The Assessment of Walkability Index in Urban Area Using Remote Sensing Data: A Case Study of Padang City

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ABSTRACT: Private vehicle users in Indonesia are increasing, so the space needed increases as the population increases. The city of Padang is one of the cities that has experienced rapid growth in private vehicle use. This study objectives were (a) mapping the walkability rate in some part of Padang City using Modified Walkability Index; and (b) analyze the parameters that influence the Walkability Index. The walkability index parameters in Padang City are obtained from Geoeye-1 imagery, i.e. building density, entropy index, connectivity, proximity, environmental friendliness, and vehicle traffic volume. Weighting is done by conducting interviews through questionnaires to pedestrian lane users to understand the condition of the parameters which are the most important priority for users. Taking interview samples using stratified sampling based on residential block density as a mapping unit in this study. Furthermore, the weighting of each parameter is determined by the Analytic Hierarchy Process, where decisions are taken using weights through relative comparisons in pairs continuously without any inconsistencies in the decision making process. In general, the AHP results show that the parameters of building density, entropy index, connectivity, proximity, and environmental friendliness sequentially from high to low indicate the preferences of some people in Padang City for factors that affect their comfort in walking. Based on the parameters, the Walkability Index value is divided into three classes, namely Low (1.00 - 1.52); Moderate (1.52 - 2.04); and Height (2.04 - 2.56). The results of the assessment of the questionnaire and accuracy test using confusion matrix resulted in the walkability index accuracy value of 75% accuracy. While the assessment of the most influential parameters on the walkability index is the proximity to public facilities with a value of 0.468, and the lowest is the parameter Environmental Friendliness (0.104).

1. INTRODUCTION

Indonesia is categorized as one of developing countries which has uncontrolled population growth as one of their issues. This issue is possible to lead imbalance between land use, increasing number of vehicles, road infrastructure

condition, and also public transportation especially in urban areas (Taleai dan Amiri, 2017). This can cause a direct impact to people which is emergence of problem related to mobility.

As the population grows, the use of private vehicle is also increasing (Badan Pusat Statistik, 2015). In recent years, Padang City as the capital of West Sumatera, has experienced the increasing of 600 private vehicles per month. That number clearly is concerning since there is limited capacity in a city to accommodate movement needs that keep increasing (Forman, 2008).

Walking capable to support activities in community. Besides, it also has a positive impact to environment, body, and soul. Walking as our means to move from one place to another can reduce the use of vehicles with oil fuel and also save natural resources so it can be allocated more precisely. Air pollution can also be reduced by walking. Walking is healthy activity that can reduce any risk of diseases and risk of distress for the urban community. Meanwhile, Indonesia is listed as a country which its cities are not pedestrians friendly (Gota, dkk., 2010). In addition, there are not many Indonesians who choose walking as their means to moving from places to places, even for a relatively close distance. This caused by environmental conditions that do not supported walking. Thereby, it reduces the individual interest to walk. So in order to be a walkable place for pedestrian, some condition must be considered such as distance between land use, distance between facilities, vegetation existence as a shade for pedestrians, and safety surrounding (Bhattarai, 2007).

Some efforts have to be made to fulfill the pedestrian's need, one of them is revamping the sidewalks which has become the focus of Padang City's government. Sidewalks revamping has to be done so that Padang City can be walkable for the pedestrians and people with disabilities. This sidewalks revamping is also included in 2014-2019 regional medium-term development plan (RPJMD) with a budget of 20 billion. Government's concern for pedestrians must be supported with accessibility factor in walking activity so that environmental condition can also supporting the carrying capacity of walking activity. This study objectives were (a) mapping the walkability rate in some part of Padang City using Modified Walkability Index; and (b) analyzing parameters which affecting Walkability Index in some part of Padang City.

