Differences of street connectivity between old and new zone in Malaysian small town

Wan Saiful Nizam Wan MOHAMAD
PhD Student, Faculty of Built Environment, Universiti Teknologi Malaysia.
Faculty of Built Environment, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia; wsnizam2@live.utm.my

Ismail SAID
Associate Professor, School of Postgraduate Studies, Universiti Teknologi Malaysia, Dr.

From the period before Malaysia’s independence until now, there are two significant characteristics of the town formed in small town. Pedestrian behavior in the streets is affected by the connectivity existed from the pattern of the street network of a town. Thus, the existing of characteristics of new and old zone require pedestrian to travel differently in those environments. By considering a small town consists of the old and new zone and population between 30,000 to 100,000, street network of Bandar Teluk Intan, Perak was selected. Three sets of data were produced from the land use map and Google Map image, then analyzed it using UCL Depthmap 10. Firstly, solid and void data was used in Visibility Graph Analysis (VGA) to measure street connectivity from pedestrian visualization. Second data which convex space data used in Convex Space Graph Analysis (CSGA) to measure street connectivity of spaces in street network that offer pedestrian interaction. Axial-line data is the third data was used in Axial-line Graph Analysis (AGA) to measure street connectivity from pedestrian movement in street network. Finding shows that in old zone, junctions act as a connector to other streets when pedestrian visualize during travel, space in square and market chosen as meeting place, and main road as a guide when pedestrian move. In new zone, main road is a connecting feature for pedestrian because it's easy to find, connect with most streets, and the possible space to meet people during travel.

Keywords: Street Network, Street Connectivity, Visibility Analysis, Convex Space Analysis, Axial-Line Analysis

1. Introduction
This study focused on connectivity form from pedestrian that used space in street network. According to Tomko, Winter, and Claramunt (2008), and Marshall and Garrick (2010), these known as street connectivity. Street connectivity is defined as the number of nodes linked to other nodes where a node can be a point represents a space or an intersection. Study in Health and Place by Leslie et al. (2007) indicated that street connectivity as the parameter in measuring built environment features that influence physical activity. Finding from the study showed the high connectivity in streets create opportunity for people to do activities such as walking because of easy access to major roads where public transport is available. A study in Social Science and Medicine by Cutts, Darby, Boone, and Brewis (2009) exposed the influence of street connectivity with walkability in explaining social barriers for pedestrian willing to walk. Finding of the study suggested the street connectivity that affected by the physical structure of street network, create perceptions of resource quality, safety, and cultural relevance leads to physical activity. Thus, both findings from the studies have showed the relation of street connectivity with the town characteristic which exposed the different behavior of pedestrian when travels.

Small towns in Malaysia have experienced the urban formation which leads to the two significant
town characteristics; old zone and new zone in town. The urban morphology study by N.Z. Harun and R.A.J Jalil (2012) indicate the street network of Malaysian towns had an indelible impact toward Portuguese, Dutch, and British that introduces grid-like and geometric structures from Euclidean geometry concept in town planning and design. After the towns rules by Government of the Federation, the development then grew rapidly guided by Malaysian Town and Country Planning Act (Ramele, Isnin, & Jabar, 2010). These have influences pedestrian behavior when travel because of the town characteristics. Therefore, the aim is to identify the differences of street connectivity between two significant town characteristics which old zone and new zone in Malaysian small town.

The street connectivity parameters used in this study are determined based on the space syntax approach presented by Peponis, Wineman, Rashid, Kim, and Bafina (1998), Jiang, Claramunt, and Klarqvist (2000), and Mohamad and Said (2014). For example, van der Hoeven and van Nes (2014) used visibility as one of parameter that connecting user to visualize in underground metro station. Jeong and Ban (2011) used convex space to measure the connectivity of interaction space which extract topological information in buildings. Önder and Gigi (2010) used axial-line in determining the change of user movement after the implementation of historical and cultural prevention project in South Haliç Area in Istanbul. The determined parameter for street connectivity measurement: visibility, convex space (interaction space) and axial-line (movement).

