EVALUATING LEVEL OF SERVICE (LOS) FOR SERVICE COVERAGE IN KUALA LUMPUR TRANSIT SYSTEM USING GIS

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ABSTRAK

Trafik jalan raya di Kuala Lumpur semakin meningkat and sesak hari ke hari. Oleh itu, ia genting untuk perkhimatan pengangkutan awam utama yang paling popular di Kuala Lumpur iaitu LRT Putra, Star LRT, KTM, KL Monorail dan Bas Rapid KL untuk dipantau, dipulih dan dikemaskini secara berterusan untuk memenuhi keperluan pengguna oleh agensi-agensi transit. Penilaian di status semasa perkhimatan telah di tentukan dengan mengira *Transit Supportive Area* (TSA) dan *Level of Service* (LOS) untuk setiap transit. Pelajaran kajian ini telah dijalankan pemetaan TSA dan LOS berdasarkan teknik – teknik *Geographical Information System* (GIS). Data banci terperinci rantau telah dikutip dari *Department of Statistics* Malaysia untuk kajian ini. Litupan perkhidmatan telah diputuskan oleh 400 meter zon penampan untuk stesen bas dan 800 meter untuk rel dalam ukuran Quality of Service sepanjang talian perkhimatan. Semua maklumat yang diperlukan telah dikira dengan menggunakan perisian GIS mengikut tempahan ArcGIS v9.3. Transit supportive area dikira dengan ketumpatan pekerjaan sekurang – kurangnya 10 kerja/hektar
supportive area dikira dengan ketumpatan pekerjaan sekurang – kurangnya 10 kerja/hektar
diliputi oleh TSA ialah 22,516 hektar dan jumlah kawasan yang tidak dilitupi atau ketumpatan isi rumah 7.5 unit / hektar dan kiraan memberi jumlah kawasan yang ialah 1718 hektar di Kuala Lumpur. LOS dikira dengan menggunakan peratusan bagi TSA yang dilitupi oleh transit untuk setiap transit. Secara keseluruhan, peratusan bagi LOS yang setiap transit adalah kurang daripada 60% dan untuk semua transit adalah kurang daripada 80% yang masih dalam kategori LOS yang sangat rendah. Penyelidikan ini telah membuktikan manfaat dengan menyediakan perkhimatan transit semasa pengendali - pengendali dengan maklumat yang penting untuk peningkatan perkhidmatan pengangkutan awam sedia ada.

ABSTRACT

Because of heavy traffic and congested roads, it is crucial that most main public transport services in Kuala Lumpur—that is, Putra LRT, STAR LRT, KTM Komuter, KL Monorail, and RapidKL buses—must be continuously improved by the transit agencies to fulfil the commuters' requirements. Transit planning is essential for transit agencies in all transit systems because commuters rely on these transit systems to travel from one place to another. The quality of service would determine the efficiency and the accessibility of every transit system for a better ridership. Therefore, evaluating the level of service (LOS) for service coverage in the Kuala Lumpur transit system has been determined using a geographic information system (GIS) as a tool for transit planning in this study. The service coverage measures of the quality of service that have been chosen in this study consist of a three-part analysis—namely, service coverage area, transit-supportive area (TSA), and service coverage LOS—for each of the transit system. The detailed census data of the region along the line of services have been collected from the Department of Statistics Malaysia. TSA covered 93% of the area, and only 7% is not a TSA in Kuala Lumpur. The service coverage LOS is calculated with the percentage of TSA served by each transit system. Overall, the percentage of TSAs serving every transit system was less than 60%, and the combination of all transit systems falls below 80%, which is still not efficient for a significant ridership. This study has proven that transit planning is important for transit agencies to provide a superlative quality of service for the commuters.

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LIST OF ABBREVIATIONS

LRT	Light Rail Transit
KTM	Keretapi Tanah Melayu
KL	Kuala Lumpur
TSA	Transit Supportive Area
LOS	Level of Service
TCQSM	Transit Capacity Quality Service Manual
GIS	Geographical Information System
VBA	Visual Basic Application
FTIS	Florida Transit Information System
FTGIS	Florida Transit Geographical Information System
GPS	Global Positioning System
JKR	Jabatan Kerja Raya
JUPEM	Jabatan Ukur Dan Pemetaan
RSO	Rectified Skew Orthomorphic
NTD	National Transit Database
TLOS	Transit Level of Service
PTAL	Public Transport Accessibility Level Index
CCS	Customer Satisfation Surveys
TIS	Transit Information System

CHAPTER 1

1.0 INTRODUCTION

1.1 Background

Transit services such as the Putra LRT, STAR LRT, KTM Komuter, KL Monorail, and RapidKL buses are some of the main public transport services in Kuala Lumpur. Riders in Kuala Lumpur rely on these public transports to travel from one point to another within the city because of heavy traffic and congested roads. Although the public transportation system in Kuala Lumpur has improved, there are still some tourist attraction sites such as the Taman Tasik Titiwangsa and Taman Tasik Perdana that are not accessible by public transport. Therefore, the public transportation system should be improved continuously by the transit agencies to fulfil the riders' requirements.

Personal transport remains the preferred mode of transportation for almost all Malaysians because of its convenience, flexibility, and social perceptions associated with its use. Public transit, conversely, is most often associated with restrictions, overcrowding, infrequency, and lack of destination choices. For public transit to compete effectively with the personal automobile, it must provide an acceptable level of convenience, including greater coverage and more frequent service to peripheral areas. Increasing the share of public transit will reduce traffic congestion, improve air quality, reduce the number of accidents, lessen energy consumption, increase the number of viable transportation options, help improve the quality of life, and create new economic opportunities. In order to reverse the trend of declining public transit usage and achieve sustainable development, particularly in urban regions, a well-utilised and efficient public transit system should be developed (Newman et al. 1999).

Transit agencies are always struggling with the attraction of riders in a highly competitive transportation market. One of the problems encountered by transit agencies is the quality of service in transit planning. Transit planning involves the planning, designing, delivering, managing, and reviewing of transit in order to balance the needs of society, the economy, and the environment (Kathy et al. 2005). According to Gan et al. (2005) from Florida Transit Geographic Information System, transit agencies rely heavily on data to help plan, manage, and improve transit facilities and services for transit planning. Some commonly used data include the National Transit Database, socioeconomic data from the Census Bureau and planning agencies, in-house transit route and stops data, employment data from commercial vendors, and so on. Although these data are available for use by transit agencies, they are usually not integrated and not easily accessible to the general users.

A key decision is determining whether transit service is even an option for a particular trip. Transit service is only an option for a trip when service is available at or near the locations and times that one wants to travel, when one can get to and from the transit stops, when sufficient capacity is available to make the trip at the desired time, and when one knows how to use the service. If any one of these factors is not satisfied for a particular trip, transit service will not be an option for that trip, so a different mode will be used, the trip will be taken at a less convenient time, or the trip will not be made at all. When service is not available, other aspects of transit service quality will not matter to that passenger for that trip, as the trip will not be made by a transit service (or at all), regardless of how good the service is in other locations or at other times.

