ACCESSIBILITY ANALYSIS AND ITS MEASUREMENT FOR REGIONAL ECONOMIC GROWTH

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Abstract

In the new global economy, accessibility has become a central issue for transportation and urban regional planning. Accessibility is an important asset of urban areas as it links transportation and land use. Accessibility also acts as a key element in analyzing the efficiency of the transportation system. By undertaking accessibility analysis with the use of GIS tools, this paper will focus on accessibility analysis and its measurement for regional economic growth. It will show how accessibility analysis has been implemented in a GIS environment. It also will support planners in providing better knowledge, thereby improving the decision-making process in the future.

1. Introduction

The dynamics of land use in economic regional development have heightened the need for improving the decision-making process, especially in assessing plans and project development. In this situation, accessibility can be used as one of the relevant elements whereby the concept itself is a key variable in land rents and decisions on density for developing urban areas (Alonso, 1964). The development and improvement of transportation planning and infrastructure seem to be important aspects for balancing economic development in the region (Holl, 2006). Consequently, analysis of accessibility should be implemented.

The concept of accessibility has been used widely in urban regional planning and transportation research, especially in connection with the ability to reach certain locations or target sites, within a particular time window with a certain transportation mode. The ability to reach a target destination needs high accessibility levels whereby land use is strongly connected to the transportation system. Accessibility needs to be measured to evaluate land use and transportation strategy in the development process.

In GIS, accessibility analysis is a common task which could be a very simple analysis or a very advanced analysis. Various studies have used GIS technology for accessibility analysis (Arentze et al., 1994; Liu and Zhu, 2004; Gutiérrez et al., 2010; Zhang et al., 2011; Salze et al., 2011).

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This research will give an account of accessibility analysis and modeling in urban and regional economic growth for the Kuala Lumpur area. This paper is organised as follows. Section 2 describes the accessibility measure used. In section 3 we explain the methodology to select the accessibility measure. In section 4, we describe an application of the accessibility measure in the study area. This paper is concluded in section 5 with a discussion of the implication for transportation and land-use planning policy. Lastly we discuss some related work in progress.

2. Accessibility

A considerable amount of literature has been published on specifications of accessibility measures. According to Halden (2002) in order to integrate spatial planning and transportation planning, some accessibility measure should be used. Accessibility has been measured in a variety of ways. Different specifications emphasize different aspects of accessibility. Therefore, it is important to choose an accessibility measure that best suits the purpose of the research project.

2.1 Accessibility measures

Geurs and Wee (2004) identified four components of accessibility: the land use component, the transportation component, the temporal component and the individual component. The land use component describes the land use system which consists of the amount, quality and spatial distribution of opportunities. The transportation component describes the transportation system which is expressed as the disutility of an individual to cover the distance between an origin and destination using a specific transport mode.

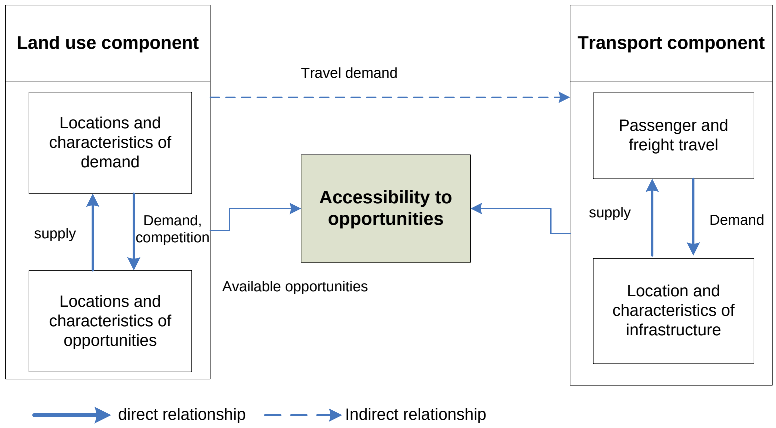


Figure 1: The relationship of accessibility components
Source: Modified from Geurs and Wee, 2004

Based on Figure 1, land use is the most important component in determining travel demand which its link to the transportation component. Each of the components has a direct relationship with the accessibility to the opportunities.

