Road orientation of housing subdivision in Majlis Bandaraya Iskandar Puteri, Malaysia

J L S Ling[1], N b Che'Man[1] and M R b Majid[1]

[1] Department of Urban and Regional Planning, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia (UTM), 81310 Johor, Malaysia

Corresponding author's email: lsljosephine2@graduate.utm.my

Abstract. Street network is a city crucial element. The current guidelines of road design generally include road width, cross-sections and street hierarchy which are to be taken into consideration during the design phase of the network. Research have shown that road orientation affects the quality of a housing subdivision. However, there are limited studies on street orientation with most of them concentrating on the effects of the orientation on housing subdivision rather than the factors which give rise to its orientation. This research aims to analyse the street network of housing subdivisions located within Majlis Bandaraya Iskandar Puteri (MBIP) to identify the aspects which influence its orientation. Street networks of 71 housing subdivisions under the administration of MBIP were extracted using the OS Mnx Python programming tool to visualize the street networks in terms of polar charts. The findings of the study imply that the size of a housing subdivision does not affect the manner of streets within it are designed. Street pattern is associated with the time of development and the socioeconomic status of the community within the housing subdivision. Such findings contribute to better understanding of street orientation and can assist urban planners to create a better living environment.

1. Introduction

Streets can be described as a connection between the private and public domain, by linking the components within a neighbourhood [1]. Street pattern design is generally divided between concern for infrastructure and transportation efficiency, and neighbourhood quality. A conventional approach encourages a strong hierarchical curvilinear street pattern with cul-de-sacs, while the grids are favoured by the new urbanism ideas. Liveable Neighbourhoods, for example encourages interconnected street pattern within site-responsive network with high quality public spaces as focal points. Hooper et al [2] suggest that the roads designed in line with Liveable Neighbourhood promote walkability to public spaces within neighbourhoods.

In Malaysia, the guidelines for road design provided by the Federal Department of Urban and Country Planning [3] in the Guidelines for Residential Development focus on pedestrian, landscape and low speed travel lanes. The section on road design of a housing subdivision highlights five aspects which should be complied with. They include mains road and junctions to take into account the traffic volume, roads on hilly areas to consider the contour, junctions to meet at a right angle and the road networks designed as curvilinear, looped or linear. There is no clear emphasis on the road orientation during the

design phase of a housing subdivision. Therefore, this study aims to understand how road networks should be designed and the factors which would influence road orientation of a housing subdivision. These street networks play a significant part in determining how people travel within an area, the sustainability of the housing subdivisions and how it continues to expand within the region in the future. Therefore, the aspects which influence the design of a road network should be identified to provide a clearer picture on the design process of a housing subdivision.

2. Literature review

A well-planned housing subdivision is one that defines access and movement networks that will encourage active transport within the area. Active transport includes non-motorised forms of transport involving physical activity, such as walking and cycling. It also includes the use of public transport as many of these trips include walking or cycling which can increase levels of physical activity [4, 5] highlights that street connectivity of a housing subdivision impacts the travel behaviour of the community whether by walking and cycling or motorized vehicles to parks and commercial areas within a neighbourhood area. A good design of a residential area should have the right mix of housing diversity, connected by good transportation network, equipped with quality park spaces and easy access to commercial areas to meet daily needs of the community which in turn helps in creating a Healthy Neighbourhood which encourages physical activities and social interaction. Another aspect which would define a good housing subdivision in the current planning system is environmental sustainability. Housing subdivisions should be designed in response to the local climate condition which considers the topography and the street orientation. Al-Jumaili [6] emphasizes that good urban designs can significantly reduce the energy consumption of buildings and provide opportunities for passive solar architecture while creating a comfortable public realm. A sustainable street is one which takes into account the street orientation which allows maximum thermal comfort and sunlight penetration into the buildings. Ismail and Muslim [7] mentioned in their assessment of the ecology design for middle income housing in Johor that the orientation of dwellings relates to the solar radiation whereby houses facing North and South is protected and shaded from the sun. Rouefchaei et al [8] also highlight the importance of creating an energy-efficient housing subdivision through the design of street orientations. An "energy-efficient" home reduce energy use and at the same time be able to provide a high level of comfort to its occupants. In this case, the orientation of a house is determined by the orientation of the subdivision and street network to ensure the dwellings can be energy efficient.

