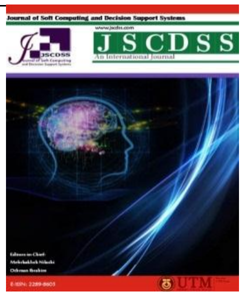
An International Journal
JSCDSS
http://www.jscdss.com
Vol.2 No.1 February 2015: 1-4
Article history:
Accepted 28 February 2015
Published online 28 February 2015

Journal of Soft Computing and Decision Support Systems



E-ISSN: 2289-8603

Modelling Multi-mode Transportation Networks in Kuala Lumpur

Muhammad Azizol Ismail [a,*], Mohamad Nor Said [a]
[a] Universiti Teknologi Malaysia, Faculty of Geoinformation and Real Estate, Department of Geoinformation, Johor Bahru, Malaysia, 81310

*** Corresponding author email address**: azizolismail@gmail.com

Abstract

The role of urban transportation becomes increasingly important. An efficient transportation network can stimulate economic transformation, physical development and improve mobility activities. In urban domain, people tend to use more than one mode of transportation to travel from origin to destination. Development in the application of Geographical Information Systems (GIS) to urban transportation problems represents one of the significant areas of GIS-technology and urban planning field nowadays. To prove how GIS can be used in assisting urban network analysis, this paper aims to highlight the determination of the best route in highly developed complex transportation system in the metropolitan city of Kuala Lumpur based on multi-mode transportation concept. More essentially, it integrates urban transportation including facilities such as Light Rapid Transit (LRT), Kereta api Tanah Melayu (KTM) Komuter, Express Rail Link (ERL), KL Monorail, bus, road driving as well as pedestrian mode into a single intelligent data model. To expedite and implement such analysis, ArcGIS's Network Analyst is adopted. As the compliment to the model, closest facility and service area analysis are also taken into consideration. With the advancement of GIS software, the final output will allow users to have a better interpretation of results in terms of visualization, total distance, total travelled time and directional map produced to find the optimal route based on either time or distance as impedance. Hence, the developed data model will facilitate policy makers and transportation planners to have a reliable decision effectively, and produce high quality geospatial information to the end users.

Keywords: Urban transportation, Multi-mode, GIS, Network analysis, Optimal route.

1. Introduction

As an important part of infrastructure, the transportation network plays a decisive role in urban development. Transportation serves people with mobility and accessibility to workplace, health facilities, community resources, and recreational areas across the country. In certain location such as an urban area, human mobility usually happens over a multi-mode transportation network. Because of that, when performing, analysing and studying transportation systems, people should not simply consider each mode of transport separately but should look at it as a multi-mode system with relationships and dynamics between components. There are works done beyond the urban territory such as reported by Mishra (2015) who highlights the development of databases at the level of regional whereby multi-modes transport databases are being setting up around the world. These databases are not only to be used for integrated mobility information services, but also for new analysis to improve the global multi-mode transportation over a territory. Multi-mode mobility combines both private and public transport modes, thereby capitalizing on the benefits of various systems. Qu et al. (2008) and Kim et al. (2015) highlight multi-mode transportation is a complex network, in which all the components should be seamlessly linked and efficiently coordinated.

With the development of GIS, route network analysis within GIS environment has become a common practice in many applications. GIS allows large data to be effectively processed, stored, logically associated, and graphical displayed thus provides a convenient and powerful tool for storing and graphical representation of information, which can be useful to the users (Preven et al., 2005; Bonham-Carter and G.F., 2015). This is of a particular importance when more people are getting mobile with the availability of new public transportation options that connects the routes. In fact, Matthew (2013) reports that transportation planners and decision-makers are increasingly considering multi-mode urban transportation strategies to support sustainable transportation associated with urban development. Sustainable transportation is a key aspect of sustainable development.