2.2 Accessibility measure

From the literature, we identified that accessibility measures can be classified into four different approaches — 1) Infrastructure-based; 2) location based; 3) person based; and 4) utility based. In the urban planning and transportation domain, these four approaches have been used in various projects related to research on jobs, population, retail services, public services, health services, education, recreation and land use (Geurs & Ritsema, 2001). The infrastructure-based measures consider only the characteristic of the transport network of the area under its consideration such as journey time and congestion. The location-based approach is usually based on location measures such as distance, cumulative opportunity measure, potential, measures based on balancing factors of spatial interaction models, and measure derived from time-space geography (Geurs & Ritsema, 2001). A well-known accessibility measures is Hansen's Accessibility Index (Hansen, 1959), which is shown in equation (1). The general equation for this gravity-type measure, or potential model, can be written as

$$A_i = \sum_j O_j \, f(d_{ij}), \qquad i = 1,2,\ldots,m;\ j = 1,2,\ldots,n, \qquad (1)$$

where,
$f(d_{ij})$ is the impedance function,
O_j is opportunity at point j,
m is the number of origins,
n is the number of destinations.

The most frequently used impedance functions are the inverse power function, $d_{ij}^{-\alpha}$, and the negative exponential function, $\exp(-\alpha d_{ij})$. Here, α is a constant representing the effect of distance decay on accessibility.

In this paper, we focus only on one of these measurers-the cumulative opportunity measure. The cumulative opportunity measure (also known as isochoric measure, coverage approach, contour measure, proximity distance and proximity count) is one of the basic and early methods of accessibility measure introduces and discussed by researchers (Al-Geneidy, 2010, Vickerman, 1974, Wach and Kumasai, 1973). This measure can be easily interpreted and is often used by planners in urban planning and geographical studies. In this approach, the number of opportunities that can be reached within a determined cost (travel time or distance) is counted. Although it is a crude measure, it does provide information of the size of the potential market and as such as useful for analysing the location configurations of firms. The measure can be summarised as:

$$A_i = \sum_{j=1}^{J} B_j O_j \qquad (2)$$

where,
A_i = Accessibility measured at point *i* to potential activity in zone *j*
O_j = Opportunity/destination in zone *j*
B_j = A binary value that equal to 1 if zone *j* is within the determined threshold and 0 if otherwise.

The person-based approach analyses accessibility at an individual level which can be described as activities that any individual can get to involve in the given time frame. Finally, the utility-based approach which El-Geneidy & Levinson (2006) claim is one of the most complex and data intensive measurements. This measure is founded in economic theory. This approach has been used by several researchers in transportation in the context of accessibility to jobs (Koenig, 1980; Handy & Niemeier, 1997) and land use (Miller, 1999). The general equation for log sum as an expression of accessibility can be expressed as follows:

$$A^i_n = \ln \left[\sum_{\forall \in C_n} \exp (V_{n(c)}) \right] \qquad (3)$$

where,

A^i_n Accessibility measure for individual *n* measure at location *i*
$V_{n(c)}$ Observed temporal and spatial component of indirect utility of choice *c* for person *n*
C_n Choice set of person *n*

3. A methodology of selecting an accessibility measure for analysis

The process involves in selecting an accessibility measure for transportation study can be described as below:

Purpose of accessibility analysis
The first step is to determine the purpose of conducting an accessibility analysis. In this study, the focus of attention is to improve accessibility of firms, recognizing that a variety of transportation modes such as public transit and private automobiles should be designed in the study area to accommodate it.