Measuring the transit performance accurately is very important for public transit agencies in transit planning. According to the Transit Cooperative Research Program Report 88, there are three main reasons for measuring transit performance. First, it is required for transit agencies as a condition for federal funding. Second, it is useful for a transit agency to assess its performance in order to maintain and improve their services. Third, accurate information is needed for decision-making bodies to oversee transit service (Peng et al. 2006).

The presence or absence of transit service near one's origin and destination is a key factor in one's choice to use transit. Ideally, transit service will be provided within a reasonable walking distance of one's origin and destination, or a demand-responsive service will be available at one's doorstep. The presence of accessible transit stops, as well as accessible routes to transit stops, is a necessity for many persons with disabilities who wish to use fixed-route transit. When transit service is not provided near one's origin, driving to a park-and-ride lot or riding a bicycle to transit may be viable alternatives. Service coverage considers both ends of a trip, for example, home and work. Transit service at one's origin is of little use if service is not provided near one's destination. The options for getting from a transit stop to one’s destination are more limited than the options for getting from one’s origin to a transit stop.

The quality of service measures is used to assess whether transit services are meeting the passengers needs or the agency’s goals. Transit service coverage is one of the key components to measure the quality of service used in this study. To assess how well a transit system serves the area’s most likely to produce transit trips; the concept of transit-supportive area (TSA) has been used (O’Neill et al. 1995).

The TSA is the portion of the transit agency’s service area that provides sufficient population or employment density to be able to service at least once per hour. TSA is determined by its potential for significant transit ridership (O’Neill et al. 1995). The level of service (LOS) is based solely on the percentage of the TSA covered by the transit service (*Transit Capacity and Quality of Service Manual*, 2nd edition).

Therefore, the geographic information system (GIS) technology has been a tool in this study in order to determine the accessibility of the Kuala Lumpur system based on TSA analysis for transit planning (O’Neill et al. 1995; Peng et al. 2006; Challuri 2006).

GIS-based transit system modelling is a computer-integrated tool for evaluating transit system models and performing various transit analysis methods for transit planning. Using this advanced tool to model a transit system can therefore plan an enhanced transit network so as to increase the effectiveness of a transit system. GIS can be used to perform the TSA analysis and to calculate the LOS based on the service coverage measure of the quality of service.

1.2 Objectives of the Study

The purposes of this study were as follows:

i. To determine the importance of the GIS application for public transit on the quality of service using service coverage measures for transit planning in Kuala Lumpur
ii. To apply the service coverage area, the TSA analysis, and the calculation of the LOS based on service coverage measures in the existing Kuala Lumpur transit system using GIS
iii. To evaluate the efficiency and accessibility of service coverage LOS in the Kuala Lumpur transit system for transit planning

1.3 Scope of the Research

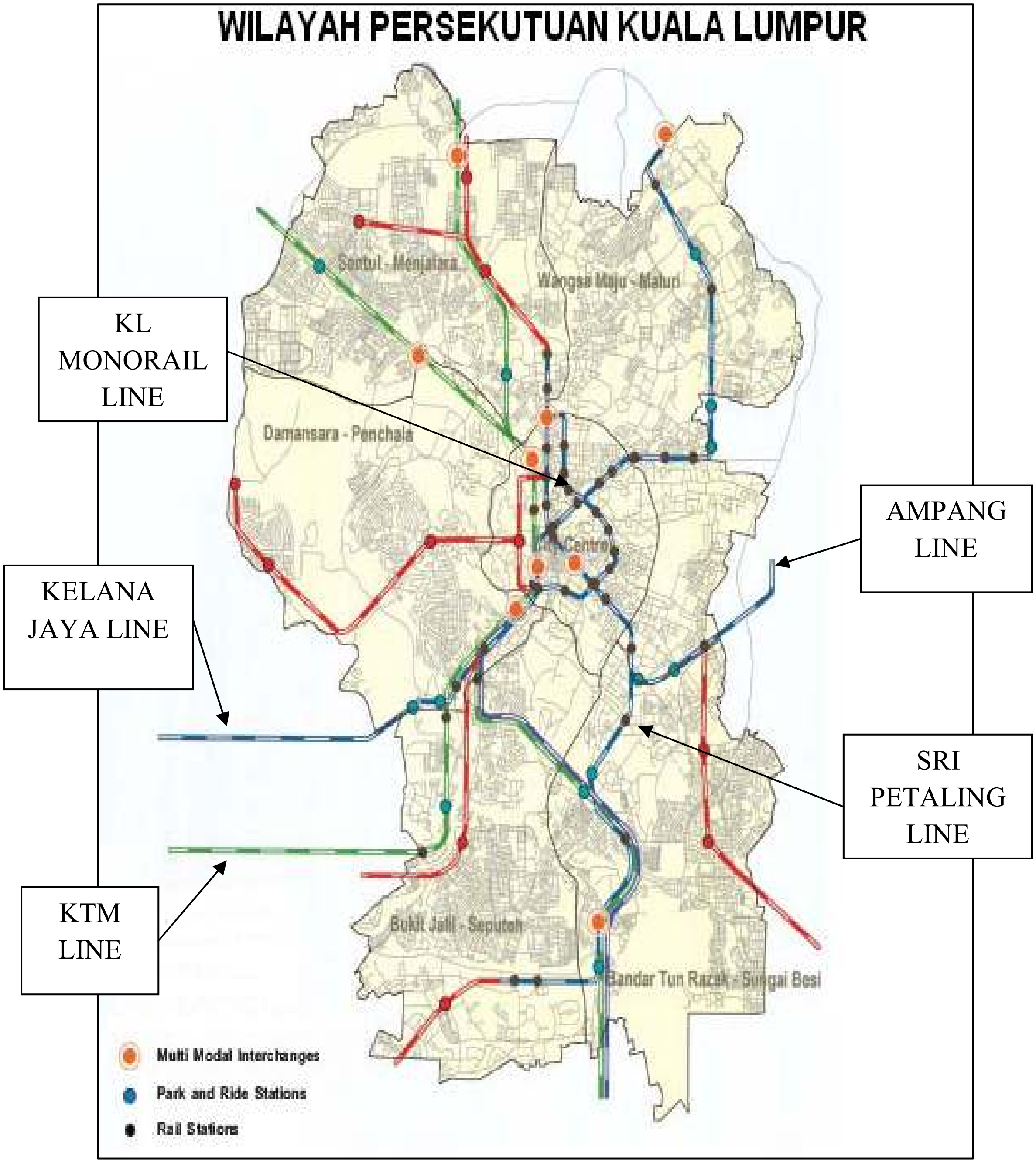
The scope of this research covers the Kuala Lumpur area with the identification of data needed for transit planning. All these parameters have been identified based on international guidelines, such as the *Transit Capacity and Quality of Service Manual* (*TCQSM*) (2nd ed.), as well as reviews from related literatures locally and internationally. The *TCQSM* (2nd ed.) has been used as a reference with the existing Kuala Lumpur transit system on the efficiency and accessibility of the system for transit planning. The data pertaining to this study were taken from relevant agencies; however, not all parameters are included in this study due to the lack of data availability. In this study, 12 parameters have been identified and collected for transit planning, namely, the transit services (Putra LRT, STAR LRT, KL Monorail, and KTM), routes and stations, road and street maps, lakes, bus stop locations, census data (population, employment, industrial, household), and building data. GPS was used to identify the locations of main RapidKL bus stops.

