RESIDENTIAL ENVIRONMENT AND BURGLARY CRIME RISK: A SPACE SYNTAX ANALYSIS OF CRIME AREAS

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Abstract

This paper explores the different morphological characteristics of residential neighbourhood spaces to understand the factors that constitute burglary crime risk in the area. The methods used for data collection include field surveys and Block Environmental Inventory. Meanwhile, inferential statistics, Geographic Information System and space syntax tools were used for data analysis. Findings indicated the influence of neighbourhood-built features on burglary crime and the vulnerability of areas to future crime risk. The analysis shows the spatial variation of crime risk factors across the study areas and how that shaped the understanding of burglary activities in the area. The study explores the influence of the permeability of grid iron layouts on vulnerability and explains high and low crime rates in the areas of Perumahan Mahsuri and Perumahan Sunway Tunas, respectively. Overall, the paper suggests further research to correlate these spatial explanations with the socio-demographics of the areas studied.

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INTRODUCTION

Environmental criminology contends that physical environmental features play a central role in the formation of crime's spatial distribution (Dwidinita et al., 2018; Frank et al., 2012a; Yue & Zhu, 2021). Different conceptions of crime in relation to research from the perspectives of environmental design, sociology, environmental psychology and criminology indicate an extensive articulation of crime based on the built environment and urban form in the city (Groff & Taniguchi, 2019; Kamalipour et al., 2014). Several decades of studies on urban crime, crime prevention through environmental design and fear of crime indicates an implicit and gradual movement from deterministic to possibilistic propositions in exploring the relationships between urban crime, fear of victimisation and environmental design in theory and practice (Abdullah et al., 2015; Armitage, 2016).

Efforts from several researchers on crime and environment in Malaysia have been mainly focused on understanding the relationship between social forces of crime (high crime rate, poverty, fear of crime and homelessness) and the characteristics of urban environments (housing types, street layout, property types and density) and their role in shaping crime areas as high, medium or low risk or crime hotspots (Zainol et al., 2022). Safety and security issues have recently become an important area of discussion amongst researchers in an attempt to localise the sustainable development goals and mainstream them into the development programmes of Malaysian cities because the urbanisation trend in the country comes at a heavy cost to the quality of life of the people (Matlamat & Mampan, 2019).

As raised by researchers, this paper shares similar research arguments regarding the city as a complex system of people and spaces and the interaction between them as defined by the buildings and street layouts, which shapes criminal activities in place. This paper intends to answer how the city, or rather, the urban spaces, shape criminal activities. The answer can be adequately obtained by examining and understanding urban spaces as a process of complex events rather than as a by-product of buildings and streets. The result of this paper will lie in understanding the different spaces (or parts of the city) that are most affected by crime and the higher vulnerability of some spaces to crime than others. How should planners and designers explore the inherent relationship between space and crime when building urban spaces? The paper applied 'space syntax' as an analytical method that allows the examination and explanation of the systematic analysis of the socio-spatial relationship between criminal activity flows and space for effective crime prevention and management.

LITERATURE REVIEW
Crime and Built environment

Several debates on the relationship between crime and the environment have been presented, the most notable amongst them are studies by Brantingham & Brantingham (1975), Donnelly (2010) and Frank et al. (2012b). The conclusion of decades of studies established that criminal activities are unevenly distributed across urban spaces and are constrained in some cases. Meanwhile, others are supported by the characteristics of the urban environment and the routine flows of people and their activities. Theories were developed to provide an adequate understanding of these relationship patterns between crime and the urban environment. Grounded within the context of environmental criminology, Cohen and Felson's routine activity approach (Cohen & Felson, 1979) and Brantingham's geometry of crime and pattern theories (Brantingham & Brantingham, 1981) have provided extensive theoretical frameworks that explain the complex spatial connections between urban form and criminal activity in the built environment. The theoretical assumption made by the routine activities approach is as follows: for a criminal event to take place, a motivated offender and a suitable target must intersect at the same time and space in the absence of a capable guardian (Felson, 2017). This intersection is influenced by the normal and daily movements of people and their activity systems; these flow patterns are facilitated by the built urban form in place (Felson & Boivin, 2015). Individual routines, which are predictable and can largely overlap with the routine patterns of other urban residents, provide clues to the understanding of crime risk factors in urban spaces. Such clues include the location of potential crime areas in relation to specific land uses and street layouts, determining accessibility, privacy and ease of escape across areas (Boivin & Felson, 2018). The formation of an urban risk island is shaped by the development of a common, shared activity space within which crime events concentrate in predictable locations and at predictable times (Curman et al., 2020). The emerging environmental criminological researchers with strong focus and growing research interest in crime and place have applied, tested and extended these theories to explore the impact of urban form and structure on the spatial pattern of crime in cities (Iliyasu et al., 2022a).