2. MATERIALS AND METHOD

2.1 Data

Data obtained and selected based on closest time suitability with the assessment of field condition of walkability in Padang City, hence using these following data:

1. Geoeye-1 Imagery with recording date 2 Januari 2018 in some part of Padang City, with physical urban boundaries which obtained from Digital Globe;
2. Humanitarian OSM Data, showing the existence of building and facilities in some part of Padang City which obtained from OpenStreet Map site;
3. Padang City's street data from BAPPEDA, showing street types in Padang City;
4. Vehicles volume in Padang City's data, obtained with Google Maps which shows real-time traffic condition in Padang City.

2.2 Methodology

2.2.1 Walkability Index Parameter

- **Density**

Density that has the most influence in walkability of an area according to Agampatian (2014) is building density because the existence of building itself indicates the population density and the activities. The number of population and the activities will also have the potential for the emergence in of important facilities in the surrounding. This calculation method is also known as building area coverage (BCR) method with this formula:

$$BCR = \Sigma F/A \quad .....(1)$$

Where;

F = Area covered by building

A = Area of study

- **Entropy Index**

Entropy Index is a measure of "evenness" – how far is a group distributed evenly in between organizational unit (Massey dan Denton, 1988). Generally, Entropy Index is an index which is used for representing the mix of land use. Entropy generally quantifies homogeneity of land use in certain areas. Entropy is stated as :

$$Entropy = \sum_j P_j \; x \; \frac{\ln(pj)}{\ln(J)} \; ..... \; (2)$$

Where;

Pj = Road area proportion

J = total land use considered in study area

Entropy score shows heterogeneity rate of land use in a group's block. In this study, the mixture size is considering the seven types of land use.

- **Connectivity**

The higher the road networks connectivity, the more the volume of pedestrian (Hajrasouliha & Yin, 2014). This is because the more connected the roads and public facilities, the area will be more conducive to walking (Berrigan et al, 2010). Network connectivity represented by intersection density. Intersection density is the amount of intersection from each unit area. The bigger the amount of intersection on each unit area, the higher the area connectivity.

- **Proximity**

Proximity between public facilities and settlements is a parameter on the measurements of walkability. Public facilities proximity will encourage people to walk. Land use that considered its proximity in this measurement of walkability is restaurant, health facility, mall, market, sport facility, and school/university. Every public facilities will be made 1000 meter buffer.

- **Environmental Friendliness**

Pleasant and friendly environment around the pedestrian route can increase the appeal of pedestrian to walking. There are some factors which affect the environmental friendliness rate around the pedestrian route, which are the existence of shades tree and facility such as police station. According to WHO study in 2009, pedestrian route tends to be unsafe because of many accidents happen, mainly to kids and elderly people (Fabian dkk., 2010).

- **Vehicle volume**

Vehicle volume is the number of vehicles that pass a certain point or line on a cross section of the road. Vehicle volume is calculated based on the number of vehicles that cross a certain point in a certain unit of time (Sukirman,

1994). This vehicle volume affects the walkability index, where the denser vehicle volume that passes, it will reduce the value of the walkability index, and vice versa.

2.2.2 Segmentation

This image processing segmentation is used to create primitive objects as the first step in object-based image analysis using eCognition software that provides various algorithms for image segmentation. The method used in the segmentation stage is multiresolution segmentation, which is a method that uses the parameters of scale, color, shape, and compactness in producing segments (Danoedoro, 2012).

Multiresolution Segmentation algorithm is an optimization procedure that serves to minimize the average heterogeneity and maximize the homogeneity of each object in the image. This algorithm can be executed at an existing level to produce objects at the sub-level or super-level, or at the initial pixel level to create new image objects at new levels. This algorithm is bottom-up because it combines several pixels or existing image objects based on pairwise region merging technique.

The important parameter of this algorithm is the scale parameter, where this parameter determines the maximum spectrum heterogeneity allowed on the resulting image object. The scale parameter basically determines the size of the resulting image object. The higher the scale parameter number, the greater the size of the resulting object segment. Objects generated for heterogeneous data will be smaller than more homogeneous data even though the parameters are the same scale. Scale parameters refer to the homogeneity of the object, consisting of three internal parameters, namely color, shape and compactness (eCognition Reference Book, 2014).