Compute distance and access
The measure of network distance using GIS-based network analysis with generating multiple network buffers to enclose all network locations varying distance from centre point of three zones in the study area. Each transportation network component such as train station, bus terminal station, highway and major road network will be included as accessibility networks which facilitates the calculation of accessibility.

4. Application

4.1 Study area

Kuala Lumpur is one of the districts in Klang Valley region (Figure 2). As the capital state of Malaysia, it is recognized as a tourist attraction, and a cultural and economic centre for the country. The area was buoyant by the development of commercial, industrial and residential activities which made Kuala Lumpur and its conurbation grow rapidly compared to other states in Malaysia. With a population of 1.6 million people (Department of Statistics Malaysia, 2008) and an area covering up to 244 sq. km., Kuala Lumpur has a comprehensive road and rail network to help workers, residents and tourists commute especially to the city centre. In Figure 3, we can see that most of Kuala Lumpur area is covered by road networks especially the highways and major roads.

Figure 2: Klang Valley region

Figure 3: Kuala Lumpur Transportation Networks.

4.2 Analysis and result

The pattern of accessibility in Kuala Lumpur area

Cumulative Opportunity measure

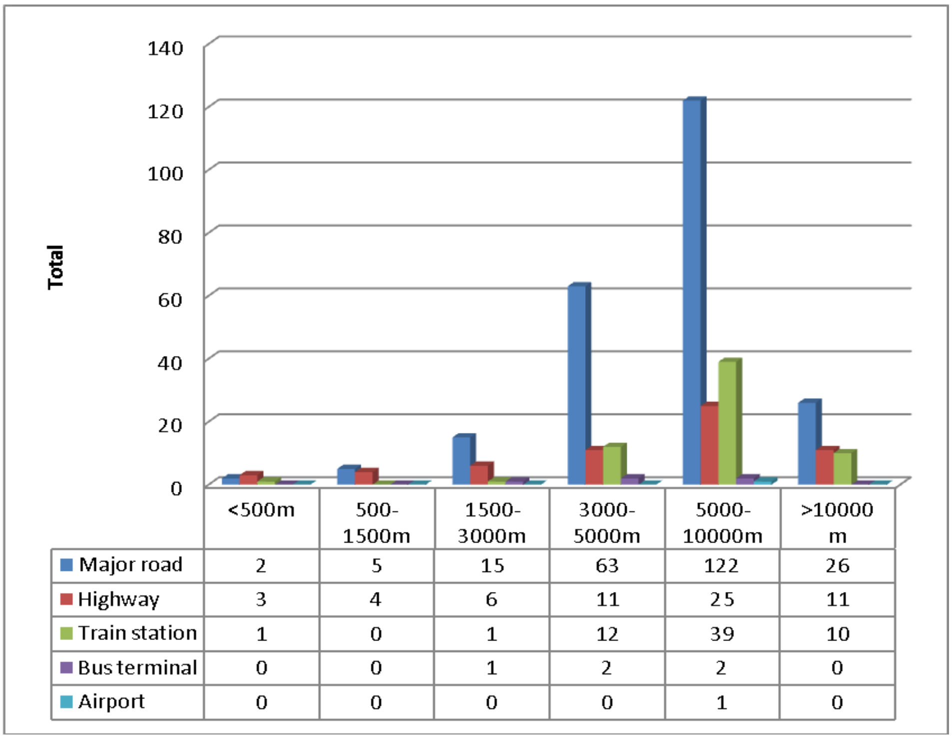
Accessibility measure in the study area was calculated using the cumulative opportunity measure for distance 500 meter, 1500 meter, 3000 meter, 5000 meter and 10 000 meter for three zones, which are Zone A - City Centre (Central Business District – CBD), Zone B – North and Zone C – South, bounded by Kuala Lumpur district edge. The purpose of this analysis is to demonstrate how many transport facilities reachable within a certain distance. These analyses give an indication of the potential market in the study area which not considering any competition effect. This method is easy to understand and calculated, but only the opportunity in between 10 000 meters away is valuable while those 10 001 meters far are not important and not valuable.