2. Problem Background

As the population of people is increasing from year to year, so does the demand for transportation. More and more traffic is on roads, which in turn creates more and more mobility-related problems such as congestion, air pollution, noise pollution, and accidents; especially in city centres where the level of human activities is high (Reza et al., 2013). Government should play a vital role in planning an efficient network transportations as well as controlling urban traffic movements to ensure mobility and mitigate mobility related problems simultaneously.

3. Problem Statement

In the Malaysia circumstances, mainly in the cities such as Kuala Lumpur, the network becomes more complex and complicated. The common transportation features that can be observed include multi-layer highways and major roads with many intersections. In fact, urban public transportation such as Light Rapid Transit (LRT), Keretapi Tanah Melayu (KTM) Komuter, Express Rail Link (ERL), bus and Monorail exist to boost economic development in Kuala Lumpur. Determination of an optimal path within a highly developed complex transportation network is not an easy task, especially for those who are unfamiliar with the local transportation system. Complicated network of route systems requires critical analysis which can only be realized with the implementation of GIS to improve the movement of people, goods, services and the flow of resources. Moreover, they are not integrated, i.e. they exist as separated systems.

According to Reem (2012), most of commercial GIS software contains packages which solve the conventional route planning problem, but without taking into account the integration of multiple transport modes. Even though some of the route planning systems are making efforts to integrate more transportation modes (such as Google Maps's "By car", "Walking", "By public transit", etc.), it is unfortunately performed totally separately for each mode, i.e. one mode at a time (Lu, 2011). Currently, the researches on the construction of the single mode transportation network (Waren et al., 2002; Luca et al., 2006; Ralf and Lars, 2012; Gubara et al., 2014; Mahmoud et al., 2015; Neutens, T., 2015; Yalcin and Duzgun, 2015), are relatively mature, and the researches on the construction of multi-mode integrated transportation networks are relatively few and in the constant exploration (Shuang et al., 2010; Zaiat et al., 2014). Due to this date, there is no such work reported which involves the modelling and integrating of urban transportation in Kuala Lumpur.

This paper reports a research being done to look into the design of a geospatial database that can cater for a multi-mode route analysis. The main aim of this study is to develop an intelligent and integrated data model of route network systems within a GIS environment for Kuala Lumpur area.

4. Research Methods

The metropolitan city of Kuala Lumpur, Malaysia has been selected as the study area. This area contains most of the transit systems (LRT, Monorail, ERL, KTM Komuter, bus) in Malaysia. This Federal Territory covers an area of 243 square kilometres. Under the 1984 Kuala Lumpur Structure Plan, the city centre was designated as the principal urban core to provide specialized metropolitan services, national and international commercial and business activities, central government activities, and much more. The main tasks to achieve the objective of this study are:

i) To design and develop a geodatabase that can support the multi-mode route analysis
ii) To build a network dataset

4.1 Geodatabase Design and Development

Geodatabase design is the process of producing a detailed data model of database to meet end user requirements. The Entity Relationship Model (ERM) is most commonly used during conceptual design. The resulting Entity Relationship Diagram (ERD) provides a data-centric and structural view of the database. A new option is to use a Unified Modelling Language (UML) which contains class diagrams that also incorporate structural views of the database. Fig. 1 depicts the geodatabase developed for the data model. This personal geodatabase is projected in the Rectified Skewed Orthomorphic (RSO) which is the local coordinate system employed before the network analysis can take place in ArcGIS10.

For this research, the major (required) feature classes (map layers) are road networks, and transit stations and line (LRT, ERL, KTM, monorail, bus) - with correct network topology. Meanwhile, the supporting feature classes include Points of Interest (POIs), transfer points, connecting stations and interchange stations. The point and line data are obtained from Google Earth's images, Google Maps, websites and Garmin BaseCamp 4.4.6 map data.