2.2.3 Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is a semi-quantitative method in which decisions are made using weights through relative pairwise comparisons continuously without any inconsistencies in the decision making process (Saaty, 1980). To calculate weights for different criteria, AHP uses the pairwise comparison matrix A. Matrix A is the real matrix m × m, where m is the considered number of evaluation criteria. Each ajk matrix A entry shows the importance of the jth criteria relative to the kth criteria. If ajk > 1, jth criteria is more important than kth criteria. While if ajk < 1, jth criteria is less important than kth criteria. If two criteria have the same importance then the ajk value is 1.

2.2.4 Questionnaire

Questionnaire is a tool used for social research, one of the research is behavioral research (Pujihastuti, 2010). The questionnaire contains walkability index parameters that are distributed to pedestrian. The purpose of using questionnaire is to determine the weight value that will be used in the AHP analysis. The weighting is done by involving the pedestrian to understand the condition of the parameters that are the top priority, that is most considered for the user. The value given for each parameter will differ from one area to another depending on the psychological condition of the community and the culture of the people there.

2.2.5 Accuracy testing

Accuracy testing is performed using a confusion matrix. Confusion matrix is a matrix where the column and row shows the amount value of the unit sample in the form of integers, that are in certain categories in a classification (Congalton dan Green, 2009). Accuracy testing using this method is effective to represent map accuracy mainly from its semantic aspect. The accuracy value from the result of the classification of visual interpretation measured

from the overall accuracy, producer's accuracy, and user's accuracy. In addition, the results of the classification of visual interpretation will also be assessed by applying the kappa index (Zhan, dkk 2005).

$$\text{Producer's accuracy (\%)} = 100\% - \text{error of omission(\%)} \quad \text{..... (3)}$$

$$\text{User's accuracy (\%)} = 100\% - \text{error of commission(\%)} \quad \text{..... (4)}$$

3. RESULTS

3.1 Vehicle Volume

Most of the roads in the Padang city have a traffic volume that is not crowded with a number of 997 of a total of 1130 existing roads. A busy road section is a segment of the main road. There are 28 roads that are classified as busy. Roads that have a moderate traffic volume of 105 roads are roads that connect two main roads. Apart from data taken from real-time google maps traffic, direct observations in the field are also carried out at sample points, this is done to compare google maps data with reality on the ground. A busy traffic volume will affect pedestrian interest. A busy traffic volume tends to reduce pedestrian interest. Based on the results of interviews the reason this happens is that comfort is disturbed by pollution caused by the excessive number of vehicles.

3.2 Connectivity level

Intersection Density value is divided into three classes, that is Low (0 - 147.97); Medium (147.98 - 295.95); and High (295.96 - 443.93). The highest Intersection Density value will usually be associated with the use of urban residential land use as shown in Figure 3.1. The results of the division of existing classes then carried out scoring as in Table 3.1. The lowest Intersection Density value is given a value of 1 (one) which indicates that the connectivity in the unit area is low so pedestrian interest is assumed to be less, while the highest Intersection Density is given a 3 (three) value which indicates the connectivity in the unit area is high.