1.1 Visibility for Pedestrian Visualization

Visibility helps pedestrian gains information from urban environments. In Space Syntax study by Peponis, Wineman, Rashid, Kim, and Bafina (1997), visibility is described as a location (node) that can visualize other locations (nodes) in an environment. Then Lam, Tam, Wong, and Wirasinghe (2003), Churchill, Dada, de Barros, and Wirasinghe (2008) and Tam (2011) discussed visibility in Air Transportation Management study as the number of sight lines from the total number of sight lines in an environment. In Computers, Environment and Urban Systems study by Omer and Goldblatt (2007) focused visibility as the location that can observe various viewpoints which could determine navigators need such as their initial locations, destinations and finding landmarks. Thus, the meaning of visibility is the connectivity of a node (a location or point) with various nodes (locations or points) through pedestrian visualization or sight.

In street environment, visibility of a location influences pedestrian movement in selecting routes to a destination. It assists pedestrian visualization to identify their references in the wayfinding process. A study by Sulpizio, Committeri, Lambrey, Berthoz, and Galati (2013), the different degree of visibility at the viewpoint strongly affects spatial memory of pedestrian during the process of encoding and updating information of locations. Moreover, pedestrian with visual experience which adapted from a location with high visibility have strong ability to allocate spatial preferences (i.e., Landmarks or facilities) during travel (Pasqualotto, Spiller, Jansari, & Proulx, 2013). Therefore, street connectivity of locations in towns has difference degree of visibility based on its environment.

In this paper, visibility is a parameter used to determine street connectivity of selected the street network based on the space syntax approach. Based on the space syntax, street connectivity for visibility is defined as a number of the nodes viewed \((n)\) connected with a node (Dawson, 2002; Peponis et al., 1997; van der Hoeven & van Nes, 2014). A node is represented by the center of a space with an area of 1.5mx1.5m (Figure 1).
Therefore, street connectivity for visibility of town is measured using Visibility Graph.

1.2 Convex space as Space for Pedestrian Interaction

Urban space is a place where pedestrian having a meeting for interaction. In space syntax study by Jiang et al. (2000), pedestrian interaction is from in polygon form of a space known as convex space. Convex space is defined as a boundary of space which has points that can be joined with all other without passing out the boundary (van der Hoeven & van Nes, 2014). A study by Jiang et al. (2000) on a layout of the school and found that corridor is a space where interaction happen between teachers and students. Then, Jeong and Ban (2011) used convex space to identify the topological information in the building based on human interaction. In the urban context, Önder and Gigi (2010) analyzed convex space of historic components in Haliç, Istanbul. They found that connection of the interaction space have strengthening the value of historical, cultural, social, physical and symbolic features to be appreciated. Thus, the degree of street connectivity for pedestrian interaction has given the meaning to the town.

This paper used convex space to determine street connectivity of street network for pedestrian interaction in town. Convex space has been introduced in space syntax approach as polygons that connect with each other in a compound (i.e. Building or urban space). Street connectivity in convex spaces is defined as a number links (h) that connected the nodes in space (Jeong & Ban, 2011; Jiang et al., 2000; Kim & Sohn, 2002; Peponis et al., 1997; van der Hoeven & van Nes, 2014). Based on Figure 3, a convex space has represented by a node at the center of the polygon. Thus, the connectivity for pedestrian interaction (C_{interaction}) in the graph is referring to equation 2.

\[ C_{interaction} = \sum n^i \]

\[ C_{interaction} = \sum h \]  

Thus, based on Figure 2, connectivity for visibility (\( C_{visibility} \)) in the graph refers to equation 1,
Therefore, street connectivity for pedestrian interaction of town is measured using Convex Space Graph.

1.3 Axial-line represent Pedestrian movement
Street in town is a public place where people used to move to a destination for any purpose. It is a motivated activity involve with two points; origin point and destination point. In a socio logic space study by Hillier and Hanson (1984), free space such as a street allowed pedestrian move straight from a start toward the end of the street. Thus, in space syntax, the straight line formed known as axial-line which to indicate the pedestrian movement (Batty, 2004; Jiang et al., 2000; Peponis et al., 1997; Porta, Crucitti, & Latora, 2006; van der Hoeven & van Nes, 2014). A study on Tunnelling and Underground Space Technology by van der Hoeven and van Nes (2014) have analyzed axial-line of the Bockstael metro station and the Annessens premetro station to improve the design of urban underground space. The finding of the study suggests that main gate highly influence movement in both metro stations, meaning that degree of connectivity for the space based on movement is depend on the main gate. In the urban context studied by Jiang (2007) used axial-line to measure topological pattern of 40 cities in US that can be adapted by pedestrian and found that one percent from the overall street in a city remain in pedestrian cognitive. Thus, these have shown a relation of street pattern and pedestrian movement in town can be determined by using axial-line.