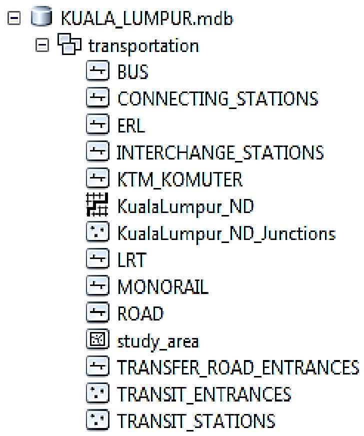


Fig.1. Personal geodatabase developed.

4.2 Building Network Dataset

Building network dataset is a compulsory procedure. It is to make sure the data is ready for network analysis to take place. There are five steps in order to create network

An International Journal JSCDSS E-ISSN: 2289-8603

dataset, i.e. (i) naming the network dataset and choosing source feature classes (ii) assigning connectivity policy, connectivity groups (iii) setting elevation policy (iv) specifying the attributes for the network dataset, and (v) configuring directions.

It is to be noted that for the travel time calculation, the formula as shown in Eq. (1) is used. It is very important to ensure the unit is correct and comply with the formula. Distance refers to the road length in meter unit while speed limit here is converted from Km/hr into meter / minute. By using ArcGIS 10, this formula can be executed using the field calculator function.

$$\text{Travel time} = \text{Distance} / (\text{Speed limit} \times (1000 / 60)) \qquad (1)$$

For those who drive a car, they just need to use road feature class. Other feature classes can be neglected. Hence, this source needs to be marked as restricted. Apart from that, transit stations need to be restricted too, so that new network analysis objects can be prevented from locating there. Fig. 2 explains how this situation is treated where all the attribute values of the associated transport modes are set to -1.

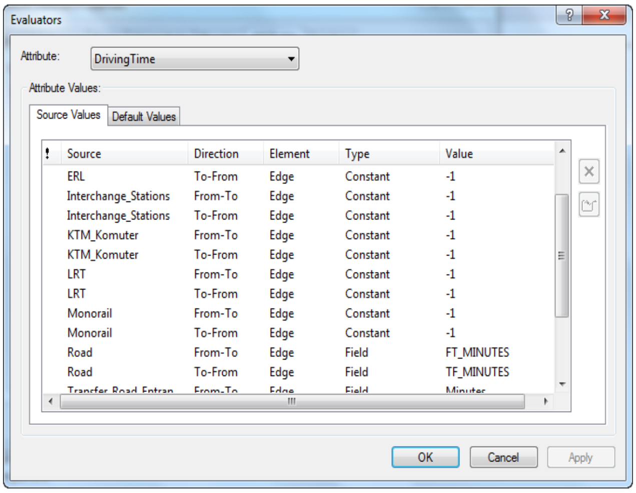


Fig.2. DriveTime (by car only) configuration.

A measure of the amount of resistance, or cost, required to traverse a path in a network is known as impedance. If the impedance is the distance (meters), the optimal route is the shortest route. On the other hand, if time (minutes) is chosen as impedance, the optimal route is the quickest route.

5. Assumptions of the Analysis

All The analysis is based on two assumptions, i.e. (a) for the travel time, it is calculated in the condition that there is no traffic jam in the streets and (b) travel speed is considered as the maximum speed limit. The maximum speed limit is assigned based on the road class as presented in Table 1.

Table 1
Maximum speed limit assigned based on the road class.

Road class	Speed (km/hour)
Highway	110
Federal	90
State	90

6. Results and Discussion

The framework presented in the previous section is used to model and analyses urban transportation systems in Kuala Lumpur. With the database associated, it assists users to have a better interpretation of the network characteristics and minimize the potential for errors generating in the network data files. The well-known Dijkstra's algorithm embedded within the Network Analyst extension make it possible to perform analysis such as optimal path, closest-facility and service area.

6.1 Multi-mode Transportation Analysis

In the real world, commuters and travellers frequently use several modes of transportation such as walking on sidewalks, driving on road, and riding on trains. For LRT, it comprises of 2 lines, i.e. the Ampang Line, and Kelana Jaya Line. Likewise, KTM Komuter consists of 2 lines which are the Sentul-Pelabuhan Klang Line and Seremban-Rawang Line.

