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GIS for Better Public Transportation and Transit

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Abstract: Transits are means of providing equal access between travelers. They reduce traffic congestion and ease environmental problems caused by private vehicles. Transport experts should try to plan a good public transit system for the people. Because of the nature of data in transportation modelling, there is difficulty in analyzing and updating spatial data. The Geographic Information System (GIS) applications for transit system modelling include transit service area analysis, data attribution, network representation, transit demand, transit distribution, linking transportation systems, among others. Research studies that utilizes GIS to shape their research in terms of public transportation and transit were collated. Method in achieving the objectives are not exclusive to GIS methods. But in this paper, the focus is on the GIS aspects due to a broad range of methodologies. The outputs or findings is presented after from route optimization to spatial analysis. The ability of GIS to combine large amounts of data from different sources makes them a powerful tool. From volume data to population density, level of service and accessibility can be determined. From there route optimization and other transport planning may be further analyzed and developed.

Key Words: Transit; GIS; Spatial; Transportation; Data

1. INTRODUCTION

In recent times, transportation is now an important aspect in everyday lives. But due to traffic congestion, many hours and money are lost. With motorists prioritizing private transport, the balance is lost in transportation equity between public and private transportation. Transits are means of providing equal access between travelers. They reduce traffic congestion and ease environmental problems caused by private vehicles. Transport experts should try to plan a good public transit system for the people.

In transportation modelling, use of big data is a necessity due to the nature and scope of the problems. As such a Geographic Information System is more than capable in dealing with these kinds of data. They can store, display, manipulate, and analyze large amount of spatial data. In GIS based transit modelling, a computer integrated software can evaluate transit system models and perform many transit analysis methods for planning.

Aspects in planning include the availability of service for time based or geographic methods. Comfort and convenience of services can also be used as data.

This paper presents Geographic Information System (GIS) as a potential decision-making method for use in transportation planning. Several papers are reviewed to fully utilized the use of GIS.

1.1 PROBLEM

Because of the nature of data in transportation modelling, there is difficulty in analyzing and updating spatial data. Because of this, experts before relied on

simplified transport models and aggregated traffic zones. Even now because there is an increase of urban population which is directly proportional to the increase in movement needs in urban transportation, data needs are also growing. In addition, improper traffic management and planning will lead to severe traffic congestion and accidents in the city.

1.2 SIGNIFICANCE

Measuring urban transport performance can lead to a sustainable city. With an increase in public transport shares, there will a reduction in traffic congestion, better air quality, a reduction of number of accidents, a reduction in energy consumptions, an increase in the number of viable options, a better quality of life, and new economic opportunities. Because of these, there is a necessity in using advanced techniques in developing traffic management schemes.

1.3 APPLICATIONS

GIS can measure the level of sustainability of urban transport performances from key parameters. These include in applications of: Accessibility, Air Pollution, Noise Pollution, Energy Consumption, Public Transportation, Transportation Network, Traffic, and Transportation Infrastructure. The GIS applications for transit system modelling include transit service area analysis, data attribution, network representation, transit demand, transit distribution, linking transportation systems, among others.

1.3.1 Spatial Analysis

A favorite of people is the analysis of spatial attributes of data. GIS is capable of analysis these attributes for an effective traffic management system. The data can be used to identify locations of traffic congestion based on the spatial information. Usually traffic volume data are carried as attributes.

1.3.2 Level of Service and Accessibility

Improvements to LOS and accessibility are major use for justifying good public transit investment. LOS is identified as a percentage in Transit Supportive Area.

1.3.3 Route Optimization

Route optimization is one of the most sought for proper traffic management. Route optimization doesn't mean shortest path, it will also increase maximum utilization of the route in a proper way.

2. RESEARCH OBJECTIVES

The five journals reviewed for this paper are related to studies for public transportation. From route optimization to mapping transit access, GIS played a role in research.