This paper used axial-line as a parameter to determine street connectivity for pedestrian movement. Street connectivity in the axial-line graph is defined as the number of intersections (I) from the connection of a line (street) with other streets (Batty, 2004; Jiang, 2007; Jiang et al., 2000; Peponis et al., 1997; van der Hoeven & van Nes, 2014). The intersection of streets is known as node (Figure 4).

Thus, the connectivity for pedestrian movement \( C_{\text{movement}} \) in the graph is referring to equation 3.

\[
C_{\text{movement}} = \sum I
\]  

Therefore, street connectivity for pedestrian interaction of town is determined using Axial-line Graph.

2. Site Study
Small town is known as a community center where people use for industrial, business and social activity. It’s performed essential functions of sales, retailing,
Small towns in Malaysia are facing a rapid development due to the influence of social-economic development. Thus, the selection of small town as the sample in this study required certain aspect related to the street network connectivity. In order to select the sample of small town represent small town in Malaysia, all small towns identified in Malaysia are filtered through three aspects; urban population size (Soltys, 2011), town zoning (Arbi, 1986; N. Z. Harun & R. A. J. Jalil, 2012; Harun, Mansor, & Said, 2013), and street network pattern (Rifāat, Tay, & de Barros, 2011).

Figure 5.0: Process of selecting sample as site study
Thus, Bandar Teluk Intan, Perak, Malaysia is selected based on the process of selecting the small town for the site study in Figure 5.

Bandar Teluk Intan, Perak is addressed as a heritage town by the local authority because of the historical value from colonial period which still exists. The urban population size of the town is 41,701. The town environment consists of the old zone (from the colonial period of British) and new zone (development after Malaysian independence) built land uses of the low-rise residential area, low-density commercial area and streets. The street network pattern of the town consists of gridiron pattern, fragmented parallel pattern, warped parallel pattern, and loops and lollipops pattern. The street network and commercial development cover a total of 80 hectares of land (Figure 6).

Figure 6.0: Landuse map of streets and buildings in Bandar Teluk Intan, Perak

3. Methodology
This study implemented space syntax approach founded by Hillier and Hanson (1984) which utilize UCL Depthmap 10 software. The procedure of analysis consists of producing input data and analyzing data.

3.1 Input Data
In this study, the analyses require three sets of input data based on parameters studied; solid and void data, convex space data, and axial-line data. In producing the data, Google Map image and landuse map of the

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Figure 7.0: Process for producing input data of street network pattern; (a) solid and void data, (b) convex space data, and (c) axial-line data.

street network pattern of Bandar Teluk Intan, Perak, Malaysia is obtained from Jabatan Perancang Bandar dan Desa Semenanjung Malaysia (JPBD). The maps of the street network pattern were digitized into drawing format (DXF) using AutoCAD 2012 as shown in Figure 7. Then, the data were imported into Depthmap version 10 for data analyses.

3.2 Data Analyses
The differences of street connectivity for old zone and new zone in this study are focused on pedestrian behavior when travel in street network; pedestrian visualization, pedestrian interaction, and pedestrian movement. The data sets produced were using analyses applicable in UCL Depthmap 10. Firstly, solid and void data was analyzed using Visibility Graph Analysis (VGA) to measure street connectivity generated by pedestrian visualization. Secondly, convex space data which created from spaces exist in the street network were analyzed using Convex Space Graph Analysis (CSGA) to measure street connectivity of spaces in street network that offer pedestrian interaction. Then, Axial-line Graph Analysis (AGA) was performed on the third data, axial-line data, to measure street connectivity from pedestrian movement in street network. Thus, results from the analyses were explored in identifying differences for the street network of old zone and new zone in Bandar Teluk Intan, Perak.

4. Results and Discussion
The results suggest that the differences of street connectivity for old zone and new zone in small town identified through pedestrian visualization, pedestrian interaction and pedestrian movement.