To demonstrate a multi-mode route analysis, the Angkasapuri KTM Komuter Station, Mid Valley KTM Komuter Station and Pudu Star LRT Station are selected as the three consecutive stops.

As the Network Analysis function is executed, the bold yellow colour in Fig. 3 highlights the best route to travel from the source to destination. Meanwhile, Fig. 4 presents the direction, total time and total distance for multi-modal transportation. In this scenario, the individual travelling uses 4 modes of transportation, i.e. KTM, Monorail, LRT, and walking.

Connecting station is the station that connects two different modes for instances, the Hang Tuah Monorail and the Hang Tuah Star LRT. Interchanges station requires that one exit either stations to make a transfer within the same mode for example, the KL Sentral serves as the interchange station when the user wants to traverse from the Angkasapuri KTM Komuter (Sentul-Pelabuhan Klang route) to the Mid Valley KTM Komuter (Seremban-Rawang route).

The result also displays the individual map for each trip. Hence, the traveller can get alerted when to switch mode of transportation and when to make an interchange. The total distance of this journey is 12 kilometres and it takes about 19 minutes as the total travel time.

Apart from that, the stops can be reordered based on preference. Indeed, it assists anyone to well plan the journey.

An International Journal JSCDSS
E-ISSN: 2289-8603

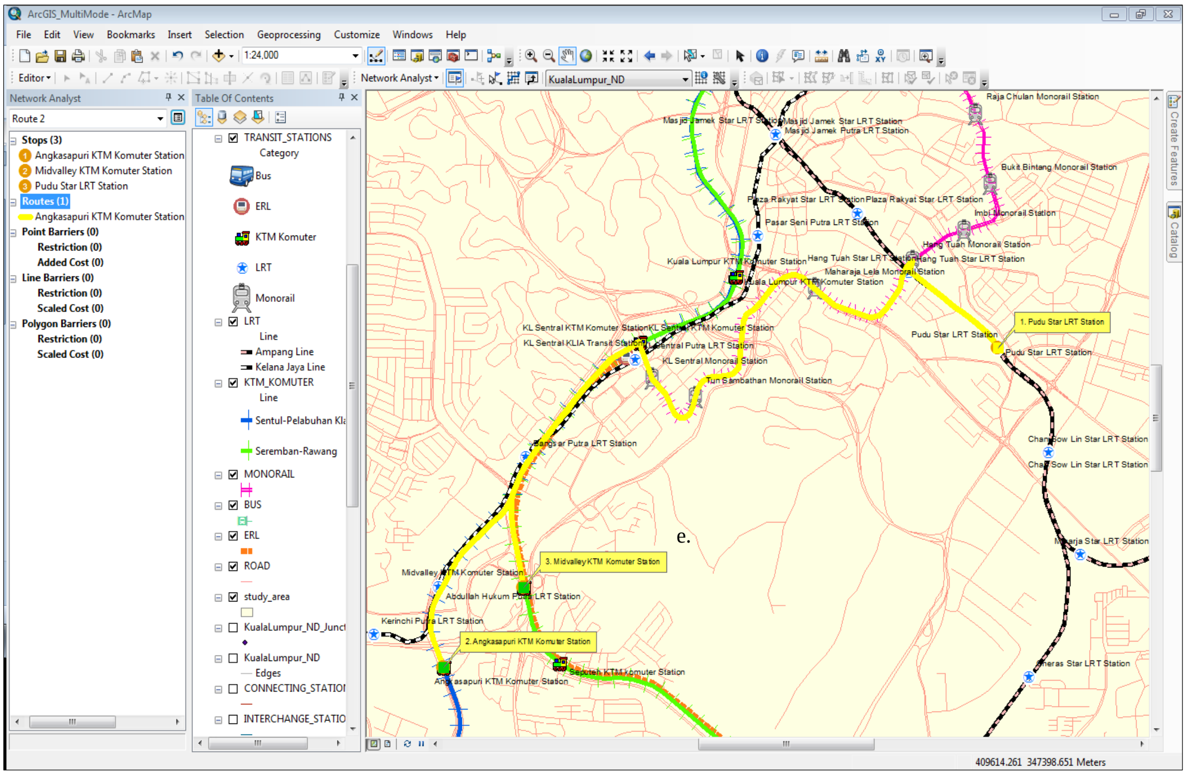


Fig.3. Map of multi-mode transportation analysis.

