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THE EFFECT OF SPATIAL CONFIGURATION ON SENSE OF SAFETY THROUGH STREET LEGIBILITY

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ABSTRACT

The paper investigates the effect of spatial configuration in creating pedestrian sense of safety in neighbourhood commercial streets in Malaysia. To this end, space syntax analysis was applied to measure the syntactical variables. Forty streets were chosen based on their integration measures in the global analysis. The questionnaires were distributed to collect data about legibility variables affecting pedestrian sense of safety. The impact of legibility factors on pedestrian sense of safety is examined by adopting confirmatory factor analysis. Then the Pearson product-moment correlation coefficient was computed to measure the relationship between syntactical variables and legibility factors. The findings show that the legibility is strongly correlated with two syntactical variables, local integration and street connectivity. In fact, the local integration and connectivity have positive correlation with two items of legibility such as easy navigation, clarity. Thus, spatial configuration affects on legibility and consequently pedestrian sense of safety.

KEYWORDS

Space Syntax, Sense of Safety, Legibility, Intelligibility

1.INTRODUCTION

Zani et al. (2001) describes the sense of safety as a subjective phenomenon due to the mental effect, which is shaped by environment. Therefore, some factors can be used to measure people mental satisfaction and comfort in urban spaces for obtaining their level of sense of safety. According to environmental stress theory (Lazarus, 1966 and 1991), people assess the environment as being unsafe or threatening through the cognitive procedure. The process of cognition is definitely associated with the people's psychological factors such as knowledge, intelligence, motive, and experience. Additionally, the environmental factors also affect the cognition process. According to Lang one of the most important factor of creating sense of safety is orientation in the urban area. Lynch (1960) indicated that the chaotic image of space always make difficulties for people's spatial orientation, which lead to environmental fear, whereas a desired image of environment can give people the sense of safety. Therefore, to assist people to understand the environment, the spatial form of the built environment must be easily perceived. It will be achieved significantly by definition of legibility.

Legibility has been considered to be one of the most important desirable qualities of navigation in urban environments. It can be defined as the ease with which the parts of the city can be recognized and organized into a coherent pattern (Cross 2007). According to Russ (2006) legibility mainly refers to human perception of space which helps to create the feeling of safety. Hillier (1996), Lynch (1960), and Bentley et al. (1985) described legibility as "quality, which makes a place intelligible" or "how easily people can distinguish between the larger pattern of space and the local parts". Intelligibility is measured as the degree of correlation between connectivity and the global integration values of the axial lines in space syntax analysis. The project of Hillier and his colleagues in Space Syntax research team in (1998) identified streets' layouts and its integration as a main factor which supports safe urban environments. Its results state that high accessible streets have a lower number of crime occurrence due to the fact that if the spatial configuration makes the pedestrians' movement easier, there will be enough number of people to use the space (Teymur, 1988). Therefore, the most successful urban areas

are those which are most well integrated into the whole urban pattern (Syed Mahdzar, 2008 and 2013). In other words, the less dangerous spaces are more intelligible spaces. Space syntax theory is supported by empirical research, which shows that places with low accessibility level, such as segregated areas, tend to have higher crime rates while places with higher accessibility have lower crime rates (Jones and Fanek, 1997; Chih-FengShu, 2000; Shu and Huang, 2003, Syed Mahdzar et al., 2017). Additionally, in terms of legibility Lucas et al. (2007) considered easy navigation and guide assist the sense of safety. Besides, safety is highly correlated with clarity (Hoon, 2003) and signage (Beeler, 2011; Hashemi et al., 2011; Pourjafar et al., 2008; Lucas et al., 2007; Hoon, 2003; Clarke and Eck, 2014). This paper investigates the relationship between space syntax variables and legibility that affect the sense of safety. Moreover, a study by Fang et al. (2015) indicated pedestrian easy navigation in urban streets is crucial issue because worry about becoming lost in an unfamiliar environment makes them to feel unsafe. Syed Mahdzar and safari (2014) and Dalton et al. (2012) suggested clarity as significant factor to create the cognitive map which displays the urban environment as experienced by people.

