Walkability Index in Pasir Gudang by using GIS

Akmal Azizi Ahmad, Nabilah Naharudin*
Centre of Studies for Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

nabilahnaharudin1290@uitm.edu.my

Abstract. Walkability is defined as the level of comfort of an environment can be provided to people so they can walk to their destination. Walkability also supports community health, safety, liveability and reduce car dependence. Walkability is vital due to urban growth and the increased number of vehicle used. Walkable city promotes the residents to walk more in their neighbourhood. In addition to that, a walkable city promotes an active transportation in the era that seems to be very much car reliance. This study aims to measure the Walkability Index in the city of Pasir Gudang while addressing a question; i) How can the Walkability Index be measured? Hence, a new index was developed to address the question. The Walkability Index is calculated for every neighbourhood in Pasir Gudang by using the 3D criteria, Dwelling Density, Land Use Diversity, and Intersection Density. The index was classified into five categories from the lowest to the highest index.

1. Introduction
Walking is a form of transportation, with physical activity that has a healthy “side-effect”. It is the most common moderate-intensity activity for adults and as it is associated with substantial health benefits. Both walking for transport and walking for recreation or exercise can contribute significantly to adult’s total physical activity [1]. Apart from health benefits, walkability also enhances the sustainability of a city in terms of transportation. Enhancing active transportation mode such as walking, and cycling can contribute to the reduction of carbon emission thus will help in making environment greener. However, the question is, how to encourage people to walk?

Therefore, an understanding in the physical environmental barriers and facilitators of this personal mobility is considered as a prerequisite in creating a neighbourhood that can help in improving public health. The relationships between urban form and physical activity have been explored in various cities in an attempt to measure the walkability level of a certain city [2]. For example, a study conducted under the title of Measuring the Unmeasurable: Urban Design Qualities Related to Walkability in the New York city [3].

Walkability refer to the level of comfort an environment can be provided to people so that they can walk to their destination. Walkability supports community health, safety, liveability and reduce car dependence. Thus, many studies had attempted to measure the walkability index which can be derived from various criteria as physical characteristics of the urban environment that supports walking such as residential density and residential mix and intersection density. The walkability is very useful in planning for urban area that can maintain sustainability. High value of walkability index means that a particular arrangement of the city supports physical activity of people whilst the low value of walkability
index means that people very often use cars in the everyday life which results into minimum physical activity [4]. Apart from that, when the area has a good walkability, it is also said to be safe for people to walk.

Pedestrian crashes might be able to be reduced when the area is walkable. It is known that the highest number of generated trip is for working purposes. Pasir Gudang is known as industrial area where many people need to travel to go to their workplace. Walking can be an alternative rather than relying on motor vehicle to enhance the city’s sustainability as walking will not lead to carbon emission. The area was also chosen as Pasir Gudang has started its own program of Safe City Program that encourages the residents to walk more. So, pedestrians in the neighbourhood in Pasir Gudang will feel safe to walk and to carry out daily routine.

Thus, this study will attempt to measure the walkability index for Pasir Gudang, Johor. This is to promote active transportation in the area that seems to be very much car-reliance. In addition, the area also had reported several accidents involving pedestrian. Thus, there is a need to study how walkable Pasir Gudang actually is by using GIS.

2. Literature Review

2.1 Definition of Walkability

Sustainable transportation has been listed as one of the Sustainable Development Goals (SDGs). It is important to ensure that transportation did not contribute much to carbon emission. Therefore, many cities across the globe had been really committed in promoting active transportation rather than vehicles emitting carbon. However, it is not easy to encourage people to walk due to safety and comfort issue. Therefore, a term walkability had been introduced. It can be defined as the degree to which the built environment encourages walking by providing pedestrian comfort and safety, linking people to multiple destinations within a short time and effort and offering visual interest in journeys throughout the network [5].

Walkability can be interpreted by any means, one of them is walkability is a situation by which walking is enabled, areas being traversable, compact, physically enticing, or safe [6]. It is about the level or a value of a walkable environments that allows a certain place to be livable and sociable which provide an excellent level of transportation between area in a city. The key here is developing a liveable city, not only sustainable city. It is undoubtedly important for a city to be developed to support economic growth. However, it is also important to ensure its liveability to ensure the good quality of life. Thus, walkability, can be one of the components in making a city liveable.