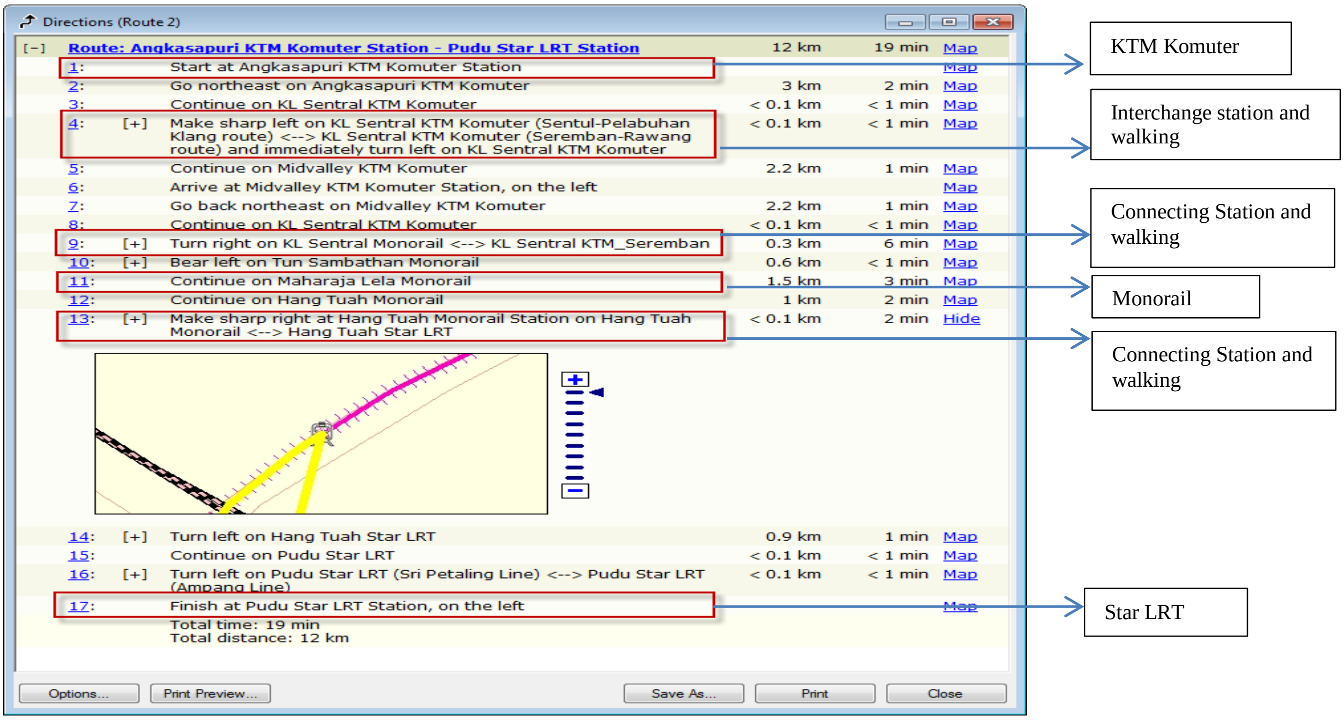


Fig.4. The direction, total time and total distance.