Many researches have shown that street patterns evolved according to the year of development. Marshall and Garrick [9] highlights the evolution of street networks patterns from pre-industrial era to grid iron pattern, loops and cul-de-sacs. Planned residential areas have been around in the city of Johor Bahru since 1950s. A study by Majid et al [10] reported that housing areas of various sizes were being developed each year with each new one located further away from the city centre, some encroaching into the rural area. Such rapid urbanisation formed varied street patterns such as the gridiron network, curvilinear network and loops which coincide with the time of the development of specific housing subdivision. Southworth and Owens [11] categorized the street systems in the United State of America (USA) into four patterns according to the time of development. During the pre-war era, streets are formed in a "gridiron" structure. This trend was followed by a curvilinear system. Cul-de-sacs pattern began to emerge during the post-war developments. These evolving patterns reduce the overall street length, intersections and create a relatively less access points into the housing subdivision units. Developments during the later era illustrate a more car-oriented housing subdivision with reduced blockings, more loops and cul-de-sacs which in turns discourage walking and cycling due to lower street connectivity of the housing subdivisions (Figure 1).
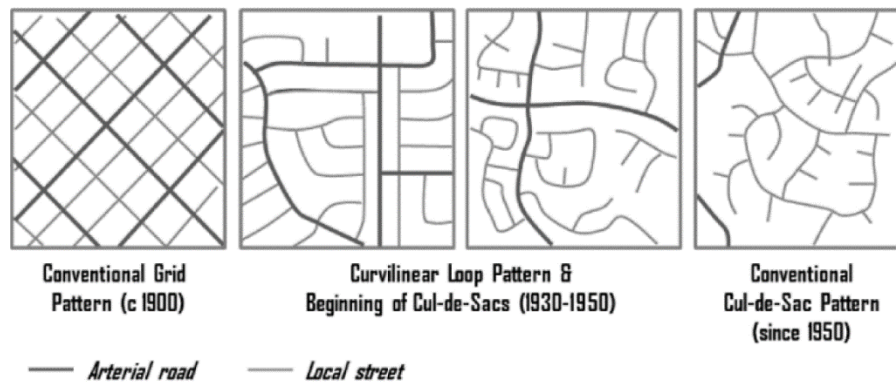
Figure 1. Type of street patterns [9].

Southworth and Owens [11] further categorize street patterns into five groups, namely gridiron, fragmented parallel pattern, warped parallel pattern, loops and lollipops and cul-de-sacs. According to Grammenos et al [1] well-designed streets would result in a desirable environment for all ages, one that is safe, quiet and healthy. These streets would support the interaction and exchange of the community in the neighbourhood. In this context, conventional loops and cul-de-sacs increase the community's quality of life but have a relatively lower connectivity and accessibility. On the other hand, a grid network would benefit the transportation efficiency and the convenience of the community as there will be much choices of movement in the area. Figure 2 shows the various street patterns.

Figure 2. Illustration of street patterns [1, 11].

2.1. Effects of street orientation

Housing orientation affects the energy consumption within the housing subdivision as it impacts the heating and cooling, and the shading from neighbouring houses. McGee [12] states that a good orientation for passive cooling keeps out the unwanted sun and hot winds while ensuring access to cooling breeze. An ideal street layout would be able to take advantage of the energy efficiency and renewable energy opportunities by ensuring that a maximum number of houses are oriented ideally by taking into consideration the orientations of street network within the housing subdivision.