2.2 Concept of Walkability

Walking can be a physical activity or a form of active transportation. In the context of transportation, walking has been the main form of transportation since the early ages. Although until now, there are massive increase of number of vehicles, interchange of places by walking is still carried out by human. This is because, people need to walk to access other mode of transportation. For example, when someone decide to ride bus or train to go to their workplace, he still needs to walk to access the station and upon alighting from the bus or train, he still needs to walk to reach his workplace. Therefore, whatever it is, walking is still considered as the most important mode of transportation. Therefore, it is important to make a walking environment to actually be walkable for people.

Walkability can be defined in many ways. One way to understand it is the basis of sustainable city, where it is measured by determining how friendly an area is to walking. It mainly depends on the quality of pedestrian the pedestrian facilities, land use patterns security and comfort for walking [7]. People might be reluctant to walk when they feel insecure to walk or when they think they rather drive instead of walking. This might be due to the pedestrian environment itself which did not encourage them to walk. Thus, a pedestrian environment should encourage people to walk.

Walkability act as the foundation for the sustainable city where without walkability, resources conservation would not be possible [5]. A highly walkable environment could also invites walking by many connected street connections that provides access for people to go on daily basis. He also added
that high walkable city is a safe and comfortable where there are easily crossed streets for people from the young ages to the old. Apart from supporting sustainable transportation, a walkable environment also will support the other SDG which is equality. Everyone should have equal opportunity in accessing public facilities, walking path is no exception where it should be able to support the demand from various age groups.

Walkability is often related to the built environment design that consider social and community interaction. Thus, it can also be divided into few dimensions where the first one is related to the community environment as to create walkability [6]. The second definition is related to perceived outcomes of walking where the last is defined as walkability is used as a kind of proxy for better design. From this, it can be seen that the definition of walkability is not limited as it can be defined into many meanings.

2.3 Benefits of Walkability
Walkability have been associated with many benefits, from health, social, economic and environment. The focus on walkability research in the recent years or so has been focusing on the health, economic and environmental aspect. Walkability has been increasing people’s health especially during the last ten years [8].

Walkability can be beneficial for environment as it is a part of sustainable transportation where no carbon will be emitted when someone walks. There are differences in air quality between area with high walkability and low walkability [9]. The higher the walkability of an area, the lower rate of air pollution index in that area and vice versa.

High walkability environment can also affect the social capital among the neighborhood as well as physical and mental health [10]. In addition, residents living in high walkable neighborhood are likely to know their neighbour tends to participate politically, trust each other and also likely to be involved socially. This is because, pedestrian-oriented neighbourhoods increase individual and collective social capital [11]. Apart from that, a greater social capital can lead to the declination of crime rates and economic activity went the opposite because in pedestrian oriented community, residents are likely to walk to desired places in a high walkable city. Walkable environment promotes positive impact on neighborhood social environment [12].

Living in high walkability neighbourhood can be regarded as attractive because of its lively and sociable, pleasant, clean and full of interesting people [7]. Moreover, a high walkability neighbourhood is beneficial for environmental since car usage is likely low [13]. Thus, this is somehow beneficial for the residents since there is low usage of vehicle, there will be low amount of air pollution.

The concept of walkability brings many benefits from improving the level of safety of the streets, decreasing the environmental air pollution, traffic noise or vibrations [14]. To add more, if the concept of walkability is successfully implemented, it will helps reducing the scale of difference in the usage of means of transport while balancing the transport system load.

2.4 Walkability Criteria
Walkability Index is the measurement of how to evaluate the walkability of a certain city. It has been applied worldwide in most of the major city. Before defining the Walkability Index, few criteria must be considered to determine the walkability score. This is because, there are many factors that influence walkability. However, there are still no standard set of criteria that can be used in measuring walkability. Different study will use different criteria. This is due to the different aim and objectives of the study as well as the need to fulfill the need and requirement of the demand in particular area. However, most studies used 3Ds as criteria in measuring walkability which are Intersection Density, Land Use Diversity and Dwelling Density.