Such research efforts have succeeded in providing substantial insight into the role of built urban form in shaping criminal activities in cities, the characteristics of urban fabric that are typically associated with crime attraction, generation or detraction and the explanation behind the formation of crime risk islanda and hotspots (Kalfaoglu & Okkali, 2022; Pitner et al., 2012; Spicer & Fraser, 1991).

Space Syntax

Space syntax is a computer-based technique used to analyse urban spatial configurations (Berghauser Pont et al., 2010). This technique is a set of space logic techniques applied in the representation, quantification and interpretation of the spatial configuration of built urban spaces and settlements (Pont & Marcus, 2015). The measurements made by space syntax correlate urban configurations with the social life of the people. In its initial form, space syntax focused mainly on patterns of movement in buildings and pedestrian flow in cities. Recently, the technique has subsequently been developed to facilitate several other urban operations, such as modelling urban traffic, predicting and modelling air pollution levels, analysing and modelling crime patterns in cities and forecasting the potential for real estate and retail development in the city (Netto, 2015; Ostwald & Dawes, 2018).

The methodology employs mathematical techniques rooted in graph theory, which involve the analysis of the street network to generate accessibility indices and movement intensity measures at the street segment level (Berghauser Pont & Olsson, 2018). Computing space syntax measures aim to understand the following: the degree of integration of street segments and the least path to different areas, which indicate the degree of accessibility, closeness and centrality of activity areas to pedestrian or vehicular movement; the degree of connectivity across areas, which is computed to determine the degree of connectedness of areas in relation to other human activity flows, explaining the choice of areas with through-movement potentials and a high value of betweenness centrality; and the degree of intelligibility, which is computed to measure the link of an area with the entire space or settlement. This degree is derived by measuring the permeability of activity areas using the global connectedness of street segments across all areas (Pont, 2018).

Several studies employed space syntax techniques to examine the influence of the spatial configuration of areas on crime patterns. Most of these studies used street segments as an element of spatial configuration. The following results are presented. Firstly, segments with high integration values have the highest street robbery and violent crime counts, especially at night (Kim, 2018). Secondly, a weak relationship exists between connectivity values and crime counts, as is the case in areas with high integration values (Kim & Hipp, 2020). However, some studies reported a positive relationship between accessibility and criminal events (Irvin-Erickson, 2014). Meanwhile, other reports indicated that areas with low accessibility values register high crime counts, especially robberies per unit of street length (Vandeviver & Steenbeek, 2019).

The emerging debate on the use of space syntax methodology is on its potential limitations, considering the reliability of its measures of the physical characteristics of places as they relate to other social characteristics of such places, particularly in relation to land use (Summers & Johnson, 2017).

RESEARCH METHODOLOGY
The study area
The study areas are the residential neighbourhoods (Perumahan) of Mahsuri and Sunway Tunas areas of Bayan Baru, Penang. These neighbourhoods were selected because they are both residential properties with different development densities and burglary crime intensities but similar spatial configurations (land uses and street layout). The study attempted to measure crime vulnerabilities in residential neighbourhoods to identify the influence of built urban form on burglary crime patterns across areas with similar spatial configurations but with varying incidences of crime. The paper aims to explore and understand the role of spatial configurations of residential areas and their crime vulnerabilities in effective crime prevention. The study utilised GIS and space syntax methods in conducting a detailed quantitative analysis of the areas using QGIS 3.28.1 and depthmapX software.