2. DATASETS AND METHODS

Space syntax is used to provide computational measures to quantitatively represent the concept of legibility using a measure of intelligibility. The intelligibility is significant for perception of the spatial configuration (Tuncer, 2007). Spatial configuration is denoted as the way the relationship between any two spaces is altered by their connection to a third space. Space syntax techniques propose a way of measuring spatial configuration (Hillier, 1996; Hillier and Hanson 1984). In space syntax, the whole urban space is considered as a configuration of individual "well-perceived" small scale spaces which forms a space-space topology (Jiang, 2009). The axial-line based representation of an urban space is the earliest approach of space syntax (Hillier and Hanson, 1984). According to Jiang et al (2000), axial line can be regarded as, from the view of how human perceive space, a unit space ("vista space") that is small enough to be perceived from one single location. The idea of axial line is to represent the large urban space with infinite and least number of unit spaces. Through the analysis of how these small unit spaces are connected or integrated to each other, the spatial structure of the large urban space can be understood and human social activities among the space can be predicted. Axial lines based model is a better representation to perform space syntax analysis than axial segments. A study of Xia, 2013 shows that the theoretical accessibility measures based on axial lines is significantly correlated to the human movement pattern and in comparison the theoretical accessibility measures based on axial segments are not significantly correlated to the human movement pattern.

The study employs the case study method to obtain data, which was included, firstly, simulation (Space syntax analysis); secondly questionnaire. This study focused on connectivity, integration values, and intelligibility (the correlation between integration and connectivity) to establish legibility. This empirical study is based on the findings of three mixed use neighbourhood in Johor Bahru city. Johor is a developed state in Malaysia. Johor Bahru Metropolitan City is located in the southernmost part of the Peninsula Malaysia. Space syntax analysis was applied using Depthmap software, and then the findings were expanded with questionnaires. Space syntax analysis was employed to understand how the structure of Johor Bahru City works. Then the study concentrated on three areas which have the same accessibility measures. The questionnaires were distributed to collect data about legibility variables affecting pedestrian sense of safety. In this study, the data was analysed quantitatively. Quantitative method was chosen in order to test the quantitative results of space syntax analysis and questionnaires. The impact of legibility factors on pedestrian sense of safety is examined by adopting confirmatory factor analysis. Then the Pearson product-moment correlation coefficient was computed to measure the relationship between syntactical variables and legibility factors.

3. RESULTS

Syntactical Variables Measurement of Case Studies

Table below shows the summary of the extracted data of Johor Bahru from axial analysis. The average of global integration, local integration, and connectivity are 0.5115, 2.1045, and 4.47 respectively. Three case studies are selected from different parts of the city based on global integration value. The average of global integration of these neighbourhoods is close to the average of global integration of

the Johor Bahru City District which is equal to 0.5115. Taman Universiti, Taman Ungku Tun Aminah and Taman Mount Austin were chosen based on their global integration. The average of global integration of each neighbourhood is 0.5362, 0.5747 and 0.5487 respectively.

Table 1 Attribute summary of space syntax measures of Johor Bahru

Space syntax measures	Average
Global integration Rn	0.5115
Local integration R3	2.1045
Connectivity	4.4736

