A GIS Approach:
Determinant of neighbourhood environment indices in influencing walkability between two precincts in Putrajaya

Diyanah Inani Azmi\textsuperscript{a,}\textsuperscript{*}, Puziah Ahmad\textsuperscript{b}

\textsuperscript{a}Centre for Environment-Behaviour Studies,\textsuperscript{b}Centre for Town and Regional Planning Studies, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Shah Alam, Malaysia

Abstract

This paper intends to fill the gaps between community facilities planning in the neighbourhood area with walkability using GIS approach to encourage more sustainable environment for all. Several studies have outlined that there are three main neighbourhood environment indices that can contribute towards improving neighbourhood walkability that are (1) residential density; (2) Landuse mixed and (3) street connectivity. The aim of this paper is to determine the neighbourhood environments indices that can influence neighbourhood walkability to reach the community facilities provided in the neighbourhood area. GIS approach was used to utilize neighbourhood environment through layout plan. The significant findings in the paper will show that residential density, street connectivity and non-residents components of mixed land use do affect the neighborhood walkability.

1. Introduction

Walking is an activity that most of people engaged in. Walking was the only way for majority of people to go about their daily life. Although there are distinct advantages to that way of building and

\textsuperscript{*} Corresponding author. Tel.: +60126670274; fax: +0-000-000-0000.

E-mail address: diyanah_inani@yahoo.com
traveling, it does make walking much more difficult and often more unpleasant. Much attention has
devoted to the interaction between land use and travel behaviour as the traffic congestion problems and
automobile travel continue to mount in communities nationwide. There is growing interest in
understanding the relationship between attributes of the built environment and habitual physical activity
especially walking. Numerous studies have found that built environments variables such as diversity of
destination, residential density, walking facilities, esthetics, convenience and safety to walk are
characteristics that positively related to walking (Cerin, Saelens, Sallis, & Frank, 2006).

Walking is seen as the activities that offering less risk of heart disease, weight control , less risk of
high blood pressure, less risk of diabetes, less depression and anxiety, less risk of cancer and less risk of
osteoporosis. According to Tee (2002), Kuala Lumpur are ranked as the third highest in level of obesity
between 12 other Asian cities. Two years later, a national survey on the prevalence of obesity among
Malaysian adults recorded that there had been a 280 percent increase in obesity since the last survey in
1996 (Lekhraj, 2007). Moreover studies done by Ministry of Health in 2010 presented a statistics that
showed 60 percent of Malaysia population are overweight. This can be argued that there are certain
factors that contribute to low interest of Malaysia people towards walking activities.

Walkability term was derived from walking ability of human being. There are several definitions of
studies that define the walkability. According to Abley (2005), walkability can be defined as “the extent
to which the built environment is friendly to the presence of people living, shopping, visiting, enjoying or
spending time in the area”. According to Frank et al. (2006), walkability is also dependent on walking
behaviour of the residents in the neighbourhood area. According to Gebel et al. (2009), walkability refers
to how ‘friendly’ the area is for pedestrians. Compact, connected urban environment with a mixture of
densities and land uses create a shorter distance between desired destinations, thus encourage people to
walk for transportation.

Walkability affected by the design of the built environment and its features. Relevant community
characteristics typically reflect proximity between places and ease of travel between places (Norma et al.,
2006). Neighbourhood environment is an important element in assessing neighbourhood walkability.
Numerous studies have found that neighbourhood environment indices such as residential density,
destination near homes (mixed land use planning) and street connectivity are related to walking. Several
literature reviews have repeatedly stated that neighbourhood environment indices are related to physical
activity such as walking(L. Frank et al., 2006; K Gebel, Bauman, & Petticrew, 2007; Transportation
Research Board, 2005)

There are many studies that have worked to identify the variables of walkability that give great
influence in designing the built environment in a way that will help increasing walking activities within
the neighbourhood. Therefore, whether a trips purpose is for utilitarian or recreation, as long as an
individual is walking then some health benefits can be accused.

2. Neighbourhood Environment

Neighbourhood environment indices can be measure with geographic information system (GIS) and
self-reported instruments such as questionnaires (Shigematsu et al., 2009). GIS derived type in measured
walkability consists of indices such as residential density, land use mix, retail floor area ratio and street
connectivity. While, self-reported instrument can captures pedestrian environments such as presence and
conditions of sidewalks, aesthetics and safety from crime and traffic.

Studies by Frank et al., (2005); Leslie et al., (2006) claim the same findings as the determinants of
neighbourhood environment to measured walkability are residential density, land use mix and street
connectivity. It also stresses out that; essential elements of ‘high walkable’ neighbourhood are high street
connectivity, high land use mix and high residential density. These neighbourhood environment attributes
can be assessed objectively using geographic information system (GIS) software or neighbourhood observational data (Leslie et al., 2007).