2.1 Level of Service in Kuala Lumpur

The purpose of this journal to evaluate the level of service of public transportation provided by Rapid Kuala Lumpur using Geographical Information System (GIS). From this, Din et al. wanted to calculate employment density at ten 1obs per Hecate of household density at 7.5 unit per hectare as support data.

2.2 Mapping Transit Based Access

The objective of this journal by Lei et al. is to develop a framework for supporting transit service analysis and planning. This should be concerned with the measurements of access provided by the transit.

2.3 Geographic Information System (GIS) to measure Sustainable Urban Transport performance.

For this journal by Nadi et al., the objective is to show how Geographical Information Systems (GIS) used to measure the performance of Urban Transport Sustainability. The paper will focus on these parameters:

Accessibility: To measure the accessibility to transit network for household and cars and to evaluate the accessibility to health care facilities

Public Transport: To measure the performance of public transport studies area to know level of service, accessibility, and catchment areas

Traffic and Road Network: To represent the multi-modal transportation network to support network equilibrium-based travel demand.

2.4 Transit Route Design Applications Using Geographic Information Systems

To apply two simple methods for designing and improving public transportation routes with the aid of TransCAD and a geographic information system was the plan of Ramirez et al. For this paper, the objective is to overlay population and transportation network and draw the impact band width on each sides of the transportation segments.

2.5 GIS Based Route Optimization for Effective Traffic Management

The objective of Sureshkumar et al. (2017) is to apply Spatial Analysis in Route Optimization. In order to so, the researchers identified the traffic volume at congested locations in the study area, developed a GIS database for the traffic volume, and determined the alternate routes for effective traffic management.

3. METHODOLOGY AND SUCCESS OF THE STUDY

Method in achieving the objectives are not exclusive to GIS methods. But in this paper, we will focus on the GIS aspects due to a broad range of methodologies. The outputs or findings is presented after.

3.1 Level of Service in Kuala Lumpur

3.1.1 Methodology

The data that were collected from literature review and local government are:

- Transit routes and stations (Putra LRT, Star LRT, Monorail, and KTM) – using GPS
- Rapid KL bus stops – using GPS
- Street maps – JUPEM, Lake, and Building Maps
- Census data i.e. population, household data, socioeconomic data, employment and industry from Department of Statistics.

The data that were collected is converted into GIS format (shape files). Where after Integration, the model will be analyzed in terms of service coverage area and transit supportive area to calculate Level of Service. Please see flowchart in Figure 1.

3.1.2 Success of the Study

The parameters collected for the transit system un GIS are: Rapid KL bus stops, Putra LRT lines and stations, Star LRT lines and stations, Monoraillines and stations, KTM lines and stations, streets, and buildings. See Figure 2.

The TSA showed a significant of transit in the area as they are covered with sufficient population and employment density. Level of Service in Green are calculated with the percentage of TSA to area in Figure 3.