Data
The paper used crime counts and spatial data sets. The crime data were obtained from the Royal Malaysian Police for a period between 2015 and 2020 (Table 1). The data were used to identify residential neighbourhoods with the highest and lowest crime counts for selection in the study. Meanwhile, the spatial data used were obtained from Google Maps with permission from the vendors for detailed spatial analysis. In the first instance, the attempt was to correlate crime locations with spatial configurations in place to identify factors that shape the variation in crime attractions and define crime risk vulnerabilities in place. However, the spatial attributes were only considered for the examination of crime risk vulnerabilities based on the works of Jubit et al. (2020) and Pont & Marcus (2015) due to the inability to obtain geographic attribute data on crime locations. The analysis presented herein is part of an ongoing research project focusing on exploring the influence of urban morphology on burglary crime patterns in Penang. The study employed space syntax techniques to examine the relationship between human activity flow and crime patterns. The syntactic analysis did not include the crime counts but rather examined the permeability and land use influence on the crime risk areas based on the crime pattern and routine activity theories due to the nature of unit of the study area and the available crime data (Armitage, 2016; Frith et al., 2017).

ANALYSIS AND DISCUSSION
Land use and crime counts.
In an attempt to examine the effect of the built environment on residential burglary risk, this study employed exploratory data analysis to firstly assess the crime incidence of the areas for a period of five years (2015–2020) and the land use pattern of the residential neighbourhoods under study. Table 1 and Figure 1

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show the annual distribution of burglary cases in the areas of the Bayan Baru residential district (Mukim 10). The annual distributions are not homogeneous but indicate dwindling distribution patterns amongst the residential neighbourhoods.

Table 1: Statistics of Burglary cases in Bayan Baru Residential neighbourhoods from 2015 to 2020

| S/No.	Neighbourhoods	2015	2016	2017	2018	2019	2020	Total	%
1	Perumahan Mahsuri	7	7	10	2	5	5	36	31.0
2	Perumahan Bukit Gedung	1	1	-	-	1	1	4	3.45
3	Perumahan Sunway Tunas	1	-	1	1	-	-	3	2.59
4	Perumahan Jalan Mayang Pasir	12	1	8	2	9	1	33	28.4
5	Perumahan Kampung Jawa	4	2	3	1	-	1	11	9.48
6	Perumahan Jalan tun Dr Awang	4	2	5	4	4	1	20	17.2
7	Kawasan Fiz/Kilang	4	1	1	-	2	-	9	7.76
	Total	**37**	**14**	**28**	**10**	**21**	**8**	**116**	**100**

Sources: Royal Malaysian Police, 2022
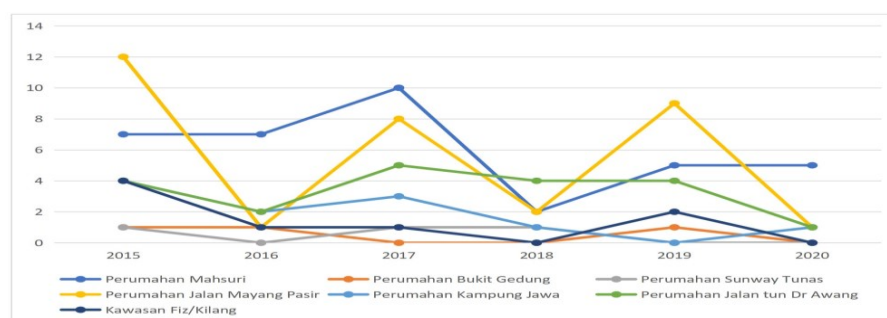
Figure 1: Burglary cases in Bayan Baru Residential neighbourhoods from 2015 to 2020
Sources: Royal Malaysian Police, 2022

The overall data show a favourable reduction in burglary crime incidence across areas and at neighbourhood levels for the five-year period. Hence, the case study areas revealed that Perumahan Mahsuri has the highest crime counts with 36 (31.0%), whilst Perumahan Sunway Tunas has the least crime counts with only 3 (2.59%). Details on the crime distribution pattern in terms of temporal characteristics such as the time-of-day and peak and off-peak periods were not considered. However, the remaining data provide the investigation with a clear picture of crime distribution in the study areas for effective analysis.