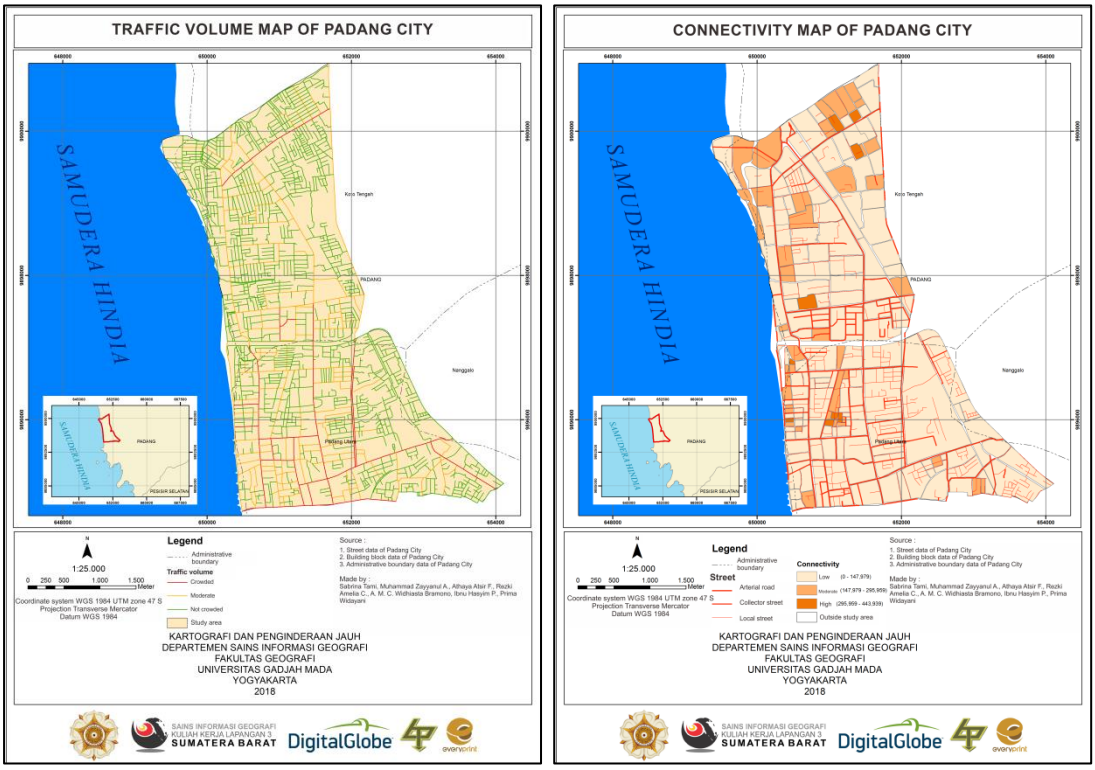

Figure 3.1 (a) Vehicle volume map (b) Connectivity level map

Class	Value	Score
Low	0 - 147,97	1
Moderate	147,97 - 295,95	2
High	295,95 - 443,93	3

Table 3.1 Connectivity level score

3.3 Proximity level

The public facilities used in this parameter are facilities used by the community in their daily activities, i.e restaurants, health facilities, malls, markets, sports facilities, and schools/universities. The relatively close distance from their home or initial location to their destination will encourage people to walk instead of using a vehicle. Mapping proximity to public facilities is done by buffering data points of public facilities as far as 500 meters.

3.4 Building Cover Ratio

In general BCR will produce a ratio from 0 to 1, in the study area the value of the ratio that appears is 0.1218 to 0.9997. The range between the lowest and highest ratios produced is quite large because the study area is an urban area in which there are many buildings, especially from settlements to office and school areas which are generally associated with the field. The value of the ratio of building densities is then tested to the field conditions by measuring directly on the area of the building and the extent of the residential block. Accuracy test results in the field produce an accuracy value of 81.48148%, where this value is good enough and can be used for further processing. Figure 4.4 shows the map of the distribution value of the building area of the study area, which is part of Padang City in percent unit (%).