2.4.1 Dwelling Density. Dwelling density is also as important as other criteria similar to land use diversity and intersection density. This is due to walking for transport will become more practical as
destinations are closer together in a more compact environment which helps since interchanging between places takes less time [15].

Urban density is a key property of walkability because it concentrates more people and places within walkable distances [16]. Density is difficult to measure since it is not accurately representing the number of residents [17]. So, in this study, the dwelling density calculations will be represented by the percentage of residential area in the study area.

Dwelling density is important in calculating or determining the walkability index. In example, higher density neighborhoods usually involve various development which supports greater retail and service where it reduces the distances between facilities with more walkable distances [15]. In fact, high density neighborhoods makes driving and parking takes longer time than walking.

2.4.2 Intersection Density. Road intersection density is one of the major indicators to determine walkability. It has been widely used because it visualizes how the area is inter-linked. Intersection Density can be defined by the number of intersections per square kilometer at a local scale where intersections are the junctions at which three or more roads intersect to each other [18].

Intersections are identified from the street centreline data and connectivity is based upon the number of route choice available at each intersection [15]. Intersections with 3 or more choices are the only included in density intersection calculation where the intersection density is measured from the number of intersections per square kilometre.

High Intersection Density is important because it shorten access distances and provide more routing options for transit users and transportation service provider [3]. Intersection density is also important for walkability study as it will help in determining the value or a walkability level for the certain place. Intersection densities influence the walkability since in high intersection density area, there will be better connectivity between streets or directness of routes between residential, stores and workplace [15]. This makes walking from one place to another place is very convenient for the residents.

2.4.3 Land Use Diversity. Measurement of land use is complex to be calculated because it uses two different that are land use and also zoning [15]. The former is the current type of land use whilst the latter is the reserved land by the local government to control the type of the land. It is mostly categorized to each function such as residential, industrial or recreational.

Land use diversity describes the land uses in geographically defined areas [17]. The definition is mostly similar to the other study by [15] where the measure of land use mix typically include the type of the land used. Land use also plays a major role in determining the walkability index as it also can be seen from previous studies.

The diversity of land use is important to indicate the walkability of an area as it will show various landuses that can be accessed from the area by walking. This is to support different walking purposes. As people walk for different purposes, some for leisure, some to go their work, some to go to shops and some to go back to their home, it is important for an area to be well-accessible to these different land uses. With this, walking will not be only limited to certain purpose only.

2.5 GIS
GIS is a system of hardware, software, data, people and institutional tool for the data capture, storage, manipulation, analysis, modelling, retrieval, and graphic presentation of spatially referenced information. GIS uses sophisticated databases and software to analyse data by location, revealing hidden patterns, relationships and trends that may not be apparent in spreadsheets or using the standard statistical packages from epidemiology or the social sciences [19].

GIS has been widely used to solve various problems related to spatial environment. It led to new ways of thinking, dealing with problem involving geographical data. It provides other benefits for the user such as performing geographic queries in a straightforward and able to understand geo-based question and obtain the answer short time. Other than that, GIS helps in integrating different database into one environment and lastly GIS can provide requirements for the needs of the user [20].
In GIS, street connectivity can be analysed by using network analysis tools. Network analysis layer stores input and properties and is mainly used to obtain a result of a network analysis performed on network dataset. GIS networks consists of interconnected line and intersections that represent routes which contain attributes which helps in performing network analysis [21]. Hence, network analysis model helps in analyzing street connectivity.

Street connectivity refers to directness of links and the density of connections in path or road network will indicate to high connectivity environment. There are author eight (8) different types of connectivity measured in the study [22]. They are Street Density, Connected Node Ratio, Link Node Ratio, Average Block Length, Effective Walking Area, Gamma Index, Alpha Index and the last one Intersection Density which will be used in this study. The intersection density involves using the calculation of real nodes area which translates to a higher number of intersection density indicated a high number of intersection and high connectivity. The study analyse the connectivity measure using half mile buffer around a randomly selected tax lot where the analysis was conducted to compare the census tract connectivity measurement for a specific point within the tract.