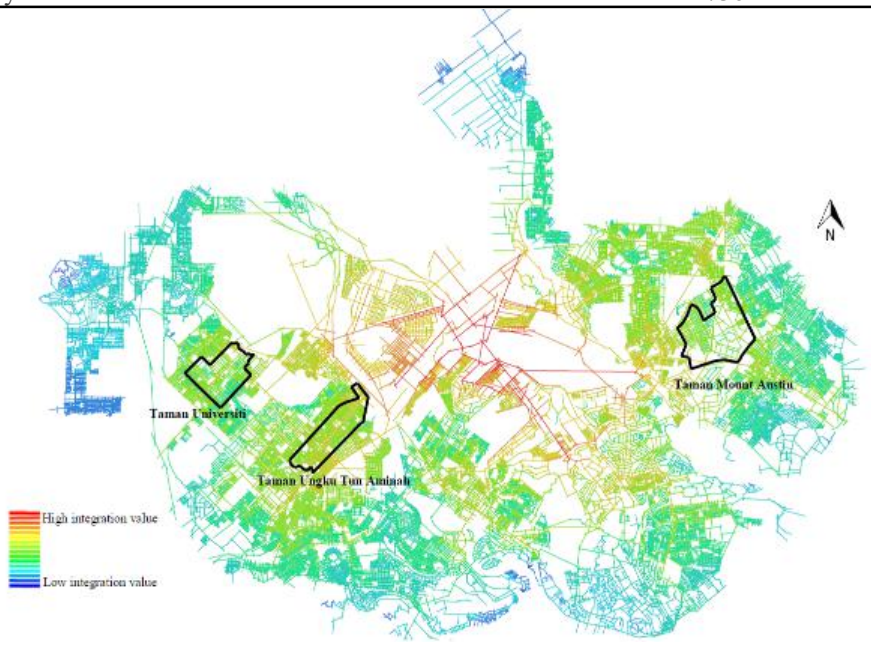


Figure 1 Axial Map of Johor Bahru: global integration value (Rn)

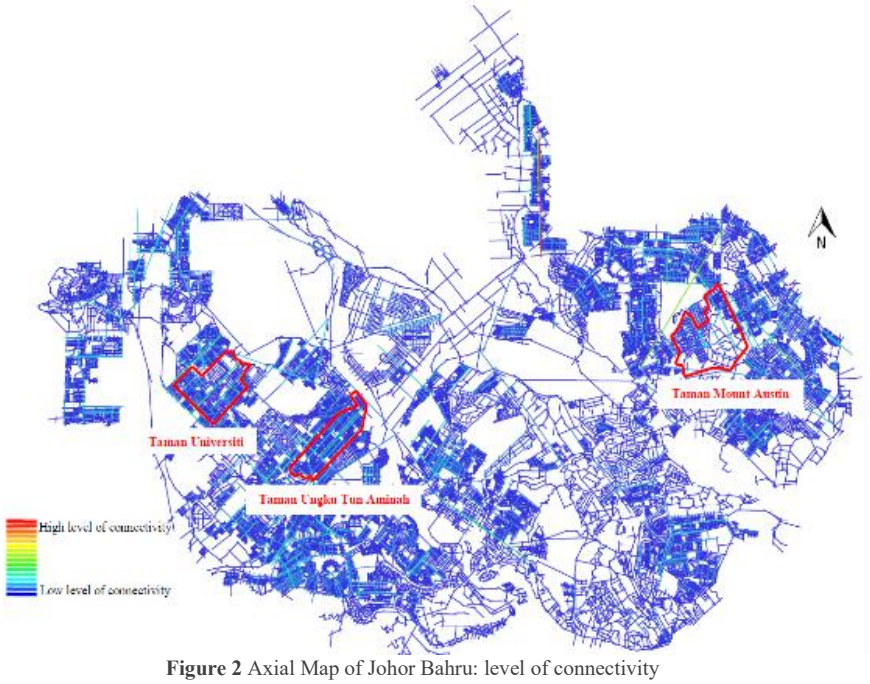
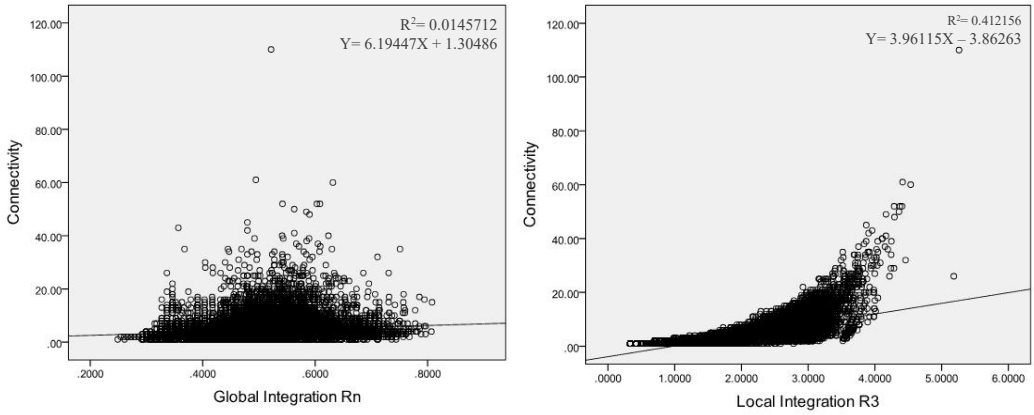