An important component of transit planning to increase the ridership in the transit system is the quality of service. There are six measures of quality of service listed (*TCQSM*, 2nd ed.), but service coverage is one of the measures that has been used in this study to derive the LOS of each transit system in Kuala Lumpur using GIS. Therefore, LOS according to the service coverage measures of each transit system in Kuala Lumpur was determined using GIS and evaluated for its better performance and services in the future. This research will apply the LOS techniques as used in the *TCQSM* (2nd ed.) to study the efficiency and the accessibility of its quality compared with the existing Kuala Lumpur transit system.

1.4 Study Area

Kuala Lumpur is the capital and the largest city in Malaysia. It has the coordinates 3°8'00" N and 101°42'00" E on the map. This territory area of 243.65 km^2 has an estimated population of 1.6 million as of 2012 and contains residential, commercial, industrial, and tourism areas. It is known as the fastest-growing metropolitan region in the country in terms of population, transportation, and economy.

The public transport in Kuala Lumpur covers a variety of transport modes such as bus, rail, and taxi. The rapid transit system in Kuala Lumpur consists of four separate transit lines and one bus mode, which meet in the city. The transit lines are the KL Monorail, the Kelana Jaya Line, the Sri Petaling–Ampang Line, and Seremban–Rawang Line, and there's the RapidKL bus. Because this research focuses on the transit system in Kuala Lumpur, these four transit lines and bus network were therefore preferred because the stations of these transit systems are within the Kuala Lumpur vicinity. The KL Monorail has all of its stations located in Kuala Lumpur. As for the Sri Petaling–Ampang Line, 21 of 25 stations are located inside Kuala Lumpur. Meanwhile, Kelana Jaya Line places 14 of 24 stations within Kuala Lumpur and serves the most important areas.



Source: http:www.dbkl.gov.my

Figure 1.1. Location of the study area and transit system

1.5 Outline of the Thesis

The work presented in this thesis has been divided into six major chapters, in which each chapter is explained in more detail in the subchapters. Chapter 1 is the introduction, in which it provides the general introduction of the study. It covers the objectives of the study, the scope of the research, the study area, and the significance of the study.

Chapter 2 generally highlights the transit information system for transit planning from the agencies' points of view about local and international guidelines. The quality of service measures are explained in detail in generating the LOS of each measure. Finally, it describes the application of GIS technology as a tool for storing and analysing spatial data and also its application in transit planning. Furthermore, the service coverage measures, which have been selected for this study for transit planning analysis in the GIS transportation, are also described.

Chapter 3 explains the methodology used to achieve the objectives of the study. It starts with the explanations about the transit quality of service measures data, in which 12 data are identified for the study area. The service coverage measures have been used, and the calculation of the service coverage LOS for the transit system is outlined.

Chapter 4 presents the results obtained from the analysis. The types of analysis—namely, service coverage area, TSA, and calculating LOS for service coverage—are shown and explained. Moreover, the service coverage LOS of each transit system is shown.

Chapter 5 presents the discussions of results after a thorough analysis of the information collected. This is the most important chapter, as it will present the research outcome.

Chapter 6 provides the conclusion of the study, which concludes the research findings in a nutshell and also proposes some recommendations for future research.

1.6 Significance of the Study

Public transportation provides people with mobility and access to employment, community resources, medical care, and recreational opportunities in communities across Kuala Lumpur. Public transit provides a basic mobility service to these persons and to all others without access to a car. The integration of public transportation options and the considerations into broader economic and land-use planning can also help a community expand business opportunities, reduce sprawl, and create a sense of community through transit-oriented development. By creating a locus for public activities, the development contributes to a sense of community and can enhance neighbourhood safety and security. Public transportation also helps to decrease road congestion and travel times, air pollution, and energy and oil consumption, all of which benefit both riders and nonriders alike. Generally, the good quality of public transit provokes economic development by providing residents with mobility and access to employment, community resources, and medical care.

This study aimed to evaluate the LOS for service coverage in the Kuala Lumpur transit system using GIS for transit planning. The benefit of this study is that Kuala Lumpur transit agencies can make better use of data to improve transit planning and service quality in Kuala Lumpur. The most important part of this study is the calculation of service coverage LOS for each transit services using service coverage measures on the existing transit system. The potential of service quality and transit ridership could be determined by transit agencies for transit planning. Ultimately, this study can be used as a guideline and proof that GIS can be performed to improve the transit system for transit agencies to plan their transit services.

An integration of the GIS and transit services for transit planning on the quality of service has been developed by using all the relevant data. All these data were kept in a proper folder for easy access. A database system consisting of all the data were created using the ArcGIS 9.3 software. Three main analysis methods were performed—namely, service coverage area, TSA, and calculating LOS—which were analysed using the ArcGIS 9.3 software.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter covers five parts of literature review. The first part explains the modern transit systems that are very important and used by the people in Kuala Lumpur. The second part encompasses the transit performances towards service quality. The third part of the study covers the main aspect of this study, which is the quality of service and transit planning used in planning most transit systems for better transit performance. Finally, the study covers the GIS. Here, it explains the concepts and the definition of GIS and its application in transportation.

2.2 Related Research Review on Transit Accessibility Measures

A number of means of measuring accessibility have been developed in several studies since the 1950s and continue to receive growing attention in the transit sector (Schoon et al. 1999). Different measures have been designed to reflect differing points of view. Some of the measures of public transit accessibility focused on local accessibility and considered both spatial and temporal coverage. The Time-of-Day-Based Transit Accessibility Analysis Tool (hereafter referred to as *Time-of-Day Tool*) developed by Polzin et al. (2002) is one measure that considers both spatial and temporal coverage at trip ends. In addition to the inclusion of the supply side temporal coverage, this tool explicitly recognises and considers the demand side of temporal coverage by incorporating the travel demand time-of-day distribution on an hourly basis.