An International Journal JSCDSS
E-ISSN: 2289-8603

6.2 Closest Facility Analysis

The closest facility analysis allows user to determine which facilities are closest to a given point. For instance, finding hospitals near a car accident. When finding the closest facilities, user can specify how many facilities to find and whether the direction of travel is toward or away from the site (incident). Users can also specify a cut-off threshold beyond which the ArcGIS Network Analyst will search for a facility. For example, finding hospitals within 6 kilometres of a car accident. Fig. 5 displays a result of closest facility. The point of interest (POI) is petrol stations. The user wants to find where are the 5 nearby facilities within 5 minutes driving from his or her current position as marked in Fig.5. So, as the closest facility function is implemented, it gives the user 5 nearby petrol stations as listed in Fig.6.

Fig.5. Result of closest facility analysis.

[-]	Route: Current_Location - CALTEX JLN. IMBI		1.1 km	< 1 min	Map
	1:	Start at Current_Location			Map
	2:	Go southwest on JLN. KIA PENG JALAN UTAMA (TAMAN) toward JLN. RAJA CHULAN JALAN UTAMA (PERSEKUTUAN)	0.3 km	< 1 min	Map
	3:	Turn left on JLN. RAJA CHULAN JALAN UTAMA (PERSEKUTUAN)	0.4 km	< 1 min	Map
	4:	Bear left on JLN. BUKIT BINTANG JALAN UTAMA (PERSEKUTUAN)	0.1 km	< 1 min	Map
	5:	Turn right on JLN. IMBI JALAN UTAMA (PERSEKUTUAN)	0.3 km	< 1 min	Map
	6:	Finish at CALTEX JLN. IMBI			Map
		Total time: < 1 min Total distance: 1.1 km			
[-]	Route: Current_Location - SHELL JLN. RAJA CHULAN		1.2 km	< 1 min	Map
	1:	Start at Current_Location			Map
	2:	Go southwest on JLN. KIA PENG JALAN UTAMA (TAMAN) toward JLN. RAJA CHULAN JALAN UTAMA (PERSEKUTUAN)	0.3 km	< 1 min	Map
	3:	Turn right on JLN. RAJA CHULAN JALAN UTAMA (PERSEKUTUAN)	0.7 km	< 1 min	Map
	4:	Turn left on JLN. P RAMLEE JALAN UTAMA (PERSEKUTUAN)	< 0.1 km	< 1 min	Map
	5:	Turn right on JLN. RAJA CHULAN JALAN UTAMA (PERSEKUTUAN)	0.2 km	< 1 min	Map
	6:	Finish at SHELL JLN. RAJA CHULAN			Map
		Total time: < 1 min Total distance: 1.2 km			
[+]	Route: Current_Location - ESSO JLN. BUKIT BINTANG		1.3 km	< 1 min	Map
[+]	Route: Current_Location - CALTEX S ISMAIL		1.3 km	< 1 min	Map
[+]	Route: Current_Location - ESSO TUN RAZAK N		1.4 km	< 1 min	Map

Fig.6. List time, distance and direction of closest facilities.

6.3 Service Area Analysis

The service area analysis is a type of network analysis for determining the region that encompasses all accessible streets (streets that lie within a specified impedance). Refers to (Fig. 7), the yellow polygons show the response time of fire stations expected to arrive at particular incidents occur within 2 minutes. Blue and red polygons show the fire stations respond time expected to arrive within 5 and 8 minutes respectively. The decision makers can analyse that some fire stations should be relocated or established a new one to better service area in red polygons.