Accessibility is considered as how close from a point to the main transportation system. A great accessibility is somehow determined by how wide of a variety of modes for travelling between a point to a destination, which translates to the higher the modes, the higher the accessibility will be. The time taken and money spent to interchanges place is also how accessibility is determined. Different types of accessibility measure have been used for studies. There are four of them which are opportunity-based measure, gravity-type measures, utility-based measure, and space time measures [23].

In addition, accessibility can be analysed by using an integrated GIS tool, Accessibility Analyst. Accessibility Analyst is an integrated GIS package which provides a flexible desktop GIS environment for accessibility analysis for a wide range of applications in urban transportation planning. Accessibility analysis involves selecting appropriate measure depends on the purpose of the study. GIS for accessibility analysis depends on the capability to model real world transportation networks based on the network data model through the spatial and network analysis functions. It also involves mapping the calculated accessibility values and linking the accessibility value with other socioeconomic data.

Reclassification, buffer generation and map overlay functions is used to determine the spatial unit for accessibility analysis by generating zones represented and also aggregate socioeconomic and land use data based on the spatial unit. The function of spatial measurement, proximity analysis and network analysis functions in GIS can work on the measurement travel by analyzing the shortest distance to particular destination [23].

3. Methodology

3.1 Dwelling Density

Dwelling density is a measurement to determine the value of residential density in particular area. High values of dwelling density implies a high number of residential area while a low value of dwelling density represents a low number of residential areas. In most cases, high density residential area is basically in the centre of the city where there will be a dense housing area with also a high number of commercial and recreational sites built around the area since there are more people to support the services where urbanization and centralization will occur. In this study, the Dwelling Density was measured by calculating the density of residential per km square within each particular neighbourhood or area as shown in Equation 1.

\[
Dwelling\ Density\ (DD) = \frac{\text{Number of Residential Area (km}^2\text{)}}{\text{Total Land Area (km}^2\text{)}} \tag{1}
\]
3.2 Land Use Diversity

Land use diversity index represent how diverse the usage of the particular area is. High diversity land use will have a high index while low land use diversity is because the area has low index [24]. The land use diversity index, $H(s)$, in this study was derived using Equation 2.

$$H(s) = -\sum_{i=1}^{k} \left( p_i \cdot (\ln p_i) \right)$$

where;

- $H(S)$: Land Use Diversity
- $p_i$: the area of a particular category of land use over the total area of all categories (within one district)
- $k$: the number of land use categories in the particular district

In this study, there were about fifteen (15) different types of land use from the data obtained from the local authority. However, in this case, the International Physical Activity and Environment Network (IPEN) methodology type and coding of land use will be used as the method to measure the land use diversity index. Similar method will be applied from the study by [24] where in the USA, each polygon represents one type of usage.

3.3 Intersection Density

Intersection density index or street connectivity index is a measurement to determine the street density in a particular area. Intersection density is calculated from the number of intersections of roads per square kilometre of total neighborhood land or in this case, the total land area in each neighborhood area.

High value of intersection density proves that the area has a high connectivity where it is typical for the city centre where there will be a high number of vehicles or any types of transportation. The opposite is the outskirts of the city where it is mostly will be a low connectivity since there are low number of vehicles compared to the city, hence it has the low number of intersection density. Intersection Density (ID) was calculated by;

$$\text{Intersection Density (ID)} = \frac{\text{Number of Intersections}}{\text{Total Land Area (km}^2\text{)}}$$

3.4 Walkability Index

Neighbourhood walkability is a calculation derived from the four (4) different indices. The indices are Dwelling Density or Residential Density Index, Land Use Diversity or also known as Land Use Mix or Entropy Index, Intersection Density or Street Connectivity Index and floor area ratio. These four (4) indices are the main variables for the measurement of the Walkability Index [25]. However, in this study, the floor area ratio was not used for the reason of data unavailability. Similar to other studies carried out previously where the studies were able to manages to measure the walkability index despite the methodological modification [26].