Lojuntin [13] highlights the strategic and affordable way to reduce carbon emission for building sectors through the design of the street networks. In this context, the Low Carbon House P14 at Putrajaya, Malaysia has successfully achieved the Net Zero Energy Home (nZEB) in 2017. The green features of the homes include East-West Building Orientation, landscape to absorb heat, natural cross ventilation and daylighting and the use of energy efficient light and appliances. These initiatives signify

the importance of the building orientation in reducing carbon emission to create a low carbon building during the design phase, in addition to energy efficiency appliances in the building.

Generally, street orientation is influenced by the street pattern used in the design process. A grid iron street pattern is most likely to results in cross-directional orientation, while a curvilinear street pattern may result in streets oriented in various directions. Residential developments may be affected by the size of housing subdivision as they are green field developments in the cities which put a limit to land available for development. A study by Jamanlunlaili et al [14] mentioned that urban sprawl phenomenon is associated with the low-density development of green field in Malaysia. While a smaller scale residential development may be influenced only by the existing street network, larger scale of new developments would have to include arterial roads to accommodate increase number of traffic in the area, and thus street designs would be influenced by the design of such major streets. Another factor which may influence the street design of a housing subdivision is the socio-economy of the targeted community. Housing subdivisions for low-cost houses are often targeted to be built in the most cost-effective way while high-cost housing emphasized on the quality of the environment.

2.2. *Methods of visualization for the orientation of street networks*
There are several studies on the visualization of street orientation carried out in the U.S. Worley [15] visualizes street orientations through a method called "Crayon the Grids" where maps of street layouts are coloured according to the orientations. Boeing [16] came up with a polar chart diagram to better visualize the street orientations. He developed a new tool called the OSMnx to ensure that the collection of data and analysis of the street networks are simple and consistent. Agofonkin [17] innovates from Boeing's street visualization tool which produces a polar histogram that shows the patterns of street orientation of the city, to come up with a polar chart embedded in an interactive map.

3. Research methodology
A detailed study was carried out on a total of 71 housing subdivisions under the jurisdiction of MBIP. The street networks of all the housing subdivisions were extracted with the OSMnx python codes. The main analysis is carried out using the OSMnx Python Programming tool. The analysis is carried out to visualize, compare and understand the effects of street network and its orientation. The first analysis requires the digitization of the boundary shapes of the housing subdivisions onto OpenStreetMaps before downloading the street network bounded by the housing subdivision boundary from the OpenStreetMaps database. This tool enables the construction, projection, visualization and analyzation of complex street networks. The results can be interpreted at which the bars represent the compass bearings of the streets and the length is reflected by the frequency of the streets with these similar bearings.

In general, the orientation of a dwelling depends on the orientation of the street fronting it. Although there are various factors involved in the design of a dwelling, this study primarily looks into the physical aspect of the subdivision to better understand the planning factors which influence the variation in street orientation. The parameters for the study of street orientation are listed below:
- Boundary of the housing subdivisions in Majlis Bandaraya Iskandar Puteri
- Street networks of all the housing subdivisions, bounded by the polygon of the housing subdivision's boundary

The next stage of the analysis is carried out to compare, explain and justify the differences between the polar charts of each housing subdivisions in term of the factors influencing street orientation in the housing subdivisions. The polar charts are also categorized based on the pattern of the bars which shows the frequency of the streets oriented in a particular direction. The categories of polar chart are shown in Figure 3.
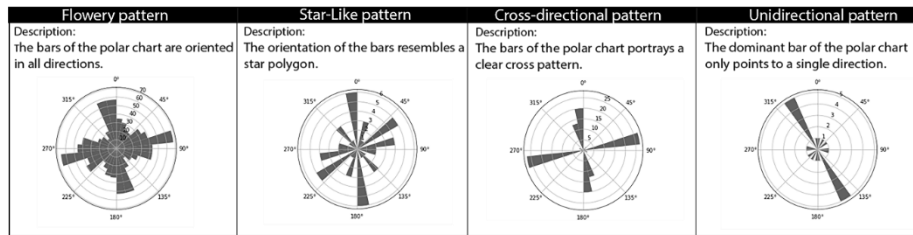
Figure 3. Categories of polar chart.