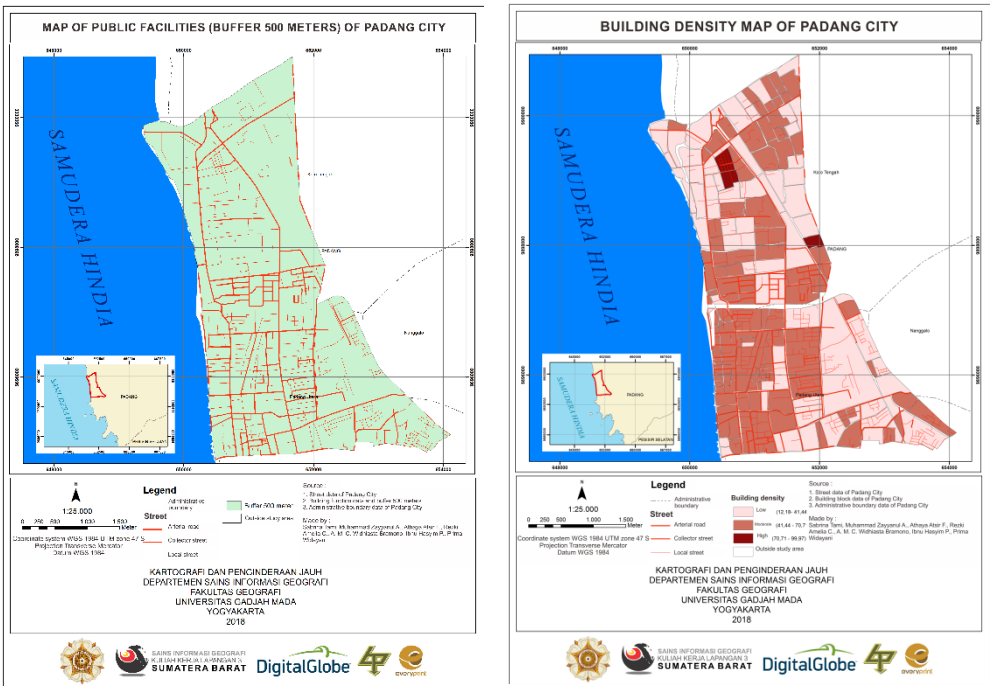

Figure 3.2 (a) Map of Proximity level from public facilities, (b) Map of building density

3.5 Landuse Classification

The rule set using object-based segmentation was originally designed to identify three main classes: vegetation, water and built-up land. Each class is classified based on the transformation of the NDVI vegetation index with the value of each land cover object listed in table 3.2. Land use classification is based on a 1: 50,000 scale land cover

mapping standard issued by the Geospatial Information Agency. The results of the classification of the segmentation process are further divided into 16 land use classes based on visual interpretation, that is:

1. Health facilities
2. Grassland
3. Hotels
4. Industry
5. Comercial
6. City residental buildings
7. Field or another open fields
8. Education
9. Office
10. Gas station
11. Rice fields
12. Railway station
13. River
14. Parks and recreation
15. Place of worship
16. Coverage natural or semi-natural vegetation

The results of the calculation of the accuracy test obtained the accuracy value of land use interpretation of 88.23%. Based on these results, the Geo-Eye 1 image can be said to qualify as a data source for calculation and mapping of walkability index. Landuse map can be seen in Figure 3.3.

Class	The object features used
Built-up land	• NDVI > 0 • NDVI ≤ 0.209
Vegetation	• NDVI > 0.209
Water	• NDVI < 0
Grassland	2nd Level; Class filter : vegetation • GLCM > 452 • GLCM< 560
Zinc roof building	2nd Level; Class filter : water • Enclosing class : built-up land