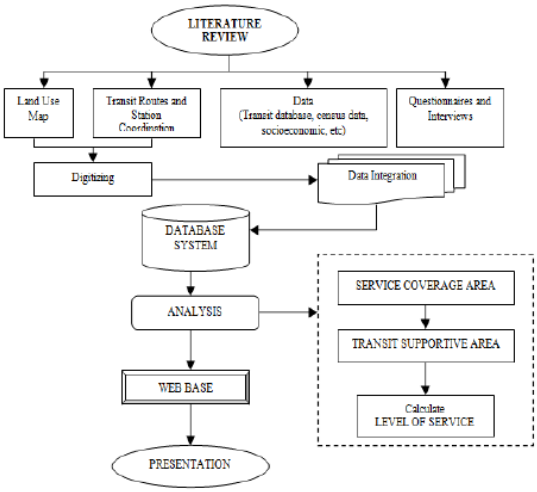

Figure 1 Methodological Framework of Kuala Lumpur Study

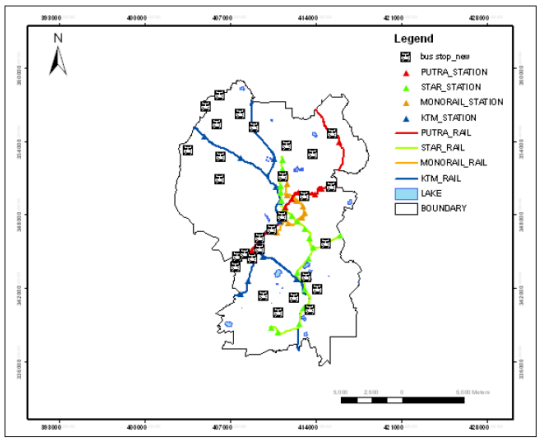

Figure 2 Transit System chosen

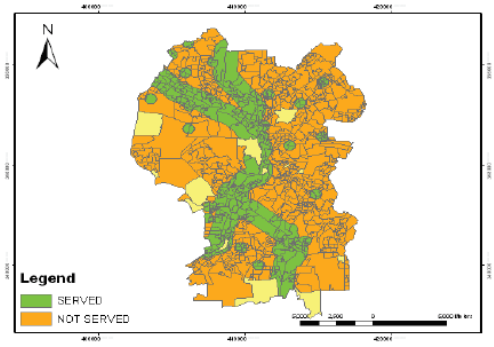

Figure 3 Transit Supportive Area

3.2 Mapping Transit Based Access

3.2.1 Methodology

Classification of GIS are collated and studied upon from Related Literature. We will discuss only two classification: Network Analysis and Buffer Analysis. For reference the summary of tools used in traffic studies are located below in Table 1.

The network analysis includes basic functions of GIS including measuring accessibility aggregates. Some related literature utilized the network to define locations for level of accessibility, calculate lengths of links, estimate pollutants in roads networks, among others. The buffer analysis is used to represent space time isochrones and denote finding spatial objects within an area.

3.2.2 Success of the Study

This journal denoted the use of GIS in Sustainable Urban Transport (SUT) performance is dominantly by network analysis and buffer analysis as seen in Figure 4. GIS approach by experts to measure the performance of public transport are not limited to level of services, accessibility and catchment area from the stations.

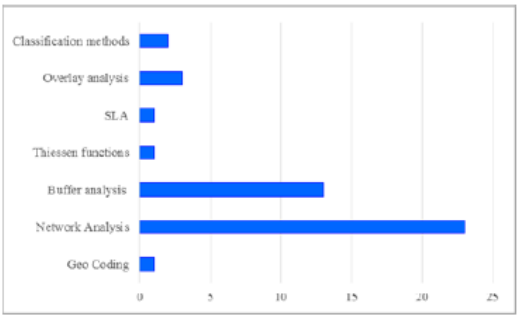

Figure 4 Proportion of paper used GIS tools in urban transport

3.3 Geographic Information System (GIS) to measure Sustainable Urban Transport performance.

3.3.1 Methodology

The key parameters for this study are a user's time budget and socioeconomic characteristics, travel by transit route, schedule, and the location of user in a time of day are used to develop a framework for supporting transit service. An accessibility measure developed from O'Sullivan was used to optimize route choices.