Residential density was evaluated as the number of households per square kilometre. People tend to walk instead of driving if they live in high density where travel by automobile is hinder by congestion and lack of parking space. People tend to walk in low density area if the area near water where the natural surrounding is quiet and the view changes continually (Untermann, 1984). Increase neighbourhood density also is the conventional theory that supports the decrease of trip distance, increase in walking activities and overall automobile use may decline. Moreover, residents in denser communities with greater street connectivity and more land use mix reported higher rates of walkability for utilitarian purposes than residents from low-density, poorly connected and single land use neighbourhoods (L. Frank et al., 2006; Saelens, Sallis, Black, et al., 2003).

Street connectivity was defined as the number of intersections with three or more intersecting streets per square kilometre. The directness of travel routes between homes, shops, workplaces and other destinations. Neighbourhoods with grid pattern street networks typically have greater connectivity than those with curvilinear layouts. Walking for transport is encouraged when the street network is more connected, obstacles are kept to a minimum, and there is no requirement to cross major roads.

Land use mix access was defined as the number of residential, commercial, educational and recreational facilities in a radius of 800 meters (L. D. Frank et al., 2005). Walker wants to walk when they are attracted to mix used urban districts where there is activity involved people such as socializing. People are less willing to walk in single use, industrial areas, and single family suburbs, where the destinations are distant, and the unfolding view is monotonous.

Other than that, Saelens, Sallis, Black, et al. (2003) also outlines that communities characterized by higher residential density, a mixture of land uses and grid-like street patterns with short block lengths will engage in more walking than do people in the sprawling area. Moreover, Leslie et al. in 2005 (as cited in Pentell, 2009) listed five elements of neighbourhood environmental characteristic that have the correlation to walkability. The elements are:

- **Residential Density**
  Neighbourhood with high-density can encourage mixed-use development that will increase the variety of retail/services. It resulted in a shorter distance to reach it by walking between places.

- **Street Connectivity**
  High intersections densities provide more potential routes for walking and greater accessibility. It resulted in greater neighbourhood connectivity and shorter distances to destinations.

- **Landuse mix**
  Multiple and diverse retail/services opportunities encourage more specialized, frequent, and shorter shopping trips by foot. More land use mix means more varied and interesting built environment, creating neighbourhoods conducive to walking.

- **Public transit density**
  High public transit density provides shorter, more walkable distances to alternate modes of transportation. Use of more accessible bus stops encourage walking between leisure, work, and home.

- **Landuse crime density**
  High-density crimes discourage walking in the neighbourhood. Sense of lack of pedestrian safety encourages more protected automobile use and alternate transportation methods.

Various studies have also revealed that micro-features in an environment largely shape how accommodating an area is for pedestrian travel. The features are sidewalk infrastructure and condition, presence of trees for shading, safety features, street lighting, aesthetics and public transportation facilities (Clifton, Livi Smith, & Rodriguez, 2006).
Moreover, Khisty (1994) found seven factors for increasing the walking activities at pedestrian facilities such as attractiveness, comfort and convenience, population density, mixed land use, safety, system coherence (directness) and continuity. Studies by Handy et al., (2002) underlying six dimensions of the built environment that can affect the choice of walking such as 1) density and intensity, 2) land use mix, 3) street connectivity- directness and availability of alternative routes, 4) street scale, 5) aesthetic qualities and 6) regional structure (distribution of activities and transportation throughout the region). Ball et al., (2001) suggested environment variable to be correlates with walking activities includes features of the local neighbourhood such as convenient facilities, presence of the shop and parks, more aesthetically favourable and safe environment.

This paper will only cover the neighbourhood environment indices that measured with geographic information system (GIS) which are residential density, mixed land use and street connectivity.

3. Methodology

The purpose of this study is to identify the neighbourhood environment indices that influence residents walkability in two different urban neighbourhood in Putrajaya. The study is conducted in an urban neighbourhood area at Precinct 8 and Precinct 9 in Putrajaya. Putrajaya is a planned city, located 25km south of Kuala Lumpur which serves as the federal administrative centre of Malaysia. The overall land use of Precinct 8 is 268 hectares while Precinct 9 is 185 hectares. This paper used the Geographical Information System (GIS) approached to collect and analyses the data. Each study area was divided into three neighbourhood units known as NA1, NA2 and NA3 (refer Fig.1 (a) and 1(b)). The neighbourhood size and the boundary is determined based on the Green Neighbourhood Guidelines by Federal Department of Town and Regional Planning Malaysia. The guideline stated that the neighbourhood boundary or size is the measure by 400 meters of walking radius range from the centre to the edge of the precinct boundary.

