deep renovation (that can achieve between 60 – 90% of energy savings) by 2030, while remaining 30% should be medium-depth renovation – estimated at 40 – 60% energy savings (BPIE, 2021). It is to ensure existing building stock can achieve carbon reduction. These findings further extend the immense potential of green retrofit strategies adoption to ensure improvements in the higher energy savings can be accomplished in the future undertaking.

In addition, a study by Ohene et al., (2022) emphasises the use of passive design strategies that are capable of reducing total energy demand by up to 50% in residential buildings. When an additional solar PV system is installed to counterbalance the residual energy needs with a payback period of 6 – 10 years, it will convert the building into Net-Zero Energy Building (NZEB). Following the green strategies highlighted in Table 1, the generic model of the front façade of the terrace house is incorporated to express the designated building components with the extent of retrofitting associated during each level of interventions.

Table 6: The extent of green retrofit strategies on terrace house retrofitting

Level 1 – Minor Retrofit	*Level 2 – Intermediate*	*Level 3 – Major Retrofit*
		
Use blinds; Repaint exterior wall with lighter-coloured paints	Replace tinted Low-E glazing windows; Install shading devices; Use light shelves	Install solar panel; Use perforated double façade; Use insulation for walls

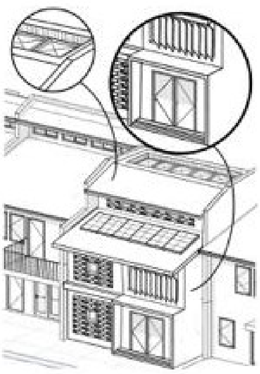
Level 4 – Complete Retrofit	*Level 5 – Demolish and Rebuild*
	
Install all previous strategies and use green roof/ roof cover/ solar PV and ensure adequate ventilation measures at walls, door and windows (passive design)	Conduct complete demolition, completely alter the whole building's appearance, structure and façade

Table 6 illustrates a simplified diagram of green retrofit application in retrofitting, showing the extent of interventions across different levels. The illustration also highlights the importance of promoting green knowledge and understanding among homeowners as carbon emission reduction has the lowest priority when deciding on the building intervention from their perspectives (Kermanshahi et al., 2020). It has further stressed the need to educate homeowners about their deprived awareness of the consideration of sustainability in modifications and how their choices can minimize the impact on the environment. It is eminent that there is ample potential for terrace house retrofitting, and steering the movement toward green seems like a great start to the initiative. It is in line with Roosli et al. (2019) that asserted the need for increased quality and improvements of residential buildings as they play a part in national environmental initiatives.

CONCLUSION

The application of green retrofit strategies in existing buildings has been studied across the world over the last few decades, featuring promising capabilities for the global reduction of energy usage and carbon footprint. However, the implementation in the context of residential buildings is rather limited, looking at the behavioural data of retrofitting trends in PJ. It should be reiterated that despite the popularized modifications conducted among terrace houses, the majority of the intervention level can only be categorized under minor and intermediate retrofit. The outcome of this study pointed out that green improvements among existing residential buildings are crucial as they may be one of the green prospects for making urban cities green and sustainable. Hence, future recommendation suggests comprehensive green retrofit strategies for the building typology to be developed for sustainable retrofitting projects in the tropics.

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