4. Analysis and findings

The analysis begins with an overall visualization of the street orientations of all the housing subdivisions in the study area before reorganising them according to various aspects to further understand the elements which give an impact towards the design of the street. The preferable street design based on the polar charts will then be identified.

4.1. Road orientation of different hierarchies

This study initially examined the road orientations of the whole state of Johor, and then narrowed down to Iskandar Malaysia and the administrative area of Majlis Bandaraya Iskandar Puteri to get an idea on the dominant orientation of the major road networks of the study area. It finds significant relationships between the street orientation and different hierarchies' road orientation. This observation supports the understanding that streets of a housing subdivision tend to be influenced by the orientation of major road networks. Figure 4 shows the polar charts of the three-hierarchy of road orientations respectively.
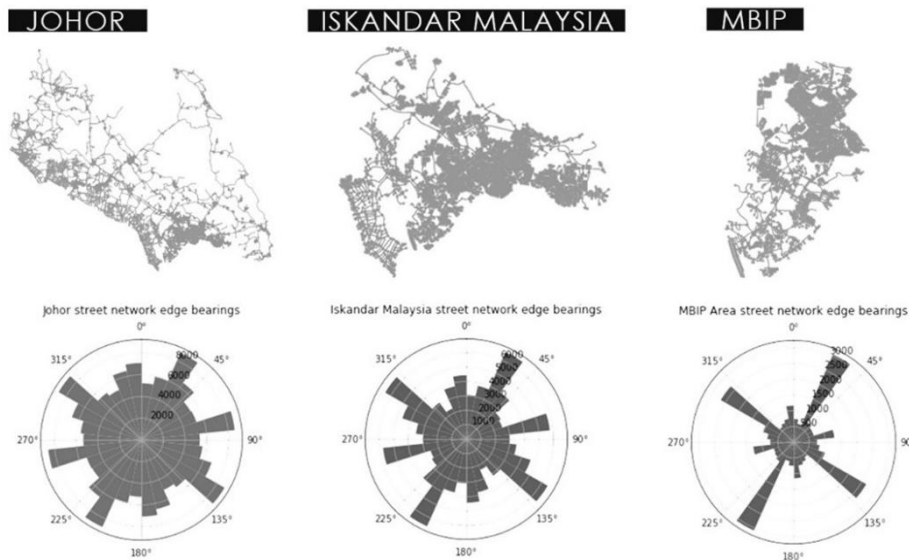

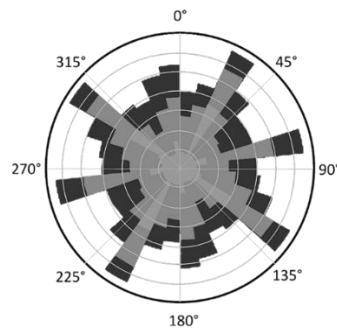**Figure 4.** Polar charts of different hierarchies in Johor.

Figure 5. A combination of the polar charts of all three hierarchies in Johor.

From the three polar histograms, it is clear that the streets of all the three hierarchies are strongly oriented towards an approximate of 45° rotation of the North-South-East-West grid. Figure 5 better illustrates the relationship between the three polar charts by combining them into one. It shows that the streets of Johor have the least grid-like streets, followed by Iskandar Malaysia and lastly the streets within MBIP. The difference in the polar chart pattern can be explained in terms of the different hierarchy where the road network of a state level when bounded in a smaller scale, would have lesser roads in it. It can be seen that all the three hierarchies shared the same road network but are bounded by a different scale of boundary. The result presented similar dominant bars oriented in the same direction but varies in length. This is because the length of the bar portrays the frequency of streets oriented in that direction. The polar charts of Majlis Bandaraya Iskandar Puteri showed that the roads within the jurisdiction are mostly oriented towards that direction which signifies that most of the housing subdivisions would have streets oriented in similar direction.