In the *TCQSM* (2nd ed.), Kittelson et al. (2003) provide a systematic approach to assessing the transit quality of service from both spatial and temporal dimensions. This procedure measures temporal accessibility at the stops by using various temporal measures (Table 2.1). Assessing spatial public transit accessibility throughout the system is carried out by measuring the percentage of service coverage area and incorporating the transit-supportive area (TSA) concept. The calculation of service coverage area using the buffer area calculation (available in GIS software) is presented as an option.

The transit level of service (TLOS) indicator developed by Ryus et al. (2000) provides an accessibility measure that uniquely considers the existence and eminence of pedestrian route connected to stops. It also combines population and job density with different spatial and temporal features (Table 2.1) to measure transit accessibility. Revealing the association of safety and comfort of the pedestrian route to stops makes this method distinctive in the evaluation of public transit accessibility. Another measure that considers the space and time dimensions of local transit accessibility is the Public Transport Accessibility Level (PTAL) Index developed in 1992 by the London Borough of Hammersmith and Fulham (Cooper 2003, Gent and Symonds 2005). This index measures the density of the public transit network at a particular point (origin), using walk access time and service frequency and integrating the accessibility index for all available modes of transport from that point.

Hillman and Pool (1997) described a measure to examine how a database and a public transit planning software (ACCMAP) can be implemented to measure accessibility for local authorities and operators. This software measured local accessibility as the PTAL index using the combination of walk time to a stop and the average waiting time for service at that stop. Network accessibility was measured between an origin and a destination, including walk time from origin to transit stop, wait time at stop, in-vehicle travel time, wait time at interchanges, and time spent walking to destination.

A new approach to identify the geographic gaps in the quality of public transit service was developed by Currie (2004). This “needs gap” approach assesses the service of public transit by comparing the distribution of service supply with the spatial distribution of transit needs. Another study by Currie et al. (2007) quantifies the associations between the shortage of transit service and social exclusion and uniquely links these factors to social and psychological concepts of subjective well-being. This paper investigates the equity of transit service by identifying the transport-disadvantaged groups and by evaluating their travel and activity patterns.

A customer demand–oriented methodology incorporating all categories of accessibility measures is best for measuring the quality of service. Such a method should not view transit as a last resort, but as a service that should be available for heavily travelled corridors because it is a good option for travellers. Any method identifying service quality must consider the populations being served, meaning that one must consider the equity aspects of service configuration. The method should be easily understandable to public transit operators and contain fundamental information about the system and the community it serves.

2.3 Related Research Review on Transit Information System

In relation to this research, Gan et al. (2005) described a statewide GIS system called the Florida Transit Geographic Information System (FTGIS). It is a stand-alone GIS component that comes with both the network and the socioeconomic data for Florida's 26 fixed-route transit systems. This system was developed using ESRI's MapObjects developer library. One of the main applications of this research is to calculate the service coverage to generate the LOS based on the TSA of the service area for planning purposes. In conclusion, on the basis of previous studies, this research paper will determine a number of specialised methods using the GIS system to transit network and bus network for specific planning applications.

A review towards LOS for service coverage in a transit system revealed that a limited number of analyses were conducted using GIS as a tool for transit planning. For example, Biba et al. (2010) carried out a research on a new method for determining the population with walking access to bus stop locations using the spatial and nonspatial attributes of parcels and the network distances from parcels to bus stop locations. This parcel-network method avoids the well-known and unrealistic assumptions associated with the existing methods and reduces the overestimation of the population with access to transit, resulting in improved spatial precision and superior inputs to transit service decision-making processes. According to Hawas et al. (2012), on evaluating and enhancing the operational performance of public bus systems using GIS-based data envelopment analysis, the baseline performance level of a public bus service is evaluated using the data envelopment analysis based on some selected input (travel time per round trip, total number of stops, total number of operators, and total number of buses) and output (daily ridership and vehicle-kilometre) variables. Sensitivity analysis was then conducted to measure the efficiency and effectiveness of each route, and the overall performance levels of the bus service by changing some route characteristics were presented.

Measuring transit system accessibility using a modified two-step floating catchment technique by Langford et al. (2012) has drawn attention to the importance of measuring accessibility to public transit services for transport planning and decision-making purposes and by GIS to produce accessibility maps. An accessibility measure based on enhanced "floating catchment" techniques has been applied to measure access to public transport opportunities, and the importance of transit accessibility were determined. Gutierrez et al. (2011) has developed a rapid response ridership forecast model based on the combined use of GIS, distance-decay functions, and multiple regression models. The number of passengers boarding at each station in the Metro de Madrid network is estimated as a function of the characteristics of the stations (type, number of lines, accessibility within the network, etc.) and of the areas they serve (population and employment characteristics, land-use mix, street density, presence of feeder modes, etc.). The analyses show that weighing the variables according to the distance-decay functions provides systematically better results. The choice of distance threshold also significantly improves outcomes. When an all-or-nothing function is used, the way the service area is calculated (straight-line or network distances) does not seem to have a decisive influence on the results.

The study by Md. Kamruzzaman et al. (2011) on using GIS to visualise and to evaluate student travel behaviour is important to increase our understanding of the relationship between accessibility and transport demand. Three different indicators such as the number of unique locations visited, the average daily distance travelled, and the average daily activity duration were used to measure the size of activity spaces. Multiple regression analyses were used to assess the impacts of students' socioeconomic status and the spatial characteristics of home location. The evaluation of these results indicated that although the service currently covers areas of high demand, 90% of the activity spaces remained unserved by the DRT service. The six new routes were designed to meet the coverage goal of public transport based on a measure of network impedance based on inverse activity density.

Table 2.1. Summary of previous transit accessibility measures

Study/Paper	**Type of Measure**	**Reflecting Local Accessibility**		**Reflecting Network Accessibility**	**Incorporated Accessibility Measure(s)**	**Important Feature**	**Computational Complexity**	**Intended Users**
		Spatial Coverage	Temporal Coverage					
Polzin et al. (2002)	Time-of-Day Tool (INDEX)	Yes	Yes	No	Service coverage, time of day, waiting time, service frequency, demographic data	Time-of-day trip distribution	Transportation specialist	Transit planner
TCQSM et al. (1999)	LOS	Yes	Yes	No	Service frequency, hours of service, service coverage, demographic data	LOS concept	Some technical skill	Transit operator, transit user
Hillman and Pool (1997)	PTAL (Index)	Yes	Yes	Yes	Service frequency, service coverage	Aggregate travel time between O-D pairs	Transportation specialist	Transit planner, transit operator
Ryus et al. (2000)	TLOS	Yes	Yes	No	Service frequency, hours of service, service coverage, walking route, demographic data	Availability and quality of pedestrian route	Transportation specialist	Transit planner, transit operator
Currie (2004)	Supply Index and Need Index	Yes	Yes	Yes	Service frequency, coverage, travel time, car ownership, demographic data	Transport needs measure	Some technical skill	Transit planner, transit operator, property developer

2.4 Transit System in Kuala Lumpur

Mass transit systems are becoming popular in metropolitan cities. Light rail transit (LRT) systems, the modern version of streetcars, are one of the more popular transit systems in Kuala Lumpur. LRT is an important part of the modern transit system due to its ability to transport high numbers of passengers comfortably, efficiently, and quickly. Monorail is also an important mode of public transportation in Kuala Lumpur. Because the tracks of a monorail system require minimal space horizontally and vertically, this system is usually located in the middle of busy and congested areas.