4.1 Differences in pedestrian visualization for old zone and new zone
The results from VGA showed that in old zone (Figure 8), space at junctions showed the higher connectivity by range color light green to red. This means that pedestrian will easily viewed junctions...
while they travel. However, the results for back-lane space indicate by dark blue color showed lower connectivity than main road which indicate as green to light blue. Junctions are used to connect the view of pedestrian in finding their destination even though space on the roads and back lanes is low visibility. Therefore, junctions in old zone used to be the pedestrian visual connector when travelling.

The differences of street connectivity for pedestrian visualization in old zone and new zone are visibility space at junctions and main roads. This is because the street pattern in old zone is designed in a period where walking is the main travelling mode while the design of street network pattern in new zone are focused on transportation which the main traveling mode use by people nowadays. These are consistent with the study by Marshall and Garrick (2010) suggested that street network pattern by gridiron pattern important for encouraging non-automobile modes of travel. However, in context of the small town which consist of old zone and new zone with various street patterns, due to the differences existed, the used of street features for navigation information are needed in making both old zone and new zone well connected.

### 4.2 Differences in pedestrian interaction for old zone and new zone

Convex space is analyzed by CSGA showed in Figure 9. The result from the CSGA for old zone indicated that the highest connectivity spotted at two spaces which are near the market and square. This means that both spaces are a meeting point for pedestrian. These spaces are designed by connecting with other street spaces to bring pedestrian to interact with other spaces into a space. However, the result of CSGA for new zone (Figure 9) showed that the highest connectivity is spotted at main road space indicated by red color. This means that there are a lot of ins and outs of blocks connect with main roads. Thus, there will be an interaction by pedestrian while they move in main road.

The differences of street connectivity for pedestrian interaction in old zone and new zone are

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the interaction spaces, street at the market and square and main roads.

Figure 9.0: Differences of street connectivity for pedestrian interaction space

This is because of the spaces connecting with the interaction space in old zone use to support the landuse activities while the interaction space at new zone used to bring pedestrian to the destinations. These findings are parallel to the study by Maleki (2012) that interaction space created from the pedestrian walk to a central focal point such as a school in a neighborhood environment. However, in context of small town, the result showed the difference in the type of space where the interaction space in small town fit the social activities in the urban environment.

4.3 Differences in pedestrian movement for old zone and new zone

From the analysis on axial-line, the results of the AGA for old zone showed that high connectivity for main roads range from red to light green and low connectivity for back-lanes range from green to dark blue (Figure 10). These suggest that the streets are connected all over the town.

Figure 10.0: Differences of street connectivity for pedestrian movement

As a result, these decrease the possibility for pedestrians to get lost in the back-lanes because they will always meet main road when they travel. However, AGA results for new zone showed that highest connectivity showed at main roads indicate by red color and low connectivity at roads in blocks range from yellow to dark blue. These mean that street network at new zone is centralize by main roads to move into the blocks. Therefore, there are two levels of pedestrian movement in street network of the new zone of the small town; the first level for pedestrian to find a destination block in the main
The differences of street connectivity for pedestrian movement in old zone and new zone are on the functions of main roads. Main roads in old zone are becoming a guide in defining a route to a destination while in the new zone, main roads used by pedestrian to find blocks. This finding fits to a study by Jiang (2007) that main road name used as a reference in wayfinding process. This means that the pedestrian would find a main road for them to find destinations. However, in small town context consist of old zone and new zone, the main roads are used as a guide but in different functions based on its environments.

Hence, overall results suggest that the differences of street connectivity in old zone and new zone of small town lead urban designer to consider in the development of urban environment especially small town for creating better social development of the town.

5. Conclusions
This paper implies that streets in small towns are connecting pedestrian with their destination differently according to street network patterns of the town. The differences of pedestrian visualization, pedestrian interaction and pedestrian movement in small town influence pedestrian perceive the town. Therefore, urban designer such as planner, architect, and landscape architect need to understand the street connectivity in street network patterns to meet the needs of pedestrian behavior in small town. However, the results of the analyses in this study need to be triangulated with other results from the interviews or pedestrian route mapping, to make sure the findings more valid and reliable. Therefore, studies on pedestrian spatial knowledge, and route mapping in small towns are recommended for further discussions on the study.

References