Figure 2 Axial Map of Johor Bahru: level of connectivity

Table 2 illustrates integration value, connectivity, local intelligibility, of these three neighbourhoods. The results show that the mean value of integration, connectivity, and local intelligibility of three neighbourhoods are close to each other.

Table 2 Mean values of space syntax variables for each neighbourhood

	Taman Universiti	Taman Ungku Tun Aminah	Taman Mount Austin
	Mean	Mean	Mean
Int-Rn	0.536293941	0.574706657	0.548796805
Int-R3	2.526621092	2.450912719	2.376604497
Connectivity	5.33460076	5.143297	5.701587
Local Intelligibility	R^2 Linear: 0.40	R^2 Linear: 0.425	R^2 Linear: 0.404



(a) **(b)**

Figure 3 Johor Bahru local and global intelligibility (a) local intelligibility, (b) global intelligibility

A strong correlation, or "high intelligibility", points that the whole can be read from the parts (Hillier et al., 1987). It will be easy to have an overview picture of the global pattern of the city from the local structure if the intelligibility is high. Figure 3 illustrate regression analysis of the global and local relation of Johor Bahru. Johor Bahru's global intelligibility equal 0.0145712. It is not strong enough to understand the city pattern from its local dimensions. It might be because Johor Bahru has a mixture of different patterns. But according to Figure 3 (b) the local intelligibility of Johor Bahru is significantly higher than the global intelligibility. R^2 of local intelligibility is equal to 0.412156.

- Legibility Factor

The study on the field of urban social geography showed the relation between urban safety (sense of safety) and quality of the urban environment (Wang et al., 2003 as quoted in Cai and Wang 2009). Legibility is one of the urban quality's factors. The existence of different choices of moving between places is meaningless if people cannot orientate themselves with street network. Therefore, to assist people to understand existing opportunities, the spatial form of the built environment must be easily perceived. Lynch believed that people recognize and perceive urban spaces. Individual features are influenced by the cognitive processes of recognition (Koseoglu and Onder, 2011). According to MacInnis and Price (1987) a cognitive map can be defined as the image of spaces which are identified by the human mind. Accordingly, clarity are significant properties of an urban space which make it intelligible for people through the physical form and activities. In this regard, successful urban spaces are assumed to be legible so that they are easy to understand, and people could find their way without confusion. A clear image of the urban environment equips people to be familiar with space easily and quickly. Additionally, there is a variety of guidance instruments and signage are available for human wayfinding.