Generally, the modern transit systems in Kuala Lumpur consist of six transit systems. They are the Ampang Line, the Sri Petaling Line, the Kelana Jaya Line, the KTM Komuter, the Express Rail Link (ERL), and the RapidKL bus system. The Ampang Line, the Sri Petaling Line, and the Kelana Jaya Line are the LRT systems operating under one main operator, the Rangkaian Pengangkutan Integrasi Deras Sdn Bhd (RapidKL). The routes of these three systems cover most areas of Kuala Lumpur and some areas of Selangor. KL Monorail is operated by KL Monorail System Sdn Bhd, which runs through the central areas of commercial buildings, hotels, and shopping arenas in the Kuala Lumpur district.

KTM Komuter is Malaysia's first electrified rail system operated by Keretapi Tanah Melayu Berhad (KTMB). This commuter rail system serves certain areas in Kuala Lumpur and Selangor. ERL is a high-speed air-rail system between Kuala Lumpur City Air Terminal at KL Central Station and Kuala Lumpur International Airport.

2.4.1 Kelana Jaya Line (Putra LRT)

The Kelana Jaya Line, locally and formerly known as Putra LRT (Projek Usahasama Transit Ringan Automatik Sdn Bhd), consists of 24 stations with 18 elevated stations, 5 underground stations, and one station at grade. The mostly elevated route runs through many high-density residential and commercial areas on a dual-track guideway. The alignment starts from the depot in Subang and ends at Terminal Putra in Gombak, totalling 29 km in length. It is to be the third longest fully automatic driverless system using linear induction motors in the world.

2.4.2 Ampang Line and Sri Petaling Line (STAR LRT)

Ampang Line and Sri Petaling Line were locally and formerly known as the Sistem Transit Aliran Ringan (STAR) LRT. STAR LRT was the first LRT system in Malaysia. Ampang Line runs between Sentul Timur in the north and Ampang in the east of Kuala Lumpur. The Sri Petaling Line runs between Sentul Timur in the north and Sri Petaling in the southern part of Kuala Lumpur. It has 25 stations including two end stations, which run through the total length of 27 km. The Ampang and the Sri Petaling Lines share the same tracks between Sentul Timur and Chan Sow Lin stations, where they diverge. This driver-operated transit system was opened to the public in 1998.

2.4.3 KL Monorail

KL Monorail, which was launched in August 2003, was developed and built in Malaysia. It was built to serve the central business, hotel, and shopping district of Kuala Lumpur. It runs 8.6 km in length from Jalan Tun Razak Bus Terminal to KL Sentral. KL Monorail consists of 11 stations, 5 power substations, 1 depot, and 12 monorail trains. All stations are fully elevated, and the distance between two stations is between 600 to 1000 m.

2.4.4 KTM Komuter Line

KTM Komuter is an electrified commuter train service first introduced in 1995 and is operated by KTMB, catering especially to commuters in Kuala Lumpur and the surrounding suburban areas. KTMB provides 248 commuter services daily, serving 45 stations along 175 route kilometres. The network consists of three lines: the Rawang-Seremban Route, the Sentul-Port Klang Route, and the Rawang-Kuala Kubu Bharu shuttle route. Trains on the two lines run at a 15-minute frequency during peak hours and at a 20-minute frequency during off-peak hours.

2.4.5 RapidKL Bus System

The RapidKL bus system is the largest bus operator in the Klang Valley, Malaysia. As of 2008, it operates 167 routes with 650 buses covering 980 residential areas with a ridership of about 400,000 per day. Express route services operate from point to point without or with very few stops in between. City shuttles operate within Kuala Lumpur's central business district, linking five city bus hubs. Trunk route buses run from these hubs to suburban or regional hubs and stop at all regulated bus stops along the way. Local shuttles operate from suburban or regional hubs into residential areas. There are in total 3 express route services in RapidKL, 15 city shuttle services, 19 trunk route services, and 140 local shuttle routes in total. As of September 2006, RapidKL had 849 buses operating on these routes. RapidKL has also divided up the Klang Valley into six areas, and the bus route numbering system, to a large extent, follows the zone numbers.

2.5 Transit Performances Measures

Performance measurement can be defined as the assessment of an organisation's output as a product of the management of its internal resources (money, people, vehicles, and facilities) and the environment in which it operates (Transportation Research Board 2004b). Performance measurement is very useful for different aims: assisting in evaluating the transit system's overall performance, assessing management performance expectations of the transit system in relation to community objectives, assessing management performance and diagnosing problems such as disproportionate cost in relation to service, allocating resources amongst competing transit properties, providing a management control system for monitoring and improving transit services, and facilitating the accountability sought by government funding agencies and demanded by legislators, regional, and transit authority boards and the general public.

Performance in general terms refers to any evaluation or comparison measure. A performance measure can be considered as a quantitative or qualitative characterisation of performance. Each of these measures has certain indicators that are used to signify transit performance for each particular measure. A performance indicator is more specifically a performance measure used to document progress towards a performance goal and to monitor performance. A review of the literature on transit performance reveals that not all agencies use the same terms for performance measures (Fielding 1987). In addition, views of performance-based allocation and how indicators are calculated vary tremendously. Therefore, in the literature, there are various classifications of the transit performance measures, some are more schematic and others more articulate.

As an example, the TCRP Report 88 (Transportation Research Board 2003a) proposes a classification that considers indicators of cost-efficiency, defined as the measure of service output compared to unit of input (cost); cost-effectiveness, defined as the measure of outcome compared to unit of input in terms of cost; and service effectiveness, which is the measure of outcome compared to the unit of input in terms of service.

A classification more oriented to the agency's point of view is proposed by Dalton et al. (2000), who considered input, output, or outcome measures. Input measures look at the resources dedicated to a programme (e.g., money spent and kilometres of pavement placed), output measures look at the products produced (e.g., materials consumed and kilometres of lanes), and outcome measures look at the impact of the products on the goals of the agency (staff time consumed, hours of bus service added, and reduced travel time). Outcome measures are preferred because they directly relate the agency's strategic goals to the results of the activities undertaken to achieve them; however, these measures might not be evident until months after product delivery and can be difficult to define.