Table 3.2 The object image feature is used to classify various land covers

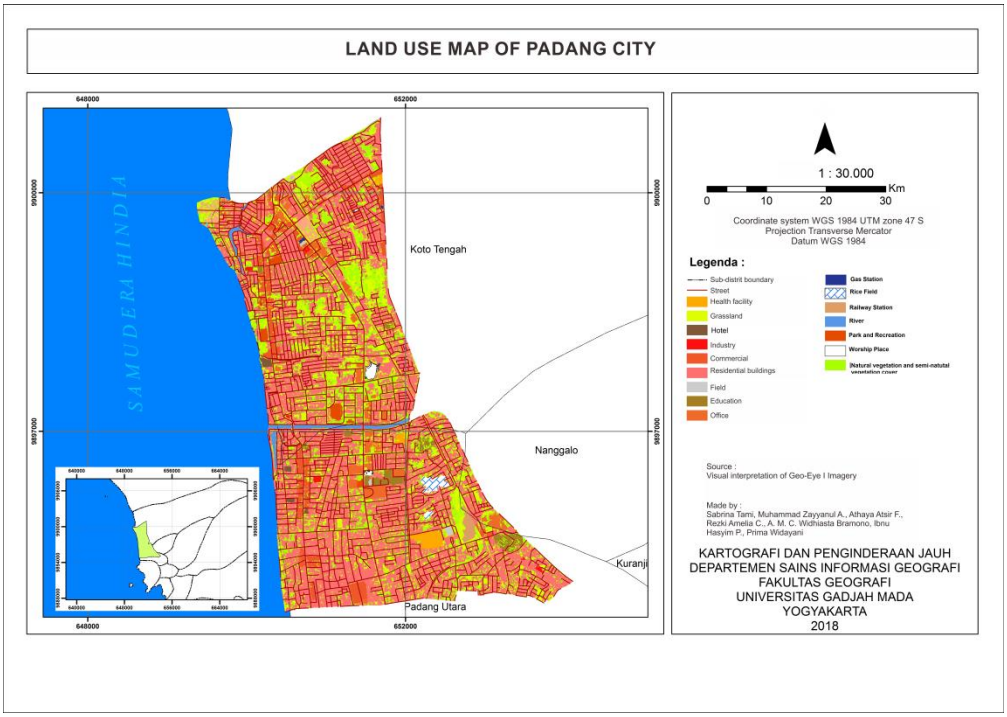

Figure 3.3 Landuse map in part of padang city

3.6 Entropy Index

In a walkability study, homogeneous landuse will reduce the comfort of walking because it will indicate great distances to destinations that are generally different in land use. In this study the resulting index value is 0 to 0.97. Low diversity classes can be associated with high and low building densities, this is because homogeneous land use

can occur in areas such as courtyards, fields, gardens or other vegetation that make a block have a low building density or other possibilities of homogeneous land use located in an area that is covered by many buildings so it is in a high density building area. Overall, the diversity of land uses in the study area is dominated by low classes, which have a value of 0.32 to 0.65.

3.7 Environmental Friendliness

Environmental friendliness parameters obtained by field observations and questionnaires that can be seen in table 4.0. Through field observations obtained data related to the presence or absence of each parameter in the samples that have been determined, while through the distribution of questionnaires obtained the values used in the calculation for weighting each parameter. The score of each parameter is indicated by a binary value or the numbers 1 and 0. The number 1 is given if the building block has a referenced parameter, while the number 0 is given if the building block has no referenced parameter.

Parameters	Existence	Score	Weight
Sidewalk existence	Yes	1	0,105
	No	0	
Trees existance	Yes	1	0,43
	No	0	
Street vendors existence	Yes	0	0,052
	No	1	
Street lights existence	Yes	1	0,259
	No	0	
Police station existence	Yes	1	0,154
	No	0	