Figures 2a and 2b show the land use patterns of the case study areas. From the land use map, the predominant land use in the study areas is residential, followed by green areas and then circulation, as presented in Tables 2 and 3, respectively. The analysis of the land use pattern allowed the establishment of the

most dominant land use in the areas and the examination of its potential for the creation of crime risk vulnerabilities. This conforms with the findings of the study by (Iliyasu et al., 2022b).

Figure 2: a Land use pattern of Perumahan Mahsuri, **b** Land use pattern of Perumahan Sunway Tuns
Sources: Google Earth, 2022 and Author, 2022

Table 2: Perumahan Mahsuri

S/No.	Land use	Area (M²)	Area (Ha)	Area (acres)	Percentage of Built up (%)
1.	Residential areas	389,180.79	38.92	96.17	53.03
2.	Commercial areas	31,003.45	3.10	7.66	4.23
3.	Industrial areas	11,748.52	1.17	2.89	1.60
4.	Green areas	151,348.09	15.13	37.39	20.62
5.	Circulation	150,587.7	15.06	37.21	20.52
	Total	**733,868.55**	**73.38**	**181.32**	**100**

Sources: Google Earth, 2022 and Author, 2022

Table 3: Perumahan Sunway Tunas

S/No.	Land use	Area (M²)	Area (Ha)	Area (acres)	Percentage of Built up (%)
1.	Residential areas	178,327.16	17.83	44.06	55.06
2.	Commercial areas	1,423.33	0.14	0.34	0.44
3.	Industrial areas	22,090.59	2.21	5.46	6.82
4.	Green areas	84,220.84	8.42	20.81	26.0
5.	Circulation	37,864.37	3.79	9.36	11.68
	Total	**323,926.29**	**32.39**	**80.03**	**100**

Sources: Google Earth, 2022 and Author, 2022

The analysis results indicated the spatial distribution of the main activities and the land use distribution in the study areas. The results revealed that the variation in burglary crime counts in the areas is connected to that in their respective densities of development, as shown in the pattern of land use distribution in place. Both neighbourhoods show dominance in residential land

uses, green areas and circulation. However, despite the conclusions of other studies such as Yue et al. (2022), this finding is still insufficient evidence for concluding the influence of the established land use distribution on burglary crime risks.

Residential densities and crime count

The relationship between the residential densities of the study areas and the crime counts was measured specifically to establish whether the density has an influence on the variation of crime counts in the areas as established in the literature. Criminological theories, such as social disorganisation, relative deprivation and subcultural deviance and general strain, argue that neighbourhood characteristics such as housing density and overcrowding are key factors that directly or indirectly shape crime patterns by inducing social control or increasing community strain (Porter et al., 2015). Meanwhile, others argue that population density, housing quality and overcrowding are not the main predictors of crime but rather social pathologies in poor neighbourhoods (Xiong, 2016).

Table 4: Comparison of the residential densities of the two study areas

Study areas	Dwelling Unit (Du)	Area (Ha)	Residential Density (Du/Ha)	Density
Perumahan Mahsuri	1844	32.39	103	High density
Perumahan Sunway Tunas	6141	73.38	157	High density

Sources: Penang Structure Plan, 2030 and Author, 2022

The analysis in Table 4 shows the residential densities in the two study areas. The results reveal that both study areas have the same density typology in place despite the difference in spatial layout, area of coverage and density of development because they were found to be within 80 Du/Ha to 250 Du/Ha. This finding indicates that both areas fall into the high-density classification based on Malaysian standards. However, this finding has referred to the above theories in the literature on the influence of residential density on crime rates.