![Fig. 1. (a) Neighbourhood units of Precinct 9; (b) Neighbourhood unit of Precinct 8](image-url)
3.1. Research Instrument

The type of a research instrument used to collect the data known as Ground Truth Verification. Ground Truth Verification was defined as any validation of mapped data against true ground conditions. Ground truth verification is usually the observations or measurements made at surface of the earth in support of the remote sensing data and GIS analysis. It may also refer to as ancillary data or reference data. It is a method with high accuracy in defined the geographic attributes being judged; usually applied to 'point' classified into a land use/land cover category (Chrisman, 1997). The purpose of acquiring the ground truth verification is to aid calibrating and interpreting remotely sensed data or GIS data by checking realities (Shekhar, 2001).

This research paper used Putrajaya land use maps (secondary data) collected from Perbadanan Putrajaya that undergoes ground truth verification survey to ensure that the land use data attributes are up to date. The ground truth verification survey was carried out to update the classifications and the attributes of the land use map with the current land use available in the study area; Precinct 8 and Precinct 9. Then, the results from the ground truth verification are inserted into the map to provide the latest updated land use data and attributes before any GIS Spatial analysis was prepared.

3.2. GIS Spatial Analysis

GIS Spatial analysis was defined as a set of methods that the results change when the location of the object being analysed change (Longley et al., 2005). It also is described as a technique that can address spatial scale and spatial patterns of an event. There are two types of GIS Spatial Analysis used in this research paper known as buffering and thematic map analysis. Buffer analysis used to identify an area surrounding by geographic features. The process involves generating a buffer around existing geographic features and then identifying or selecting features based on whether they fall inside or outside the boundary of the buffer (“Buffer Analysis,” 2013). A thematic map is a type of map specially designed to show a particular theme connected with a specific geographic area (“Thematic Map,” 2011). These maps display spatial information to show the location and distribution of a specific phenomenon. Thematic maps convey patterns visually (Esri, 2013).

The types of GIS Spatial analysis used and the process of conducting the analysis for every tested indices used in this paper are outline in Table below (refer table 1).

Table 1. Process in conducting GIS spatial analysis in this study

<table>
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<tr>
<th>Indices</th>
<th>Explanation</th>
<th>Type of GIS spatial analysis</th>
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| Residential density| The size of neighbourhood boundary(400 meters) that is generate from buffering analysis used as a starting point to conduct this analysis. Thematic map was carried out using ‘Density’ attributes as the theme to show just types of residential density layers Different types of density that fall inside the buffer boundary are analyses. | -Buffering Analysis  
-Thematic Map |
| Road Intersection  | The size of neighbourhood boundary(400 meters) that is generate from buffering analysis used as a starting point to conduct this analysis. Total numbers of 3-to-4-way intersections that fall inside the | -Buffering Analysis |
4. Results and Discussion

The results are divided according to the three indices examined such as residential density, the road intersection and mixed land use. Mixed land use are divide into two analyses known as non-residential components of mixed land use and residential mixed land use.

4.1. Residential Density

Residential density in Putrajaya is calculated based on the gross density, where the number of dwelling units per acre of gross residential land. Gross density land includes land for street, parking, open space and non-residential buildings. Residential density can be divided into four categories which are; (1) Low density (1 – 8 units per acres), (2) Medium density (9 – 24 units per acres), (3) Medium high density (25 – 50 units per acres) and (4) High density (51-75 units per acres). Fig. 2(a) and (b) shown the residential density of both neighbourhood units where darker color indicated higher residential density.

The results specified that there is residential density do influence the walkability pattern in Precinct 8 and Precinct 9. The result for Precinct 8 explained NA1 contains only three types of residential density which are high density, medium high density and medium density. NA2 comprises the residential density from low density to high density. Meanwhile, NA3 comprises only two types of residential density that is high density and medium high density. It also showed that three (3) out of three (3) neighbourhood units with the majority of high density houses, whereas only one (1) neighbourhood units with the majority of medium high density houses.