Table 3.3 The result of weighting each environmental friendliness parameter

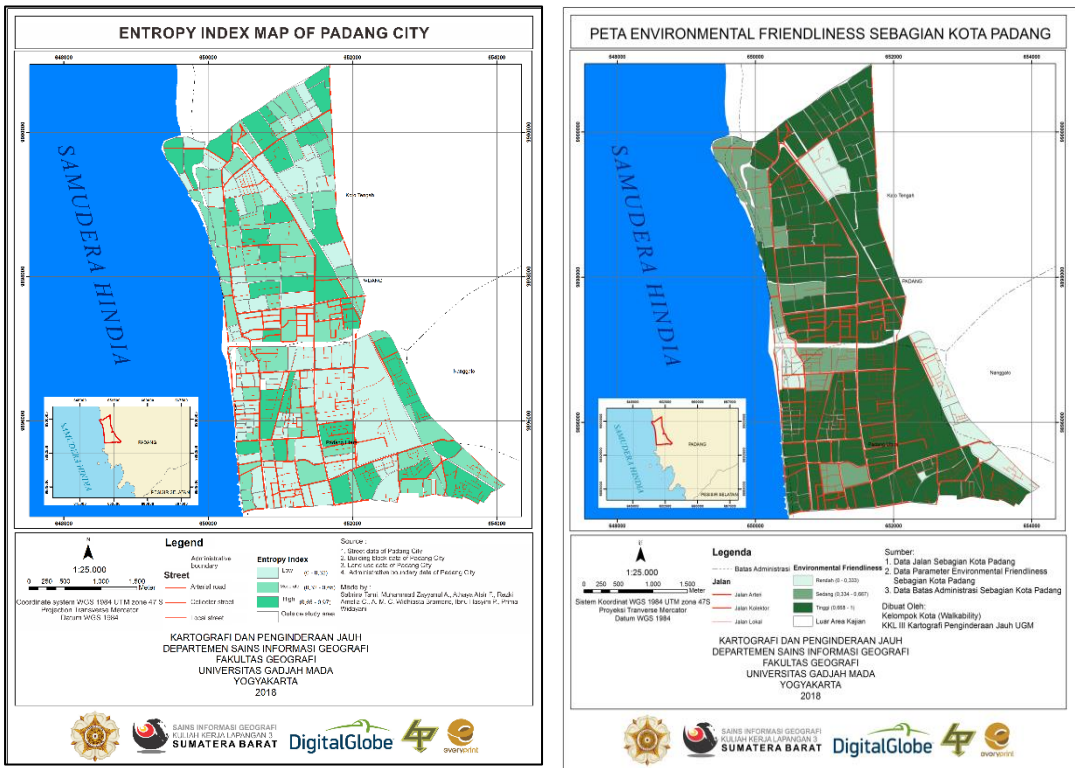

Figure 3.4 (a) Entropy index map (b) Environmental friendliness map

3.8 Walkability Index

The parameters used and having an influence on Walkability are environmental friendliness, building density, entropy index, and level of connectivity. The weighted value given is the value obtained using AHP based on the recapitulation results of the entire questionnaire distributed to the community, the weighting value shown in Table 4.6 calculated in the following equation:

Weight = (Total Entropy Index Score * 0.260) + (Total BCR Score * 0.458) + (Total Environmental Friendliness Score * 0.104)

+ (Total Connectivity Score * 0.179)

Parameters	Weight
Environmental Friendliness	0,104
Building density	0,458
Entropy Index	0,26
Connectiviity	0,179

Table 3.4 The weight of parameters of Walkability Index with AHP

The consistency value shown by the AHP for the Walkability Index is 0.06 which indicates that the AHP is consistent and able to represent real-world conditions. Then based on the parameters, the Walkability Index value is divided into three classes, that were Low (1.00 - 1.52); Medium (1.52 - 2.04); and Height (2.04 - 2.56). The Walkability Index values in some Padang City areas are dominated by the Medium class. The highest value is usually owned by residential land use with consideration according to the community proximity to public facilities (associated with building density parameters) and the presence of public facilities (associated with entropy index parameters) is the main attraction in influencing walking interest, shown in Figure 3.5