Meyer (2000) classified the performance indicators into three more comprehensive categories. A first category is represented by general performance indicators, such as service area population, passenger trips, vehicle kilometres and hours, and so on. The second category is represented by the effectiveness measures, including the following subcategories: service supply (passenger trips per capita and passenger trips per hour), quality of service (average speed, average headway, and number of incidents), and availability (weekday span of service and route kilometres per square kilometre). The third category includes efficiency measures divided into the following: cost-efficiency (operating expenses per passenger trip and operating expenses per revenue hour), operating ratios (local revenue per operating expenses), vehicle utilisation (vehicle kilometres per peak vehicle and vehicle hours per peak vehicle), labour productivity (passenger trips per employee), energy use (vehicle kilometres per kilowatt-hour), and fare.

Vuchic (2007) proposed an enough comprehensive classification of performance indicators: transportation quantity or volume (number of vehicles or fleet size, fleet capacity, number of lines and network length, and annual number of passengers), system and network performance (intensity of network service and average speed on a transit system), transportation work and productivity (annual vehicle kilometres, annual space kilometres, and annual passenger kilometres), transit system efficiency indicators (vehicle kilometres/vehicle/year, passengers/vehicle kilometres, daily passengers/employee, and vehicle kilometres/kilowatt-hour), and consumption rates and utilisation indicators (operating cost/passenger, operating cost/vehicle kilometres, and scheduled vehicles/fleet size).

A similar classification was proposed by Carter et al. (1992), structured in six categories of indicators: cost-efficiency (cost per kilometre and cost per hour), cost-effectiveness (cost per passenger trip and ridership per expense), service utilisation/effectiveness (passenger trips per kilometres and passenger trips per hour), vehicle utilisation/efficiency (kilometres per vehicle), service quality (average speed and vehicle kilometres between accidents), and labour productivity (passenger trips per employee and vehicle kilometres per employee).

What is important and vital in the performance and delivery of a transit service depends significantly upon perspective (Transportation Research Board 2003a). As an example, the traditional cost-efficiency and effectiveness indicators can be considered as performance measures from the transit agency perspective, although they are not linked to customer-oriented and community issues, which are fundamental perspectives in the evaluation of a service (Transportation Research Board 2003a). Many researchers consider the customer's point of view the most relevant for evaluating transit performance; as an example, Berry et al. (1990) pointed out that "customers are the sole judge of service quality." Passengers evaluate services in many ways that may not be systematically associated with the amount of use of the service because the measures of efficiency and effectiveness, as aggregate indicators of total output, implicitly assume homogeneity of service quality (Hensher 2007). Hence, from the passenger's point of view, transit performance must be evaluated by considering indicators of service quality (Transportation Research Board 2003b).

2.6 Transit Quality of Service and Transit Planning

Transit service quality can be measured by a range of simple disaggregate performance measures, which can be used for measuring the ability of a transit agency to offer services that meet customer expectations (Transportation Research Board 1999b). These performance measures are quantitative measures expressed as a numerical value, which provides no information by itself about how "good" or "bad" a specific result is, and for this reason, it must be compared with a fixed standard or past performance.

These measures can be considered as objective measures. Service quality can be also evaluated on the basis of transit user judgements. These judgements, which can be considered a subjective measure of service quality, were generally derived from the well-known Customer Satisfaction Surveys, which help transit operators to identify which service quality factors are considered the most important by their customers. Customer judgements can be expressed in terms of expectations, which represent what customers expect of the service, and perceptions, which represent what customers receive from the service (Parasuraman et al. 1985). Service quality measurement based on customer opinions allows the perceived performances of a given transit service to be analysed. The main disadvantages of this type of measure are the strong subjectivity of transit users' judgements and the failure to take nonusers' perceptions into account. In addition, considerable statistical errors could occur when respondents are not correct sampled or users' judgements are too heterogeneous.

The transit quality of service is the appraisal of transit service from the passenger's point of view. It takes a different approach to service evaluation than that historically used by the transit industry, which is to measure the business aspects of transit service—things such as ridership, cost-effectiveness, and productivity. The transit quality of service appraisal are not intended to replace these traditional measures but somewhat to supplement them. For an example, the transit quality of service measures can help transit agencies have better understand their ridership patterns and help them plan their service to supply the best quality of service possible to the greatest number of potential customers within the constraints of their budget.

There are two primary aspects of quality of service to consider. The first is the availability of service both geographically and by time of day. If service is not available between the locations where one wants to travel or is not provided at the time one wants to travel, then transit is not an option for that trip. Besides, even if the service is available, people need to know how to use it. This is when transit planning is very important for the transit agencies to make sure the transit service is available for the convenient of the commuters.

The second aspect is the comfort and convenience of the service. This encompasses a number of factors, for example, the waiting environment at the bus stop, the ability to get a seat on the bus, the overall travel time, the reliability of the service, the passenger's perceptions of the safety and security of the trip, and the cost of the trip relative to other choices. Assuming transit is an option for a trip, these factors help influence whether one would choose the transit or not to use it.

Six measures of quality of service for fixed-route transit system has been identified in the *TCQSM* (2nd ed.), which is to passengers and transit agencies. The six measures are listed in Table 2.2.

Table 2.2. *TCQSM* fixed-route transit quality of service measures

	Transit Stop	**Route Segment**	**System**
Availability	Frequency	Hours of service	Service coverage
Comfort and Convenience	Passenger load	Reliability	Transit-auto travel time

Source: *Transit Capacity and Quality of Service Manual*, 2nd ed.

2.6.1 Transit Availability

There are a number of conditions that affect transit availability, all of which need to be met for transit to be an option for a particular trip:

- Transit must be provided near one's trip origin. If a demand-responsive service is not provided to one's door, a transit stop must be located within walking distance, and the pedestrian environment in the area should not discourage walking (e.g., due to a lack of sidewalks, steep grades, or wide or busy streets). Persons with disabilities require a continuous ADA-accessible path to the transit stop. One may also be able to ride a bicycle to a transit stop if bicycle storage facilities are available at the stop or if bicycles can be carried on transit vehicles. Similarly, one may be able to drive to a park-and-ride lot if such a lot is provided along the way and space is available in the lot.

- Transit must be provided near one's destination. The same kinds of factors discussed for the trip origin apply to the trip destination as well, except that bicycles or automobiles left behind at the boarding transit stop will not be available to passengers at their destination.

- Transit must be provided at or near the times required. In most cases, service must be available for both halves of a round trip—from one's origin to one's destination, as well as for the return trip. If passengers perceive a risk of missing the final return trip of the day or if transit is available for only one of the two halves of passengers' round trips, transit is less likely to be an option for those passengers.

- Passengers must be able to find information on when and where transit service is provided and how to use transit. If passengers are unable to find out where to go to board transit, where they need to transfer, how much the fare will be, and so forth, transit will not be an option.

- Sufficient capacity must be provided. If a transit vehicle must pass up passengers waiting at a stop because the vehicle is already full, transit service was not available at that time to the passengers waiting at the stop.