Analysis of residential neighbourhood permeability using space syntax method

Measure of Integration

The measure of spatial integration in the case study areas was syntactically analysed, and the results were compared between the areas to understand the pattern and variation in spatial characteristics of places in the neighbourhoods. The variable used was the average integration value, as shown in Figure 3 and presented in Table 3.
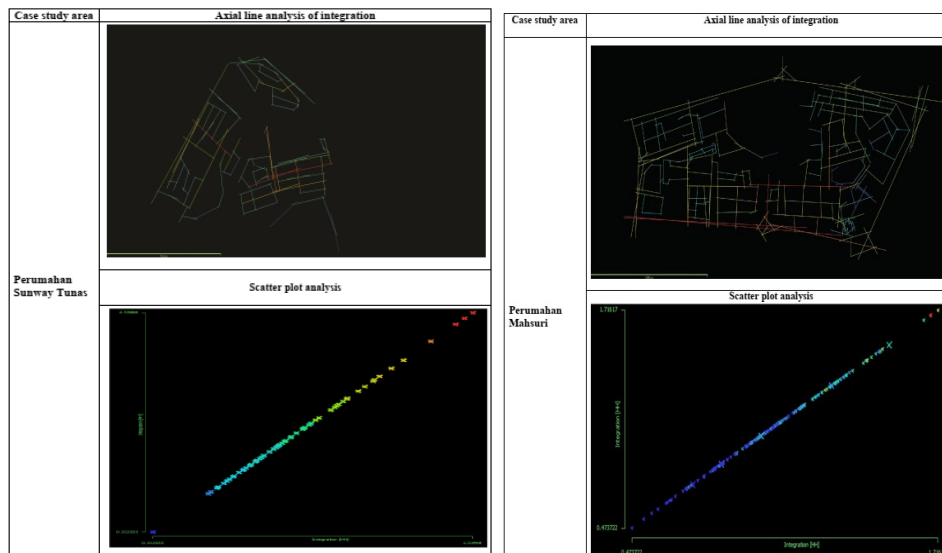
Figure 3: Comparison of integration levels of the study areas using axial line analysis
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Table 5: Comparison of the measure of integration in the two study areas

Study areas	Minimum	Average	Maximum	Standard Deviation (SD)
Perumahan Mahsuri	0.473722	1.05482	1.71617	0.243399
Perumahan Sunway Tunas	0.333333	1.28654	2.53968	0.419812

       The findings show that case study 2 (Perumahan Sunway Tunus) has the highest integration average with an average value of 1.05482 in comparison with case study 1 (Perumahan Mahsuri), and the spatial arrangement of the road layout in the neighbourhood explained the movement pattern of people and activities in the area better than that of case study 2. In the case of study area 2, the results indicate a poor integration level with an average value of 1.28654, which is due to the poor spatial arrangement of the building blocks and the road layout, in which a recti-linear street pattern was used with numerous disconnected streets and spaces as shown in the axile map. Previous space syntax-based studies suggested that highly integrated areas are safer than those with poor integration (Baran et al., 2006). However, the findings of this study reveal that houses in integrated spaces are less vulnerable to burglary compared to areas that are less integrated. Therefore, the study confirmed the positions in the existing studies.

Measure of Connectivity
The study further investigated the spatial configurations of all the axial lines to determine the degree of connectivity of areas within the neighbourhoods. The

results in Figure 4 and Table 5 show the comparison of the connectivity indices of the study areas based on the average connectivity levels. The analysis reveals high connectivity in case study area 1, with an average of 3.83099, indicating a higher number of nodes in place. By contrast, case study area 2 has a lower level of connectivity with an average index of 3.25532, indicating fewer nodes in place as shown on the exile map and the scatter diagram. Furthermore, when run with radius n (i.e., global integration), the results show that 52% of the lines linking the buildings and activities are less globally integrated (Figure 4).

Figure 4: Comparison of connectivity levels of the study areas using Axial line analysis.

Table 6: Comparison of the measure of connectivity in the two study areas

Study areas	Minimum	Average	Maximum	Standard Deviation (SD)
Perumahan Mahsuri	1.0	3.83099	17.0	2.4321
Perumahan Sunway Tunas	1.0	3.25532	11.0	1.78013

Comparison of the results with the crime counts in Table 1 reveals that these lines connect the houses where burglary occurs. Interestingly, 84% of the lines in case study 1, which also has higher crime counts, are more connected compared to those in case study 2, which has fewer connections at 41%. The findings show that areas with more connections are more vulnerable to crime events than areas with fewer connections. This finding disagrees with previous studies that concluded that axial lines with increased connections with other lines are more vulnerable than areas with fewer axial lines and low connections (Kim, 2018; Laouar et al., 2017).