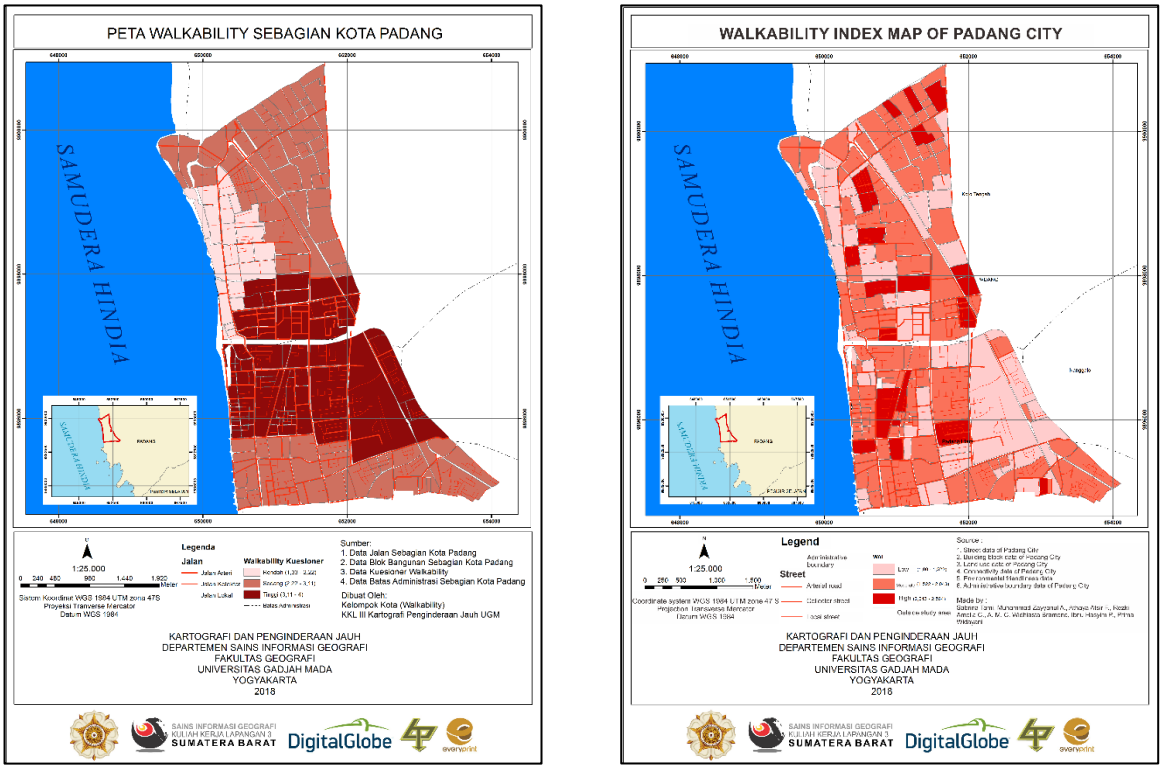

Figure 3.5 (a) Walkability map (b) Map of walkability indes in part of padang city

Based on Figure 3.5, moderate and low levels of walkability are found in commercial land uses, that is markets. This is because the road that should function as a sidewalk and a place to walk is used as a kiosk and vehicle

parking area. These factors have an effect in reducing the comfort level of pedestrians, especially for market consumers. Although based on the results of the field survey, the land use has a high level of pedestrians. And based on the distribution of questionnaires and accuracy testing using confusion matrix, it can be seen that the walkability index analysis performed has an accuracy of 75%. This shows that the AHP weights obtained through the questionnaire can be used to represent the comfort conditions of pedestrians in a part of Padang City.

4. CONCLUSSION

1. Based on the results of the Walkability analysis, it can be seen that most areas of the study area have a moderate level of Walkability. This condition is obtained based on the calculation of the Walkability Index parameter which each weight of the parameter is obtained by the AHP method based on questionnaire data.
2. The most influential parameter on the walkability index for most Padang cities is proximity to public facilities with a value of 0.468, while the lowest is the Environmental Friendliness parameter (0.104).rameter yang paling berpengaruh terhadap walkability index untuk sebagian Kota Padang yaitu kedekatan dengan fasilitas umum dengan nilai 0,468, Sedangkan yang paling rendah adalah parameter Environmental Friendliness (0,104).

5. ACKNOWLEDGEMENT

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