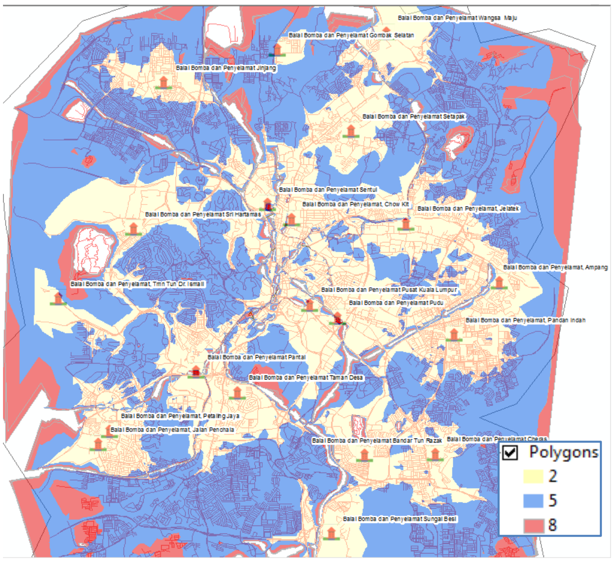


Fig.7. Result of service area analysis.

6.4 Model Builders

Model builder is a user-friendly tool on how someone can create a model by encapsulating the sequence of processes for specific tasks. The model flow chart gives a visual representation of geoprocessing work flow. Building a model by model builder will automate all the tasks that are necessary to be done by the Network Analyst extension. Fig. 8, Fig. 9 and Fig.10 show the developed model builder for optimal route, closest facility and service area respectively.

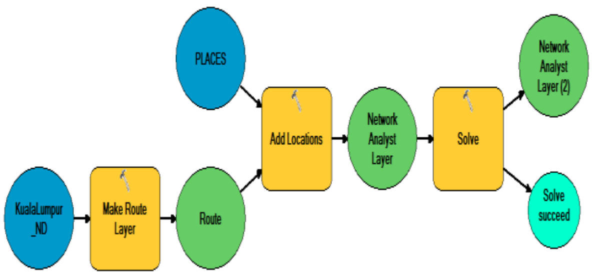


Fig.8. Optimal route model.

An International Journal
JSCDSS
E-ISSN: 2289-8603

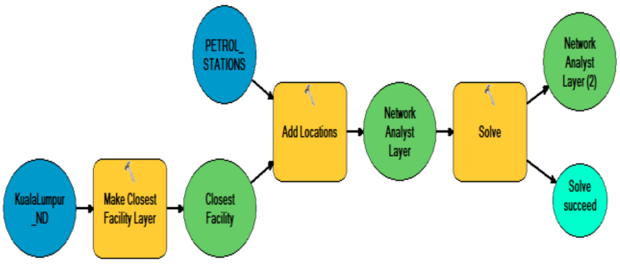


Fig.9. Closest facility model.

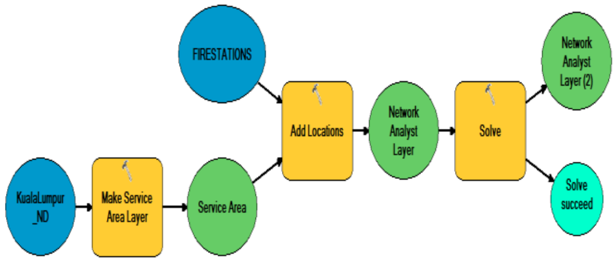


Fig.10. Service area model.

7. Conclusion

Throughout this study, all of the urban transportation systems (LRT, Monorail, KTM Komuter, ERL, bus, car driving and walking) in the city of Kuala Lumpur are successfully modelled into a single, intelligent and integrated geodatabase model. By configuring the Network Analyst Extension accordingly, performing route analysis based on multi-mode transportation concept in ArcGIS10 can be done. This is to support the real needs by the people when moving from one place to another in a situation that has many modes of transport available. All of these facilities are modelled in such a way that they are interconnected and an individual can travel from the start point to the end point. With a proper design of the database, users can freely choose the mode of transportation by either selecting the single or multi-mode. This data model also supports the display of the information regarding the total time, total distance, directions as well as map to the selected destination. It is particularly useful to assist the travellers in planning their journey. This type of analysis can be used to find not only the shortest or quickest routes but also for other network applications such as determining accessibility rate to health facilities. Consequently, by using GIS, complicated network of routes can be visualized and worked out in a very precise manner. Hence, the developed data model will facilitate policy makers and transportation planners to have a reliable decision effectively, and produce high quality geospatial information to the end users.