Table 1 GIS tools used in Transport Performance Studies

GIS TOOLS	FUNCTION	AUTHORS
Geocoding	- to identify the location of place in the map - to create points on a map from a table of addresses	(Murad, 2004)
Network Analysis	- to define the locations to determine their levels of accessibility - to calculate the length of each network link from geometry - to estimate the main pollutants from road networks - traffic model for traffic flows mapping - traffic simulation and analysis - presenting road network - to assess the level of service of the existing public bus transport system - to identify deficient network elements	(Paudel et al, 2009), (Gutierrez et al, 2010), (Mavoa et al, 2012), (Chapleau and Morency, 2005), (Ford et al, 2015), (Chen et al, 2012), (Zhang et al, 2016), (Aljoufie, 2016a), (Yigitcanlar and Dur, 2010), (Abreha, 2007), (Al-Ali, 2016), (Wang, 2005), (Machado et al, 2015), (Armstrong & Khan, 2004), (Arampatzis et al, 2004)
Buffer Analysis	- to define the object area based on a defined distance from other objects - to evaluate the accessibility of any location according to the factor of distance	(Mavoa et al, 2012), (Murad, 2003), (Murad, 2008), (Murad, 2011), (Murad, 2014), (Abreha, 2007), (Alshuwaikhat & Aina, 2006), (Paudel et al, 2009)
Theissen Functions	- to have polygon feature data where the area inside the polygon is closer to the point than to any other point	(Murad, 2003)
Straight-Line Allocation Function (SLA)	- to identify costumers/clients served by a service or stores - to identify closest hospital or health center - to find areas with a shortage of fire hydrants - to locate areas not served by a chain of supermarkets	(Murad, 2008)
Overlay Analysis	- to have a GIS layer that have patient data and facilities catchment area - to get a layer that have district such as population size and proximits health centers	(Murad, 2003), (Murad, 2004), (Murad, 2008)

$$\overline{A_{ij}} = \frac{t_{ij} + t_{ji}}{2} \qquad \text{(Eq. 1)}$$

where:

$\overline{A_{ij}}$ = the average time in travelling to a given destination j by a given travel time in the first trip and returning at a given departure time in a second trip

t_{ij} = the travel time from i to j for a desired arrival time at j using transit
t_{ji} = the travel time from j to i for a specified departure time at j using transit

3.3.2 Success of the Study

From GIS and route optimization from accessibility analysis, a system was proposed that uses a detailed route planning-based approach. Presented below in Figure 5 is a result generated services provided by the SBMTD. This shows from a root node the best way a route can be planned on from a catchment area.

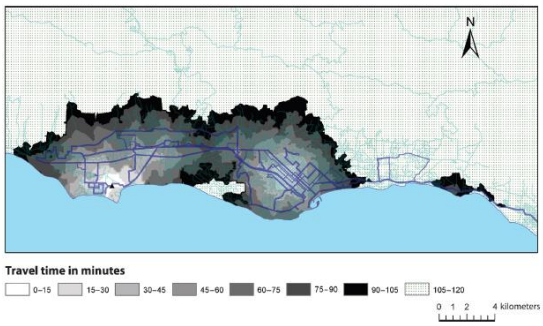

Figure 5 Composite Access Time

The framework in (Eq. 1 can be developed to model accessibility in terms of time constraints, in respect to the ability to make several trips and return at a given time.

3.4 Transit Route Design Applications Using Geographic Information Systems

3.4.1 Methodology

For this study, a direct-demand model was utilized to optimize path for a brand-new route. This will minimize the optimal alignment as an input to generalized impedance. Data such as population density, worker employed, bus trips, and so much more were analyzed in spatial analysis to derived equations which are shown in Table 2.

3.4.2 Success of the Study

A ridership prediction was successfully calculated. Route alignment from analysis and model was determined by use of minimal length and impedance criteria. An optimized path is presented in Figure 6. This method is good for small transit agencies and local planning authorities.