Results

Table 1, Figure 4 and Figure 5 illustrates the results of a number of transportation features located within less than 500 meters and more than 10 000 meters from three zones for the analysis.

Table 1: Results of transportation features located within determined distances in Zone A

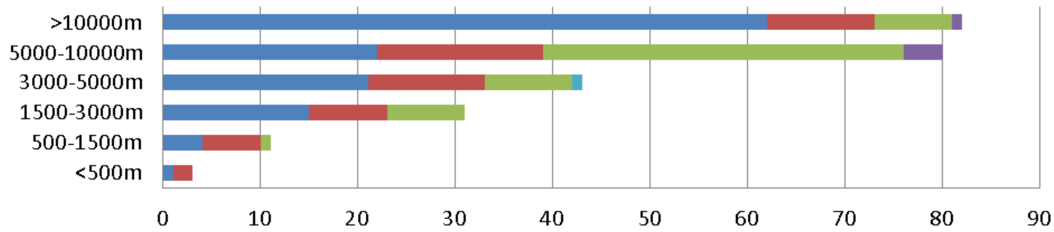
Distance / Transportation features	<500m	500-1500m	1500-3000m	3000-5000m	5000-10000m	>10000m
Major road	6	36	71	64	77	12
Highway	0	1	5	14	22	8
Train station	0	17	16	11	18	1
Bus terminal	0	1	3	1	0	0
Airport	0	0	0	1	0	0



	<500m	500-1500m	1500-3000m	3000-5000m	5000-10000m	>10000 m
Major road	2	5	15	63	122	26
Highway	3	4	6	11	25	11
Train station	1	0	1	12	39	10
Bus terminal	0	0	1	2	2	0
Airport	0	0	0	0	1	0

Figure 4: Results of transportation features located within determined distances in Zone B

Because of the density of land use in the City Centre, only six major roads can be accessed within less than 500 meters from the centre and there are no others' transportation features that can be reached within that range. Similar pattern can be seen in Zone B and Zone C accessibility to highway and major road whereby small number of major road network can be access within less than 1 500 meter from the centre. In the three zones, most highways are accessible further away from the centre since that the highway is served as a link to the other sub districts and major city nearby Kuala Lumpur.



	<500m	500-1500m	1500-3000m	3000-5000m	5000-10000m	>10000m
Major road	1	4	15	21	22	62
Highway	2	6	8	12	17	11
Train station	0	1	8	9	37	8
Bus terminal	0	0	0	0	4	1
Airport	0	0	0	1	0	0

Figure 5: Results of transportation features located within determined distances in Zone C

The train networks are the most popular transport mode for Kuala Lumpur commuter due to less travel time. Currently, the public transport network in Kuala Lumpur covers rail with 63 stations. In Zone A, most of the stations are located within 5 000 and 10 000 meters (18), followed by an area within 500 and 1 500 meters (17), 1 500 to 3 000 meters (16), 3 000 to 5 000 meter (11) and less than 500 meters and more than 10 000 meters (1 each) respectively. In Zone B and Zone C, most of the train stations are also located within 5 000 and 10 000 meters (39 and 37 respectively), but only one located less than 1 500 meter in both zones. This show that the concentration of train stations in between the centre and the edge of Kuala Lumpur gives an equal distribution of train services from downtown to other areas.

Generally, the main bus terminals are located in the range 1 500 to 3 000 meters from the centre of Zone A. In Zone B, it is situated between 1 500 to 10 000 meter radius and in Zone C, four of the bus terminal situated within 5 000 and 10 000 meters range. The location of the main terminal is nearby the major road and highway due to the fact that the main terminal serves for long distance journeys all over Peninsular Malaysia. There is one small airport located in the study area which is used by The Military. This airport is located approximate 4 000 meters from the City Centre.