4.2. Patterns of street orientation

The results of the polar charts can be further classified into 4 categories according to their order of grid-like street orientation (Figure 6). The first category would represent the most disordered street orientations, where the chart's visualization resembles a flowery pattern. Of the 71 housing subdivisions studied, a total of 8 housing subdivisions (11.27%) fell under this category. The second category represents a more ordered pattern with lesser variation in street orientations; this category can be said to resemble a star-like street orientation. A total of 28 housing subdivisions (39.44%) can be classified under this category of street orientation. The third category of street orientation pattern resembles a cross-directional pattern and is considered as the most ordered pattern among the three categories. Majority of the housing subdivisions under the MBIP jurisdiction belong to this category with a total of 34 housing subdivisions (47.89%). The last category of the polar chart pattern shows a more unidirectional pattern and only one housing subdivision in MBIP fell under this category.
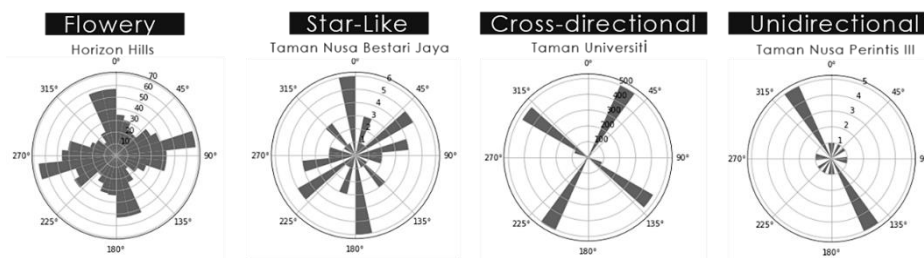

Figure 6. Classification of polar chart patterns

4.3. Factors of street orientation

This analysis is to determine the reasons behind the street orientation of a neighbourhood and provide a broader perspective on how planning a neighbourhood street system affects the street orientations of the neighbourhood. Table 1 summarized the results of the aspects of neighbourhood which influence the street orientation of a neighbourhood. It is categorized according to the similarity of selected aspect of housing subdivisions and the associated polar charts.

Table 1. Aspects of neighbourhood according to its street pattern.

Name of housing subdivision	Size of housing subdivision			Year of development			Type of housing subdivision		Type of housing development		
	Less than 50 hectares	50 – 100 hectares	More than 100 hectares	Before 2000	2000 - 2009	After 2010	Gated or Guarded	Non-Gated or Guarded	Exclusive	Mixed	Affordable
Flowery Polar Chart											
Horizon Hills			√		√		√		√		
Star-Like Polar Chart											
Taman Nusa Bestari Jaya	√				√		√			√	
Cross-directional Polar Chart											
Taman Universiti			√	√				√			√
Unidirectional Polar Chart											
Taman Nusa Perintis III		√			√			√		√	

The first section represents housing subdivisions with a flowery pattern polar chart. Generally, these housing subdivisions can be described as large, having a size of more than 100 hectares except for Taman Nusa Perintis II. They are considered as relatively new development. These type of housing subdivisions, whether it is gated or guarded, or non-gated or guarded housing subdivisions do not affect the resultant polar charts. The results however indicate a clear pattern of exclusive housing subdivisions and mixed housing subdivisions which produces this type of polar chart pattern due to curvilinear street designs often found in these types of housing.

The second section of the table shows the list of housing subdivisions with a star-like polar chart pattern. Majority of housing subdivisions reflecting this pattern are relatively smaller i.e. less than 50 hectares and large-scaled housing subdivisions with over 100 hectares in size. Most of the housing subdivisions in this category are non-gated or guarded housing subdivisions, developed at the beginning the year 2000 until 2019. The pattern of housing developments is more inclined towards mixed developments made up of low, medium and high cost housings which resulted in a mixture of winding roads and iron grid structures.

The cross-directional polar chart patterns are explained in the third section of the table. The size of the housing subdivision does not influence the pattern as they consist of small, medium and large sized housing subdivisions. However, the non-gated or guarded housing subdivision is proven to be a significant aspect of this polar pattern. These housing subdivisions are made up of mostly affordable and mixed housing with a strong grid-like road structure with high street connectivity.