In this study, the questionnaire was constructed to collect the participants' satisfaction of the legibility factors and feeling of their subjective safety in two parts. In part one, participants indicate their opinions about safety in the commercial street neighbourhood by their answers to the following questions; how safe it is considered to go outside during day in this area? And part two, were used for assessing respondents' view about the variables of legibility to find which have the most impact on sense safety of pedestrian. Four items of Legibility are: easy navigation (L1), clarity (L2), signage

(L3), and guide (L4) which are extracted through factor analysis. This four items are related to wayfinding. The model of legibility was drawn in Amos Graphics 23. The proposed one-factor congeneric model for legibility factor is demonstrated in Figure 4. The results showed that the level of sense of safety of in three neighbourhood is roughly high.

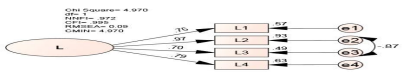


Figure 4 The proposed one-factor congeneric model for legibility of townscape

The result indicated that L2 (clarity) has the greatest effect on legibility factor with factor loading of 0.97 accounting for 93% of the variance effect. It is followed L4 (guide), L1 (easy navigation), and L3 (signage) with factor loading of 0.79, 0.75, and 0.70 respectively.

Table 3 Statists of proposed model for legibility

Identification of Model				Model Fit Statistic					
Observed variables	=	4		X2	=	4.970	CFI	=	0.995
Estimated parameter	=	9		CMIN	=	4.970	RMSEA	=	0.056
Df	=	1		NNFI	=	0.972	GFI	=	0.994
Model Is Identified							AGFI	=	0.940

Factor Loadings							
Items		variable	S.E	C.R	P	SMC	COMMENT
L1	<---	L	0.054	17.394	***	0.567	Convergence Holds
L2	<---	L			***	0.934	Convergence Holds
L3	<---	L	0.053	13.774	***	0.492	Convergence Holds
L4	<---	L	0.042	18.869	***	0.631	Convergence Holds
Model fit admissible							

The model shows a mediocre fit because of RMSEA which is in the range of 0.08 to 0.10 (MacCallum et al., 1996). The results indicate the value of CFI index equals 0.99 which is close to the perfect fit. The value of CMIN is equal to 4.970 within the acceptable threshold of 5.

- Relationships between Syntactical Variables and Legibility

This section presents the relationship between syntactical variable (local integration value, street connectivity, control value and line length) and legibility as one of the most important factors of creating a pedestrian sense of safety in Neighbourhood Commercial Streets. These relationships are measured through the correlation analysis of the variables. A Pearson product –moment correlation coefficient was calculated to quantify the relationship between syntactical variables (local integration, connectivity) and legibility and between syntactical variables and the items of legibility. The matrix in Table 4 shows the strengths of the relationships amongst the syntactical variables and urban street legibility.

Table 4 Correlation matrix between syntactical variables and legibility of urban streets

		Legibility	Local Integration Value	Connectivity
Legibility	Pearson Correlation	1	.672**	.573**

	Sig. (2-tailed)	.000	.000

"**Correlation is significant at the 0.01 level (2-tailed)."

The result indicates the strong positive correlation between legibility and local integration value (correlation coefficient r=0.672 and coefficient determination r^2=0.451). This means that increases in the level of legibility in urban streets is highly associated with the increasing in the value of local integration. Moreover, the correlation results demonstrate a moderate positive correlation between level of connectivity and legibility factor (r=0.573, p=0.000).

- The Correlation Coefficient of the items of legibility factor and syntactical variables

Additionally, the correlation coefficients of the items of legibility were calculated with the syntactical variables. It can be seen in Table 5 there is a strong positive relationship between easy navigation and integration value as well as between easy navigation and street connectivity which are; r=0.711, p=0.000 and r=0.638, p=0.000 respectively. In addition the relationship between clarity and integration value is moderate positive correlation r=0.594, p=0.000. Furthermore the relationship between signage and syntactical variable and guide and connectivity is a moderate positive correlation. The correlation coefficient of guide and integration value is almost high in compare to the other items. With comparing the results can be conclude that the easy navigation and clarity have more effect on urban legibility and consequently on sense of safety through the space syntax analysis.