From the analysis, we can summarize that most of the transportation features are located within 500 meters to 10 000 meters from the centre within the three zones. The concentration of the road networks and the rail networks are more towards 3 000 meters away from the centre possibly due to easy access by workers and the location of jobs and residential area.

For more detail overviews, we apply analysis by intersecting the zones. From this analysis, we discover that the intersections cover almost the central part of Kuala Lumpur (Figure 6) which encompasses 91 sq. km. of area (37 per cent from whole

Kuala Lumpur area). The ~~areas~~region incorporate the most transportation networks throughout the study area, especially the train networks (45 stations) and bus terminal (4 terminals). Besides, the connections of highways and major roads are good in this area. Based on firm data available for the study area, we are also able to find out 58 per cent from 55 071 of firms can be found in this area. It proves that better transportation networks, particularly in development of highways and major roads appear to be an important determinant of firm location choice, especially in urban economic research (Maoh et al., 2005).

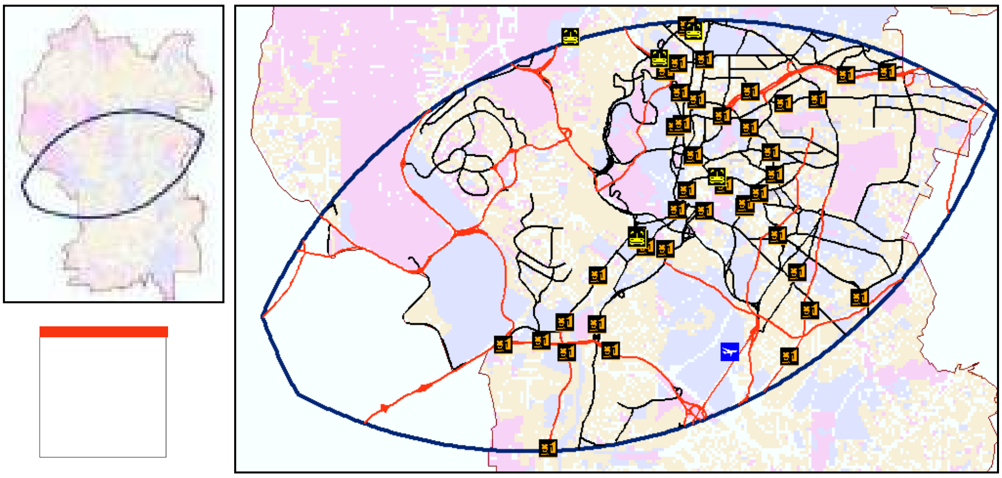


Figure 6: Intersections area of the three zones.

5. Discussion and Conclusion

In this paper, we have presented the results of an accessibility analysis measure on transportation networks with GIS tools for regional economic growth in urban and transportation planning. From the analysis, it shows that for the most part of Kuala Lumpur area can be access through the transportation networks. The central parts of the city appear to have the best accessibility because relatively it was the hub of commercial and business chain. However, in contrast, better transportation network could encourage firms to locate outside of congested urban areas for more opportunities of cheaper land price and labour (Rothenberg, 2011).

Accessibility measure can give an implication for transportation and land-use planning policy. The location model was developed to give planner and decision maker more insight into the location of existing firms and could give an improvement of transportation network in the future. The uses of every type of accessibility measure however, have advantages and disadvantages. For example, the application of cumulative opportunity measure is simple to calculate. It also considers all opportunities are equal because not taking into account the impedance of reaching the origin. This measure also very efficient to determine changes in accessibility of a location and closely linked to the rational view of transportation system and makes it as a valuable tool for communities (Cerdá, 2009).

The present application of accessibility measure is still in progress. Other related work is a development of potential accessibility index measure for more details levels of accessibility for each sub-district in Kuala Lumpur area. The result from this analysis will be used afterwards for producing analysis for firm location model, which will be applied using econometric approaches.

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