The unidirectional polar chart pattern is only observed in Taman Nusa Perintis III. This is due to the orientation of the major road structure of the housing subdivisions which only points to one direction and the remaining streets are of a shorter street pointing into different orientations.

A comparison of the aspects which influence the street orientation of the housing subdivisions shows that while the size of a housing subdivision does not really influence the street orientation, the year of development does show some impact on them. It is becoming more apparent that streets are being oriented in a more star-like and flowery pattern from the year 2000 till 2019. While the type of housing

subdivisions does not really influence the street orientation, it can be seen that gated or guarded housing subdivision have a higher number of flowery and star-like polar charts. This is also supported by the next analysis where flowery pattern of polar charts is often found in exclusive housing developments while cross-directional patterns are generally associated with affordable housing developments. That said, if an area has high population of lower income communities, it can likely influence the street design of housing subdivisions targeting such community.

4.4. Characteristics of the polar charts
The analysis suggests that a flowery pattern of polar chart can be generally associated to large, gated and luxurious housing subdivisions. A star-like polar chart on the other hand, is generated from either small or large housing subdivisions which are non-gated or guarded and developed in recent years. These charts appear in mixed housing subdivision where there are precincts of affordable housings, medium cost houses and high cost houses. A cross-directional pattern polar chart is usually a product of a non-gated or guarded affordable housing with a strong grid-iron street network.

Findings of the analysis also show that the star-like pattern would be the preferable street orientation design since it is a cost effective and environmentally friendly design. Even though such housing subdivision pattern seemed to have higher pedestrian-vehicular crashes, such street layouts which have a relatively higher number of cul-de-sacs create a higher perceived safe environment. The star-like patterns can also be seen to be North-South-East-West orientated signifies that it is moving towards a sustainable housing subdivision design by taking into consideration the orientation of housing lots. When compared to the cross-directional polar charts which are perceived to be the best oriented street design, taking into consideration other aspects such as livability or cost efficiency, the star-like pattern would emerge as the most beneficial orientation.

5. Conclusion
This study has identified the factors which affects street orientation in a housing subdivision under the jurisdiction of Majlis Bandaraya Iskandar Puteri. As the street orientation of any housing subdivision is influenced by its street pattern, urban planners should take into consideration of this aspect in the future street design. of housing subdivision for a more sustainable and energy-efficient development. Streets of a housing subdivision should be designed by aligning them in approximately East-West direction to gain the maximum solar benefits. The preferable street orientation to achieve both the best housing orientation with a freedom of designing curvilinear street pattern, cul-de-sacs and reduction of infrastructure costs would be the star-like pattern where it is usually warped parallel or loops and lollipops street pattern. Well-designed streets which consider their orientation would result in a higher mobility and create an environment which promotes walkability with a higher level of comfort such as better urban road microclimate with North-South oriented roads. A star-like pattern can also be seen to be more North-South-East-West oriented than the flowery pattern and signifies housing developments in line with sustainable housing design. While cross directional street orientation does benefit in having the most ordered pattern, however, it lacks the freedom of a curvilinear street pattern and with mostly grid street network, it promotes the vehicular movement in the area.

This study recognizes that the impacts of street design are equally important as the factors which influence street orientation of a housing subdivision. It is therefore recommended that a study is undertaken to further understanding on how street orientation affects energy use in a housing subdivision using patterns of polar chart and the energy-efficiency of the housing subdivisions is undertaken. This can assist urban planners to plan for a lower carbon emission residential development to further contribute to better future environment.