Walkability Index was measured from the total of the z-score from the 3Ds criteria. The criteria that was used to calculate walkability index are Dwelling Density, Intersection Density and Land Use Diversity. The Walkability Index was calculated by using the weightage summation technique, which summing-up all the 3Ds indices calculated earlier. The indices were considered as the weightage of walkability criteria. They were combined to derive the Walkability Index as described in Equation 4.
Walkability Index = \[(2 \times z - ID) + (z - DD) + (z - H(s))\]  \hspace{1cm} (4)

Where;

- \(z\) the z score for each criteria
- \(ID\) Intersection Density
- \(DD\) Dwelling Density
- \(H(s)\) Land Use Diversity

In order to determine the value of the Walkability Index. The z score of each criteria needs to be determined first. The z score for each criteria is a statistical Z-scores [unitless (mean = 0; SD =1)].

4. RESULTS AND DISCUSSION

4.1 Walkability Index

Figure 1. Map of Walkability Index
Figure 1 illustrates the map of Walkability Index in Pasir Gudang and Table 1 represents the Walkability Index of different neighbourhood in Pasir Gudang that were produced by using formula in Equation 4 that used three (3) different criteria in the calculation. The first criteria used were the Dwelling Density, Land Use Diversity, and Intersection Density. From the three (3) criteria, the formula of Walkability Index was used to calculate the walkability index for each neighbourhood.

Table 1. Walkability Indexes in Pasir Gudang

| Neighbourhood                  | Walkability Index | Classes |
|--------------------------------|-------------------|---------|
| Bandar Layangkasa              | 0.23              | 2       |
| Bandar Seri Alam               | 0.49              | 3       |
| Felda Cahaya Baru              | 0.18              | 1       |
| Johor Port                     | 0.14              | 1       |
| Kampung Bukit Dagang           | 0.38              | 2       |
| Kampung Kong Kong              | 0.16              | 1       |
| Kampung Kopok Baru             | 0.18              | 1       |
| Kampung Kuala Masai            | 0.32              | 2       |
| Kampung Pasir Gudang Baru      | 0.11              | 1       |
| Kampung Pasir Putih            | 0.37              | 2       |
| Kampung Sentosa                | 1.00              | 5       |
| Kampung Sepakat                | 0.29              | 2       |
| Kampung Sungai Latoh           | 0                 | 1       |
| Kampung Sungai Tiram           | 0.35              | 2       |
| Kampung Tanjung Langsat        | 0.05              | 1       |
| Kawasan Perindustrian P. Gudang| 0.24              | 2       |
| Perindustrian Tanjung Langsat  | 0.38              | 2       |
| Sierra Perdana                 | 0.35              | 2       |
| Taman Air Biru                 | 0.41              | 3       |
| Taman Bistari Perdana          | 0.27              | 2       |
| Taman Bukit Dahlia             | 0.62              | 4       |
| Taman Bunga Raya               | 0.24              | 2       |
| Taman Cahaya Masai             | 0.5               | 3       |
| Taman Cendana                  | 0.57              | 3       |
| Taman Desa Rakyat              | 0.14              | 1       |
| Taman Flora Height             | 0.46              | 3       |
| Taman Kota Masai               | 0.66              | 4       |
| Taman Mawar                    | 0.42              | 3       |
| Taman Nusa Damai               | 0.48              | 3       |
| Taman Pasir Mas                | 0.28              | 2       |
| Taman Pasir Putih              | 0.57              | 3       |
| Taman Rinting                  | 0.49              | 3       |
| Taman Scientex                 | 0.61              | 4       |
| Taman Tanjung Puteri           | 0.51              | 3       |

The calculated value of the Walkability Index is the summation of the index for the three (3) criteria chosen for this study which are Dwelling Density, Land Use Diversity, and Intersection Density. The table also shows the walkability index for every neighbourhood that is in the city of Pasir Gudang. For this study, there are about 34 numbers of neighbourhood located in the district.