Acknowledgments

The work is financed by Zamalah/ Institutional Scholarship provided by Universiti Teknologi Malaysia and the Ministry of Higher Education of Malaysia.

References

Bonham-Carter, G. F. (2014). Geographic Information Systems for Geoscientists: Modelling with GIS. Canada: Elsevier.

Gubara, A., Amasha, A., Ahmde, Z., Ghazali, S.E. (2014). Decision support system network analysis for emergency applications. In 9th International conference on informatics and systems in Cairo, Egypt, 2014 (pp. 40 – 44). IEEE.

Kim, H. S., Kim, D. K., Kho, S. Y. and Lee, Y. G. (2015). Integrated decision model of mode, line, and frequency for a new transit line to improve the performance of the transportation network. KSCE Journal of Civil Engineering, pp. 1-8.

Luca, C., Raffaele, P. and Walter, U. (2006). Minimizing fleet operating costs for a container transportation company. European Journal of Operational Research, 171(3), pp. 776-786.

Lu, L. (2011). Data model and algorithms for multimodal route planning with transportation network (Ph.D.'s thesis, Technical University of Munich, Germany). Retrieved from http://mediatum.ub.tum.de/node?id=1004678.

Mahmoud, M. S. A., Magid, M. I. A., Abdullah, S. M. A. and El-Tayeb, N. M. (2015). Development of health care systems in sub-areas of KSA using GIS concept. Journal of Information Sciences and Computing Technologies, 1(1), pp. 7-54.

Matthew, J. E. (2013). Life cycle assessment in support of sustainable transportation. Environment Research Letter, 8(2). 021004.

Mishra, S. (2015). A tour-based analysis of travel mode choice accounting for regional transit service. Journal of Central South University, 22(1), pp. 402-408.

Neutens, T. (2015). Accessibility, equity and health care: review and research directions for transport geographers. Journal of Transport Geography, 43, pp. 14-27.

Preven, K., Varyn, S. and Reddy D. (2005). Advanced travel information system for Hyderabad City. Intelligent Transport Systems, IEEE Transaction, 6(1), pp. 26-37.

Qu, L., Chen, Y., and Mu, X. (2008). A transport mode selection method for multimodal transportation based on an adaptive ANN system. In Fourth international conference on natural computation, (pp. 436 – 440). IEEE.

Ralf, S. and Lars, M. (2012). A methodology to solve large-scale cooperative transportation planning problems. European Journal of Operational Research, 22(3), pp. 626-636.

Reem, F. M. (2012). Multimodal transportation system : modelling challenges. (Master's Thesis, University of Twente). Retrieved from *www.itc.nl/library/papers_2012/msc/upm/mahrous.pdf*.

Reza, Z. F., Elnaz, M., W.Y. S., Hannaneh, R. (2013). A review of urban transportation network design problems. European Journal of Operational Research, 229 (2), pp. 281-302.

Shuang, L., Shaokuan, C., Zhili, L., Baohua, M. (2010). Modelling and simulation on multi-mode transportation network. In International conference on computer application and system modelling (ICCASM), 7, (pp. 438 - 443). IEEE.

Waren, B. P., Arun, M., Jack, G. and Steve, B. (2002). Implementing real-time optimization models: a case application from the motor carrier industry. Operation Research. 50(4), pp. 571-581.

Yalcin, G. and Duzgun, H. S. (2015). Spatial analysis of two-wheeled vehicles traffic crashes: Osmaniye in Turkey. KSCE Journal of Civil Engineering, pp. 1-8.

Zaiat, A., Rossetti, R. J. and Coelho, R. J. (2014). Towards an integrated multimodal transportation dashboard. In Intelligent transportation systems (ITSC) proceedings of the 2014 17th International Conference IEEE 2014 (pp. 145-150). IEEE.

An International Journal JSCDSS
E-ISSN: 2289-8603