If all of these conditions are met, transit is an option for a particular trip. Then the passengers' decision to use transit will depend on the comfort and convenience of the service relative to competing modes.

2.7 Service Coverage Quality of Service Measures

Service coverage is a measure of the area within walking distance of transit service. As with the other availability measures, it does not provide a complete picture of transit availability by itself, but when combined with frequency and hours of service, it helps identify the number of opportunities people have to access transit from different locations. Service coverage is solely an area measure: at the transit stop level, if transit service is provided, coverage obviously exists at that location.

Because it is an areawide measure, service coverage LOS takes more time to calculate and requires more information compared with the transit stop and route segment/corridor LOS measures. This task can be simplified through the use of a GIS.

One measure of service coverage is route miles per square mile (route kilometres per square kilometre). This measure is relatively easy to calculate but does not address on a systemwide basis how well the areas that generate the most transit trips are being served, nor does it address how well transit service is distributed across a given area.

Another measure would be the percentage of the system area served. However, land uses and population and job densities may vary greatly from one system to another, depending on how land uses have developed and how the system's boundaries have been drawn. Urban transit system boundaries might include large tracts of undeveloped land that may be developed in the future, whereas countywide systems will likely include large tracts of rural land. Neither area would be expected to generate transit trips in the near term. How the boundaries are drawn will determine how much area is included within the service area, which in turn will affect any area-based performance measures. As a result, service areas, by themselves, are not the best basis for developing service coverage performance measures.

As a compromise, service coverage LOS looks at how much of the areas that would typically produce the majority of a system's ridership—that is, the densest areas—are served. Specifically, those areas that may be capable of supporting hourly transit service are addressed.

2.7.1 Transit-Supportive Area

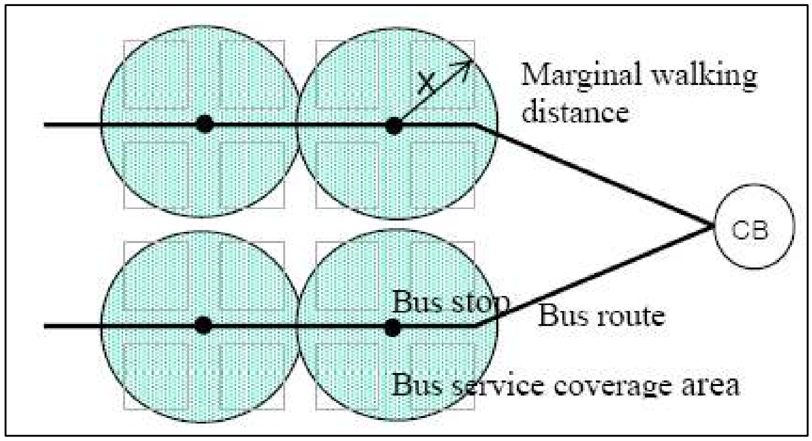
Pushkarev et al. (1977) suggested that a household density of 4.5 units per net acre (11 units per net hectare) is a typical minimum residential density for hourly transit service to be feasible. This equates to a density of approximately 3 units per gross acre (7.5

units per gross hectare). Net acres are often referenced in zoning codes and consider only the area developed for housing or employment. Gross acres are total land areas, which may include streets, parks, water features, and other land not used directly for residential or employment-related development. Gross acres are easier to work with in calculations and are therefore used in this methodology. Hourly service corresponds to the minimum LOS "E" value for service frequency as well as the minimum frequency used for determining hours of service LOS.

A long-range service planning study by Nelson et al. (1997) found that an employment density of approximately four jobs per gross acre (10 jobs per gross hectare) produced the same level of ridership as a household density of 3 units per gross acre (7.5 units per gross hectare). These density values are used in this methodology as the minimum job densities that are capable of supporting hourly transit service.

Areas with a minimum density capable of supporting hourly service are referred to as TSAs in this methodology. For policy reasons or simply to provide a route connecting two higher-density areas, an agency may choose to—and likely will—cover a larger area than that defined by its TSAs

The TSA focuses on the locations where transit riders are assumed to reside and their desired destinations. The measure examines whether the transit system is travelling along appropriate routes. The TSA is the portion of a transit agency's service area that provides sufficient population or employment density to require service at least once per hour.



Source: *Transit Capacity and Quality of Service Manual*, 2nd ed.

Figure 2.1a. The concept of bus service coverage and marginal walking distance

TSA was generated using the model builder tools in ArcMap. ModelBuilder is an application used to create, edit, and manage models. Models are workflows that string together sequences of geoprocessing tools, feeding the output of one tool into another tool as input. ModelBuilder can also be thought of as a Visual Basic programming language for building workflows. Although ModelBuilder is very useful for constructing and executing simple workflows, it also provides advanced methods for extending ArcGIS functionality by creating and sharing the models as tool.

ModelBuilder can even be used to integrate ArcGIS with other applications. An example of model builder processes is shown in Figure 2.1b.

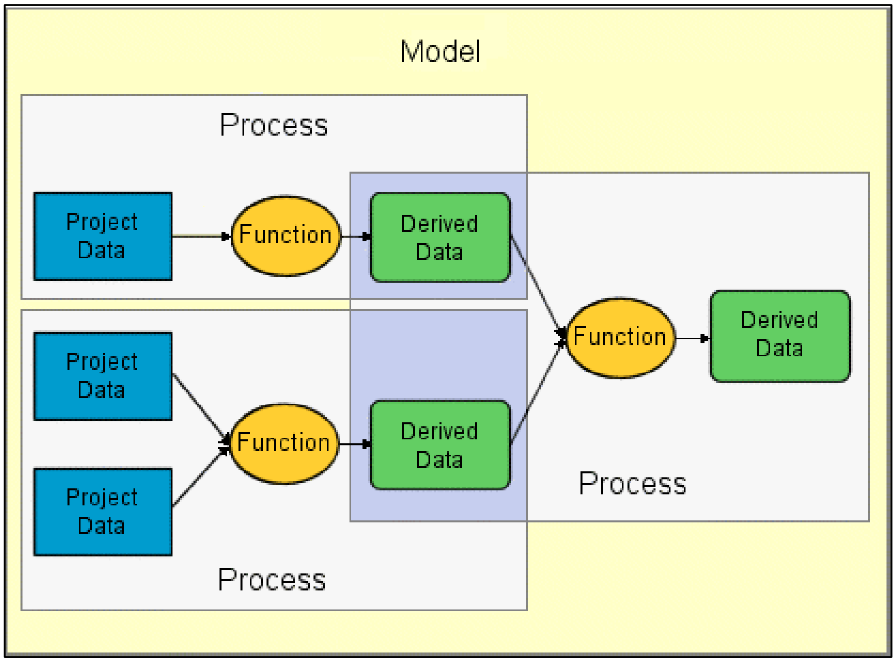


Figure 2.1b. Example of model builder processes

2.7.2 Service Coverage LOS

Service coverage LOS measures the size of the area actually served by transit capable of supporting at least hourly daytime service. Higher LOS levels show a greater variety of origins and destinations that potential passengers can travel between. Service coverage LOS emphasises on the area within walking distance of transit stops.