Table 2 Transit Route Design Applications Equations Used

Lists of Derived Equations from Spatial Analyses	
$R_i = p_i r_i$	(Eq. 2)
where: p_i = proportion of workers resident in zone i using bus as mode of travel to work r_i = workers resident in zone i	
$(p_i)^{0.5} = 0.3052 + 0.001(popden_i) - 0.1261(white_i) + 0.2993(zerocar_i) + 0.001(cov_i)^{0.5}(freq_i)^{0.5}$	(Eq. 3)
where: $popden_i$ = population density in thousands per 2.59 kilometers squared $white_i$ = proportion of white population in zone $zerocar_i$ = proportion of households with no automobile cov_i = percentage if zone within 0.4 kilometers of route $freq_i$ = combined frequencies of bus routes in the zone	
$W_i = q_i w_i$	(Eq. 4)
where: q_i = proportion of workers employed in zone i using bus as mode of travel to work w_i = workers employed in zone i	
$q_i = 0.0847 + 0.001(wrkden_i) - 0.079(white_i) + 0.3741(zerocar_i) + 0.007(freq_i)$	(Eq. 5)
where: $wrkden_i$ = thousand employees per 2.59 kilometers squared $white_i$ = proportion of workforce that is white	
$N_i = x(R_i + W_i)$	(Eq. 6)
where: x = 1.6 ratio of non-work trips to work trips from the 1990 NPTS	
$M_i = R_i + W_i + N_i$	(Eq. 7)
where: M_i = total bus trips per zone	

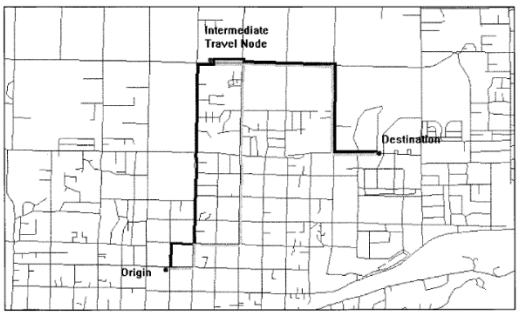

Figure 6 Optimized Routing from GIS

3.5 GIS Based Route Optimization for Effective Traffic Management

3.5.1 Methodology

Spatial analysis is carried out for the traffic volume data. The materials needed to apply spatial analysis for route optimization are:

- Preparation of base map
- Identification of traffic congested location
- Collection of traffic volume data
- GIS analysis
- Identification of new routes

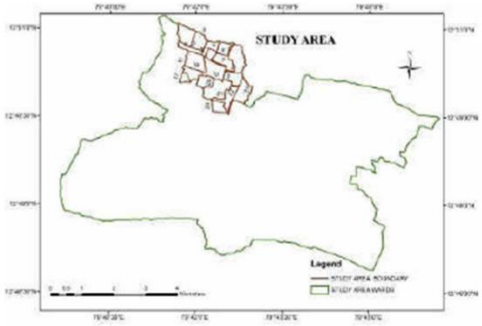

Figure 7 Kanchipuram is one of the famous tourism locations

3.5.2 Success of the Study

The study identified the present traffic volume in Kanchipuram city. From the analysis, a new route was proposed seen below. The adoption of new routes in the study area is useful to increase the transit service and may help in proper traffic management.

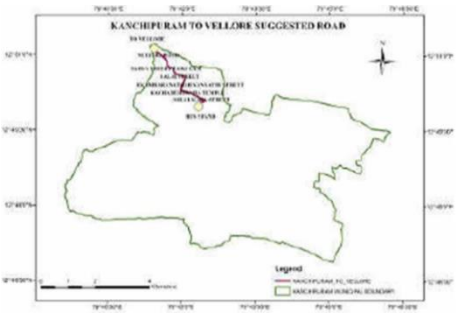

Figure 8 Proposed Route

4. CONCLUSION

After collating the five literature, a GIS analysis was a big help in each study. Though GIS is were not the primary tool, aggregated big data enabled researchers to meet their objectives. The ability of GIS to combine large amounts of data from different sources makes them a powerful tool. From volume data to population density, level of service and accessibility can be determined. From there route optimization and other transport planning may be further analyzed and developed.

5. RESEARCH OPPORTUNITIES

From this research, GIS has an impact to be a stand-alone tool in research. Because of the flexibility and power, someone who is well versed in coding can enable a researcher to manipulate data. GIS has the potential also to be integrated with other software to help research specifically aimed at the strength of a tool. There is an abundance of research opportunities in transportation such in land use planning and network developments.

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