For the Walkability Index, the index was then normalized so that it will reduce the anomalies and reduce the difficulties in analysing the data. However, the normalized Walkability Index for this study does not represent the standard value of the Walkability Index but will illustrate the range of the Walkability Index for each neighbourhood which helps in understanding which among the neighbourhoods has the highest and lowest Walkability Index.
The Walkability Index is divided into five (5) different classification. For the visualization of the walkability index in the study, equal interval classification is used since the value of the index is uniformly increased. Hence, based on the calculation, 5 classes were used to visualize each range of value of the walkability index.

The first class is the neighbourhood that has the index that is below 0.2. The neighbourhood classified under this class are the Felda Cahaya Baru, Kampung Sungai Latoh, Kampung Tanjung Langsat, Kampung Pasir Gudang Baru, Taman Desa Rakyat and Kampung Kopok Baru. The first class has a lowest value of Walkability Index in the district, hence, based on the calculation, which indicates that they are the neighbourhoods with low walkability index.

The second class is the index that ranges from 0.2 to 0.4. The neighbourhood that has the walkability index below 0.4 are Bandar Layangkasa, Taman Bunga Raya, Kawasan Perindustrian Pasir Gudang, Taman Bistari Perdana. Taman Pasir Mas. Kampung Sepakat, Kampung Kuala Masai, Kampung Sungai Tiram, Sierra Perdana, Kampung Pasir Putih, Kampung Bukit Dagang and lastly Perindustrian Tanjung Langsat area.

The third class is the index that has the range between 0.4 to 0.6. In this range it is also the middle value for the normalized Walkability Index, indicating these neighbourhoods has the average value of Walkability Index. The neighbourhoods with the average value of Walkability Index are Taman Air Biru, Taman Mawar, Taman Flora Height, Taman Nusa Damai, Bandar Seri Alam, Taman Rinting, Taman Cahaya Masai, Taman Tanjung Puteri, Taman Cendana and Taman Pasir Putih.

The fourth class is the index that has the range value between 0.6 to 0.8. This classification indicates that the neighbourhoods has high Walkability Index among others in Pasir Gudang. The neighbourhood that in has the high walkability index is Taman Kota Masai, Taman Bukit Dahlia and Taman Scientex. Lastly, the fifth class which is the class that has the highest Walkability Index. The neighbourhood is KampungSentosa.

5. Conclusion

Walking as a fact has been proven can be beneficial towards our health, plus walking, has been a form of transportation used for long. A high walkability environment also enhances the sustainability of a city in terms of transportation. This study aims to measure the Walkability Index for different neighbourhood in Pasir Gudang, Dwelling Density, Intersection Density and Land Use Diversity are used as the main criteria to calculate the Walkability Index. Using the formula from the previous papers, the Walkability Index is measured from the three different criteria as mentioned before. The first criteria that is Dwelling Density is measured from the density of a population in each neighbourhood, Intersection Density is a measurement of how dense a neighbourhood with an intersection, and Land Use Diversity is measured from how diverse of a land use in the particular neighbourhood. Then, from the three factor, the Walkability Index were calculated. They were then normalized as to reduce complexity and reduce redundancy for the indexes. The objective is successfully achieved as the Walkability Index of Pasir Gudang has been measured. The result from the processing then classed into 5 different categories as to put it in a better form of representation. The study found that Kampung Sentosa is one of the highest neighbourhood that has a high Walkability Index followed by Taman Bukit Dahlia and Taman Scientex.

For the improvement of this study in the future, it is recommended that additional criteria can be used if there is any available, in example the Floor Area Ratio or Commercial Density. This criterion is one of the objective criteria that is not used in the study due to the data unavailability, however for future research, these criteria can be used as some additional criteria as it will create a better analysis for the study. In addition to that, the other subjective criteria can also be used in example, the Walking Behaviour or Socio Economic Status (SES). This additional factors can be used as to produce clearer and more accurate results as it will widen the scope of view for the analysis of the study.
References

[1] Owen, N., Cerin, E., Leslie, E., duToit, L., Coffee, N., Frank, L. D., . . . Sallis, J. F. (2007). Neighborhood Walkability and the Walking Behavior of Australian Adults. American Journal of Preventive Medicine, 33(5), 387-395.