The result for Precinct 9 represented that all three neighbourhood unit (NA1, NA2 and NA3) comprises there are two types of residential density such as high density and medium high density. It also showed that three (3) out of three (3) neighbourhood areas with a majority of high density houses. It concluded that Precinct 9 has higher number of high density houses compare to Precinct 8. Higher number of residential density indicating more walkable the neighbourhood area ((Frank et al., 2005; Pentella, 2009; Saelens et al., 2003))
4.2. Road Intersection

The result for road intersection is calculated by identifying the number of 3-to-4-way of intersections within the neighbourhood unit. The result for Precinct 8 showed that NA2 have a higher number of road intersection (58 road intersections) compared to other neighbourhood units. NA3 shows the lowest number of road intersection (18 intersections). Precinct 9 showed that NA3 have a higher number of road intersection (43 road intersections) compared to other neighbourhood units. NA1 shows the lowest number of road intersection (37 intersections). The result by Precincts exemplified that Precinct 9 have a higher number of intersection (122 road intersections) compare with Precinct 8.
In summaries, this road intersections result show the same pattern with result from walking trips within the neighbourhood as residents in Precinct 9 walk more than residents in Precinct 8. Moreover, Precinct 9 consist more high rise houses where higher number of short-cut within the housing area which make more access routes available to reach the community facilities by walking. Previous studies Saelens et al. (2003), (Pentella, 2009) and Frank et al. (2005) outlines that road intersection is associate with street connectivity. Higher number of road intersection (high intersection density) provides more potential routes for walking and greater accessibility. Greater number of street connectivity, shorter distances to destination (short-cut).

4.3. Mixed Landuse

There are seven types of community facilities are choosing to be analyses within the neighbourhood unit which are neighbourhood shop, park/recreational facility, elementary school, secondary school, community centre, surau(place of worship) and bus stop. Mixed land use result for non-residential components show that Precinct 8 showed that there are six (6) community facilities located within walking radius in NA1 except for elementary school. Whereas, only three (3) community facilities located within walking radius in NA2; which are park or recreational facility, elementary school bus stop. Only four (4) community facilities located within walking radius in NA3 except for neighbourhood shop, secondary school and community centre. In summarize, there are only two (2) community facilities available within walking radius in all neighbourhood unit which are park or recreational facility and bus stop in Precinct 8. In additional, there are 33 total units of community facilities available in Precinct 8.

The result for Precinct 9 showed that there are only four (4) community facilities located within walking radius in NA1 except for elementary school, secondary school and community centre. NA2 indicated all community facilities available within walking radius. There are also five (5) community facilities located within walking radius in NA3 except for neighbourhood shop and community centre. In summarize, there are only three (3) community facilities within walking distance in all neighbourhood unit which are park and recreational facility, surau (place of worship) and bus stop. In additional, there are 50 total units of community facilities available in Precinct 9.

Fig. 4. (a) Residential Mixed Landuse of Precinct 9; (b) Residential Mixed Landuse of Precinct 8
Fig. 3(a) and (b) showed the residential mixed land use whereby blue colour described bungalow houses, gold represented semi-detached, pink represented terrace houses, green represented apartment and purple represented flat houses. The result for residential mixed land use explained that Precinct 8 showed that there are three (3) types of houses in NA1; which are semi-detached, terrace and flats. NA2 comprises with the highest number in the type of houses with four (4) housing types consist of bungalow, semi-detached, terrace and apartment. However, NA3 shown the lowest number in the type of houses with only one housing type which is apartments. Precinct 9 explained the same result for all three neighbourhood area (NA1, NA2 and NA3) involves only two (2) types of houses consist of terrace houses and apartments.

Mixed land use result for non-residential components concluded that Precinct 9 have higher availability of community facilities within 400 meters of walking radius in the neighbourhood units compared to Precinct 8. Other than that, Precinct 9 also has the higher number of community facilities located within the Precinct compared to Precinct 8. Previous studies by (Leslie et al., 2005; Lund, 2003; Pentella, 2009; Saelens et al., 2003) indicate that the mixed land use of retail, commercial, civic and variety of housing types contribute in encouraging residents to walk in the neighbourhood area. It also stresses out that destination located in proximity between community facilities and to residential uses help in increasing the level of walkability within the neighbourhood area.

However, residential mixed land use can be summaries that Precinct 8 has more variety in the type of houses as compared to Precinct 9. The result in this study shown different pattern associated to the literature review. This is because the result in this studies shown that residents in Precinct 9 making more walking trips rather than residents in Precinct 8.

5. Conclusion

This paper concluded that the neighbourhood environment indices listed that have been analyses which are residential density, street connectivity and non-residential component of mixed land uses do influence the residents walkability pattern in Putrajaya neighbourhood area; Precinct 8 and Precinct 9. Moreover, the higher number of residential density, the higher number of street intersection and the higher availability of community facilities located in Precinct 9 compared to Precinct 8 neighbourhood area. This study only covers three neighbourhood environment indices in measuring the neighbourhood walkability within the neighbourhood area. Further research need to be undertaken to cover other indices that may also influence the neighbourhood walkability in the neighbourhood area.

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