References

[1]   Grammenos F, Pogharian S and Tasker-Brown J 2002 Residential street pattern design *Socio-economic Series* 75 Canada Mortgage and Housing Corporation Available at https://ideas.repec.org/p/wop/pennzl/389.html#download Accessed 12-01-2020

[2]   Hooper P, Knuiman M, Foster S and Giles-Corti B 2015 The building blocks of a 'Liveable Neigbourhood': Identifying the key performance indicators for walking of an operational planning policy in Perth, Western Australia *Health & Place* **36** 173-83 DOI: 10.1016/j.healthplace.2015.10.005

[3]   Jabatan Perancangan Bandar dan Desa Semenanjung Malaysia 2011 *Garis Panduan Perancangan Perumahan* [online] Available at https://www.townplan.gov.my/index.php/garis-panduan-perancangan/2093-15-gpp001-a-gpp-perumahan Accessed 12-01-2020

[4]   Villanueva K, Giles-Corti B and Mccormack G 2008 Achieving 10,000 steps: a comparison of public transport users and drivers in a university setting *Preventative Medicine* **47** 338-41 https://doi.org/10.1016/j.ypmed.2008.03.005

[5]   Mazlan A 2017 *The Relationship Between Street Pattern and Neighbourhood Travel Characteristics* [Thesis on the internet] Universiti Teknologi Malaysia Available at http://eprints.utm.my/id/eprint/78931/ Accessed 12-01-2020

[6]   Al-Jumaili S K M 2014 Street orientations: The first step towards a sustainable place *American Journal of Environmental Protection* **3** 305-17 DOI: 10.11648/j.ajep.20140306.12

[7]   Ismail A S and Muslim M M 2017 An assessment of user perception towards the need of ecology design for middle income housing in urban context *Journal of Advanced Review on Scientific Research* **36** 8-24 Available at http://www.akademiabaru.com/doc/ARSRV36_N1_P8_24.pdf Accessed 12-01-2020

[8]   Roufechaei K M, Abu Bakar A H and Tabassi A A 2014 Energy-efficient design for sustainable housing development. *Journal of Cleaner Production* **65** 380–88 DOI: https://doi.org/10.1016/j.jclepro.2013.09.015

[9]   Marshall W E and Garrick N W 2011 Does street network design affect traffic safety *Accident analysis prevention* **43** 769-81 DOI: https://doi.org/10.1016/j.aap.2010.10.024

[10]   Majid J F and Nordin A N 2011 *Neighbourhood Design and Vmt: Is Malaysia Planning To Achieve the Spirit of New Urbanism?* pp. 1–11 Available at https://pdfs.semanticscholar.org/21f8/87b61c375b31dca14dfe6187f0ad961674c4.pdf Accessed 12-01-2020

[11]   Southworth M and Owens P M 1993 The evolving metropolis: Studies of community, neighbourhood, and street form at the urban edge *Journal of the American Planning Association* **59** 271-87 https://doi.org/10.1080/01944369308975880

[12]   McGee C, Reardon C and Clarke D 2013 Passive design: Orientation *YourHome* [online] Available at https://www.yourhome.gov.au/passive-design/orientation Accessed 14-01-2020

[13]   Lojuntin S. A. 2018 Northern Region @ Pulau Pinang *Introduction of Low Carbon Buildings*. Available at https://efit.seda.gov.my/?omaneg=0001010000000101010100010000100000001010000100 0110&id=3550 Accessed 14-01-2020

[14]   Abdullah J, Yahaya M Z, Yunus M Z M and Safudin M S Md Ali 2009 Urban sprawl in Malaysia: Evidence from three largest metropolitan areas *Planning Malaysia Journal* **7** 69-82 DOI: http://dx.doi.org/10.21837/pmjournal.v7.i1.72

[15]   Worley S V 2014 Crayon the Grids *Arch Daily* Available at https://www.archdaily.com/562808/enter-the-mesmerizing-world-of-rainbow-coloured-maps-with-crayon-the-grids Accessed 12-01-2020

[16]   Boeing G 2017 OSMnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks *Computers, Environment and Urban Systems* **65** 126–39 DOI: 10.1016/j.compenvurbsys.2017.05.004

[17]   Agafonkin V 2018 Visualizing street orientations on an interactive map *Points of interests* Available at https://blog.mapbox.com/visualizing-street-orientations-on-an-interactive-map-1eefa6002afc Accessed 12-01-2020