[2] Stockton, J. C., Williams, O. D., Stamakis, E., Mindell, J. S., Brunner, E. J., & Shelton, N. J. (2016). Development of a novel walkability index for London, United Kingdom: crosssectional application to the Whitehall II Study. BMC Public Health.

[3] Ewing, R., & Cervero, R. (2010). Travel and the Built Environment. Journal of the American Planning Association, 265-294.

[4] Divbesova, Z., & Krivka, T. (2012). Walkability Index in the Urban Planning: A Case Study in Olomouc City. Advances in Spatial Planning.

[5] Southworth, M. (2005). Designing the Walkable City. Journal of Urban Planning and Development-asce, 131, 246-257.

[6] Forsyth, A. (2015). What is a walkable place? The walkability debate in urban. URBAN DESIGN International.

[7] Noriza, R., & Zahari, R. K. (2013). Perceptions of the Urban Walking Environments. Procedia - Social and Behavioral Sciences, 589-597.

[8] Hajna, S., Ross, N. A., Joseph, L., Harper, S., & Dasgupta, K. (2015). Neighbourhood walkability, daily steps and utilitarian walking in Canadian adults. BMJ Open.

[9] Marshall, J. D., Brauer, M., & Frank, L. D. (2009). Healthy Neighborhoods: Walkability and Air Pollution. Environmental Health Perspectives.

[10] Leyden, K. M. (2003, September). Social Capital and the Built Environment: The Importance of Walkable Neighborhoods. American Journal of Public Health, 93(9), 1546-1551.

[11] Singh, R. (2016.). Factors Affecting Walkability of Neighborhoods. Procedia - Social and Behavioral Sciences, 216, 643-654. doi:https://doi.org/10.1016/j.sbspro.2015.12.048

[12] Hun, H. J., & Hur, M. (2015). The relationship between walkability and neighbourhood social environment: The importance of physical and perceived walkability. Applied Geography, 115-124.

[13] Talen, E., & Koschinsky, J. (2014). Compact, Walkable, Diverse Neighborhoods: Assessing Effects on Residents. Housing Policy Debate.

[14] Turon, K., Czech, P., & Juzek, M. (2017). The Concept of a Walkable City as an Alternative. scientific Journal of Silesian University of Technology. Series Transport.

[15] Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A., & Hugo, G. (2007). Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes. Health & Place, 111-122.

[16] Dowe, K., & Pafka, E. (2018). What is Walkability?: The Urban DMA. Urban Studies.

[17] Croucher, K., Wallace, A., & Duffy, S. (2012). The influence of land use mix, density and urban design on health; A critical literature review.

[18] Xue, H., Cheng, X., Jia, P., & Wang, Y. (2020). Road network intersection density and childhood obesity risk in the US: a national longitudinal study. Public Health, 31-37.

[19] Ali, E. (2020). Geographic Information System; Definition, Development, Applications & Components.

[20] Chang, K. T. (2016). Introduction to Geographic Information Systems. New York: McGraw-Hill Education

[21] Das, D., Ojha, A. K., Kramasapi, H., Baruah, P. P., & Dutta, M. K. (2019). Road network analysis of Guwahati city using GIS. SN Applied Sciences.

[22] Tresidder, M. (2005). Using GIS to Measure Connectivity: An Exploration of Issues. Portland: Field Area Paper.

[23] Liu, S., & Zhu, X. (2004). Accessibility Analyst: an integrated GIS tool for accessibility analysis in urban transportation planning. Environment and Planning B: Planning and Design,
[24] Krivka, T., & Dobesova, Z. (2012). Walkability Index in the Urban Planning: A Case Study in Olomouc City. Advances in Spatial Planning

[25] Riberio, A. I., & Hoffimann, E. (2015). Development of a Neighbourhood Walkability Index for Porto Metropolitan Area. How Strongly Is Walkability Associated with Walking for Transport? International Journal of Environmental Research and Public Health.

[26] Sundquist, K., Eriksson, U., Kawakami, N., Skog, L., Ohlsson, H., & Arvidsson, D. (2011). Neighborhood walkability, physical activity, and walking behavior: The Swedish Neighborhood and Physical Activity (SNAP) study. Social Science & Medicine, 1266-1273.