Measure of Intelligibility

The study measures the level of intelligibility by comparing the average of intelligibility and synergy in the case study areas, as shown in Figure 5 and Table 7. The findings reveal that case study 1 has higher intelligibility and synergy with an average value of 2.68133, as compared to case study 2 which has less intelligibility and synergy with an average value of 2.60347. This phenomenon indicates that neighbourhoods in case study area 1 have a higher degree of permeability and are spatially organised better than those in case study area 2.
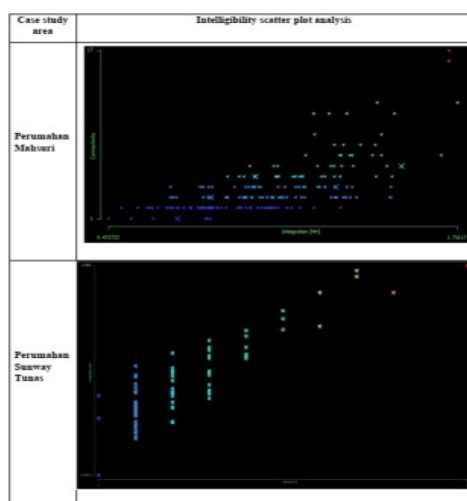

Table 7: Comparison of the measure of intelligibility in the study areas

Study areas	Average
Perumahan Mahsuri	2.68133
Perumahan Sunway Tunas	2.60347

Figure 5: Comparison of intelligibility of the study areas using axial line analysis.

Furthermore, the study showed that out of the case study areas, case study area 1 has a high degree of intelligibility but low synergy values. Meanwhile, case study area 2 has low burglary crime counts but with low values in its intelligibility and high synergy values, whereas areas with low values are those with moderate or minimal burglary counts. A well-configured area could have high synergy value (as in case study 2) where strong social cohesion exists amongst residents and non-residents in the neighbourhood (Abdullah et al., 2015). When the degree of permeability is compared to these values, an area (e.g., case study 1) with the highest degree of permeability may not be highly intelligible but has low synergy levels, which could help reduce its vulnerability. Similarly, an area with remarkably low permeability (e.g., case study 2) can still have good permeability despite its high synergy level but with a moderate degree of intelligibility. However, areas can also be highly vulnerable with moderate and low degrees of permeability despite their high degree of intelligibility and synergy, as in case study 1.

CONCLUSION

The grid-iron pattern has been a common street layout configuration in residential neighbourhoods throughout Malaysia due to the colonial planning legacies. Previous studies, such as those by Frith et al. (2017), Hillier & Sahbaz (2005) and Laouar et al. (2017), have suggested that grid-iron layout is generally safer compared to tree-like layout. However, these studies also identified some space features in the former layouts that constitute vulnerabilities to burglary. Therefore, this paper attempted to examine how various built environmental elements in residential neighbourhoods in Penang, Malaysia, explain vulnerability to burglary crime events.

The findings from the examination at the micro scale have shown that planning and design inputs into the development programmes of these neighbourhoods can influence vulnerability to burglary crimes. Only some factors have a link to burglary when variables of urban morphology are considered independently (as shown in this study), but findings have indicated areas exposed to burglary crime risk. Nonetheless, the findings of this study have shown that at the at the micro scale (street block level), buildings that have a direct connection with the highly permeable streets are highly vulnerable to burglary crime events. These findings further suggest that planners and designers should consider the hierarchy and connectivity of street networks. Accessibility is necessary because it provides convenience to residents; however, accessibility should be limited to avoid a negative impact on its residents' safety. Similarly, having only a few houses along a street segment may also put houses at risk of being burgled. The space syntax tool facilitated the comparison between elements of urban form and burglary counts in the case study areas to understand the spatial indices of vulnerability that attract burglary crime in place, which is otherwise too difficult and impossible. The findings of this study have important implications for future urban development policies and crime prevention and law enforcement systems. This study is exploratory; thus, the findings could not provide a conclusive position because the study is an ongoing project. Moreover, the study is limited to vulnerability to burglary risk but has also explored critical issues that require further studies to rigorously investigate and establish the validity of the claims made in the paper.

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