Table 5 The Correlation Coefficient of the items of legibility factor and syntactical variables

	Easy Navigation	Clarity	Signage	Guide
Easy Navigation	1			
Clarity	.715** .000	1		
Signage	.567** .000	.519** .000	1	
Guide	.598** .000	.778** .000	.526** .000	1
Local Integration Value	.711** .000	.594** .000	.443** .000	.492** .000
Connectivity	.638** .000	.493** .000	.368** .000	.404** .000

**Correlation is significant at the 0.01 level (2-tailed).

The correlation matrix in Table 6 shows the relationship between the local integration values and the level of connectivity in three neighbourhoods commercial streets. The correlation results illustrate that the intelligibility, or the interaction between the local integration and the connectivity of the core area's streets (commercial streets) in the spatial configuration of each neighbourhood, is well correlated. Therefore, with referring to the result of Table 4 and 5 it can be seen that the urban configuration has effect on legibility through its intelligibility which make the urban streets safe. The results illustrates that the neighbourhood layout's intelligibility influences legibility. In this study, the spatial configuration of urban spaces was the most important factor in defining the viable cognitive map, clarity, and easy navigation that improve urban sociability and consequently increase the pedestrian sense of safety.

Table 6 The value of intelligibility of core area of each neighbourhood

	Taman Universiti	Taman Mount Austin	Taman Ungku Tun Aminah
	Connectivity		

Local Integration (r3)	r	r^2	r	r^2	r	r^2
	0.753	0.567	0.654	0.428	0.562	0.315

Correlations are significant at the 0.01 level (2-tailed).

4. CONCLUSIONS

Lynch (1960) suggested the urban legibility as a major quality of a city. According to his view, the urban legibility is ease with which a route can be understood and identified in urban system. Intelligibility as the level of understanding of the urban environment has a direct relationship with legibility. It was initially considered by Hillier et al (1987) who measured intelligibility as the degree of correlation between connectivity and the global integration values of the axial lines in space syntax analysis. The results shown that legibility is highly correlated with the integration value, while it has moderate positive relationship with street connectivity. On the other hand, the result of correlation coefficient shows that the integration value is highly correlated with all four items (easy navigation, clarity, signage, and guide) and connectivity in highly correlated with easy navigation. In addition there is a moderate correlation between clarity and connectivity. In fact, the effect of spatial configuration on pedestrian sense of safety is established by its impact on the items of legibility. With comparing the results it can be conclude that the easy navigation and clarity have more effect on urban legibility and consequently on sense of safety through the space syntax analysis. In this study, the spatial configuration of urban spaces was the most important factor in defining the viable cognitive map, clarity, and easy navigation that improve urban sociability and consequently increase the pedestrian sense of safety. The results indicates that the connectivity with local integration value assist in increasing the sense of safety. Figure 5 illustrates the effect of spatial configuration on sense of safety in detail.

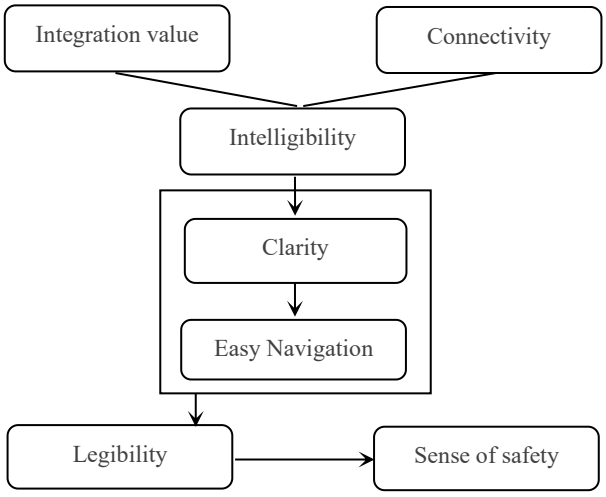


Figure 5 The effect of spatial configuration on sense of safety through the legibility

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