2.8 GIS (Concepts and Components)

The general concepts and components of GIS are relatively very familiar to almost all who deal with GIS. Since the urgent situation of GIS in the 1960s, there have been developments in the field, which has guided the refinement of the GIS definition, its core components, and its key functions. There is no single definition of the term GIS, and the definitions differ from one user to another to suit his or her application.

However, the following definitions are prominent and acceptable amongst GIS users and researches:

> Longley et al. (2005) defined GIS as follows: "Geographic information systems are specials class of information system that keep track not only of events, activities, and things, but also of where these events, activities and things happen or exist."

> de By (2004) defined a GIS as "a computerized system that facilitates the phases of data entry, data analysis and presentation especially in cases when we are dealing with geo-referenced data."

> Burrough and MacDonnel (1998), quoted in Maguire et al. (1991), defined it as "a powerful set of tools for collecting, storing, retrieving at will, transformation and displaying spatial data from the real world."

> Worboys and Duckham (2004) defined GIS as "a computer-based information system that enables capture, modelling, storage, retrieval, sharing, manipulation, analysis and presentation of geographically referenced data."

The main common and significant element in all definitions is that GIS deals with data that have a geographic position (georeferenced data or spatially referenced data). All definitions tell what a GIS does, particularly the one given by Worboys and

Duckham (2004), is a functional-based definition that enlists the functions of GIS-based information system.

In the last decade from the 1990s, Maguire et al. (1991) defined the well-known four components of GIS, which operate in institutional settings and comprised the following: computer hardware, computer software, data, and people. However, today, due to advances and developments that have evolved in the GIS field in the 2000s, the network is today's most fundamental GIS component and procedures. There are six main components of GIS as mentioned and maintained by Longley et al. (2005) and Worboys and Duckham (2004):

1. Computer hardware
2. Computer software
3. Data
4. People
5. Procedures
6. Network

GIS also uses two types of data structures for representing objects in the computer environments. The two well-known structures are vector and raster data. Many researchers have conducted studies about GIS data structures or data models, including Maguire et al. (1991), Bernhardsen et al. (1992), Burrough and MacDonnel (1998), de By (2004), Worboys and Duckham (2004), Longley et al. (2005), Neteler and Mitasova (2005), and Galati (2006).

The GIS definition provided by Worboys and Duckham (2004) lists some functions of a GIS. Generally, the functions of a GIS can be generalised into five main functions:

1. Data capture and editing
2. Data manipulation (storage, management, retrieval, and updating)
3. Spatial analysis and modelling
4. Data integration
5. Geovisualisation (output/display)

2.8.1 GIS (Application in Transportation)

GIS has been widely used in the field of transportation because location information is crucial for transportation applications, such as transportation planning, intermodal facility management, pavement management, bridge inventory and modelling, accident analysis, fleet management, transit service planning, and many more (Zhao 1997; Sutton 2007). All transportation applications require transportation network data, and GIS has been used for the representation and analysis of transportation networks.

The GIS-Transportation (GIS-T) short form is defined as the "principles of applying geographic information technologies to transportation problems" (Miller and Shaw 2001; Shaw and Rodriques 2006). GIS-T is a very broad term that encompasses all of the activities that involve the use of GISs for some aspects of transportation planning and management. Government institutions, agencies, and private companies are just some of the entities that build and use GIS-T applications (Curtin et al. 2003; Rodrigue et al. 2006).

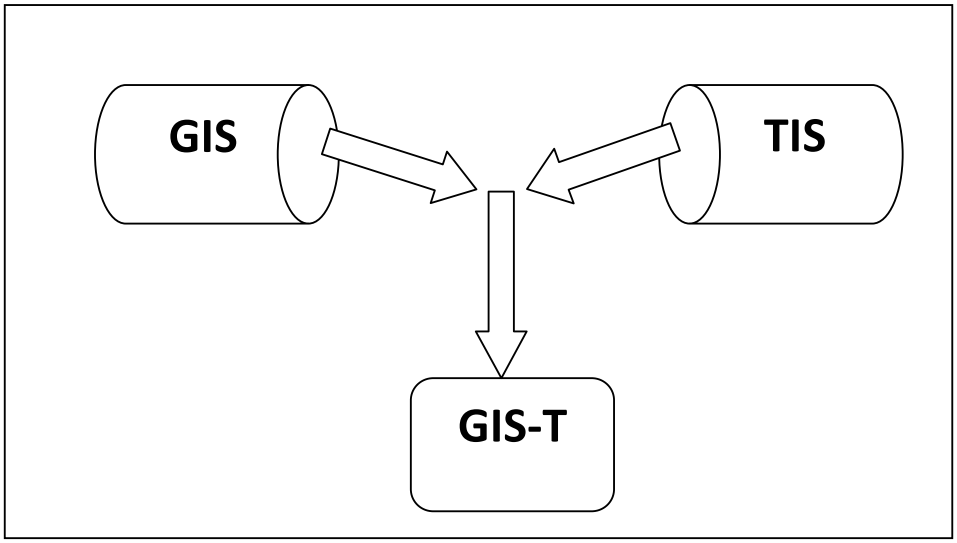
GIS-T application requires the design and development of a geographic database that has the following key items:

i. Development of geodatabase

ii. Development of attribute or nonspatial database

iii. Development of spatial referencing system

In general, transportation data that can be supported in GIS-T include nodes, links and networks, paths, and origin destinations data. GIS-T also combines the use of GIS and information technology in transportation files known as the transportation information system (TIS) into one integrated system framework called GIS-T as shown in Figure 2.2.



Source: Vonderohe (1993).

Figure 2.2. GIS-T as an integrated GIS and TIS

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CHAPTER 3

3.0 METHODOLOGY

3.1 Introduction

The design of the research is explained in this chapter. The steps are presented in a form of a diagram (see Figure 3.1), and each of the steps is explained in detail in chapter 3.2. The related data for the transit system are explained and discussed based on local guidelines, international practices, and literature review. Finally, the most essential step for evaluating the service coverage LOS is the analysis using the GIS, the spatial analysis that will be elaborating and generating a programme for the final application.

3.2 Methodology

The overall process of the evaluating the service coverage LOS in the Kuala Lumpur transit system is outlined in Figure 3.1. It illustrates the series of processes which starts with the objectives of the study, identifying the related data; data acquisition, preparing and organising the data into GIS; and finally the analysis of service coverage measures, processing and presenting the results in map formats. The service coverage measures method is divided into three parts, namely, service coverage area, TSA, and LOS.

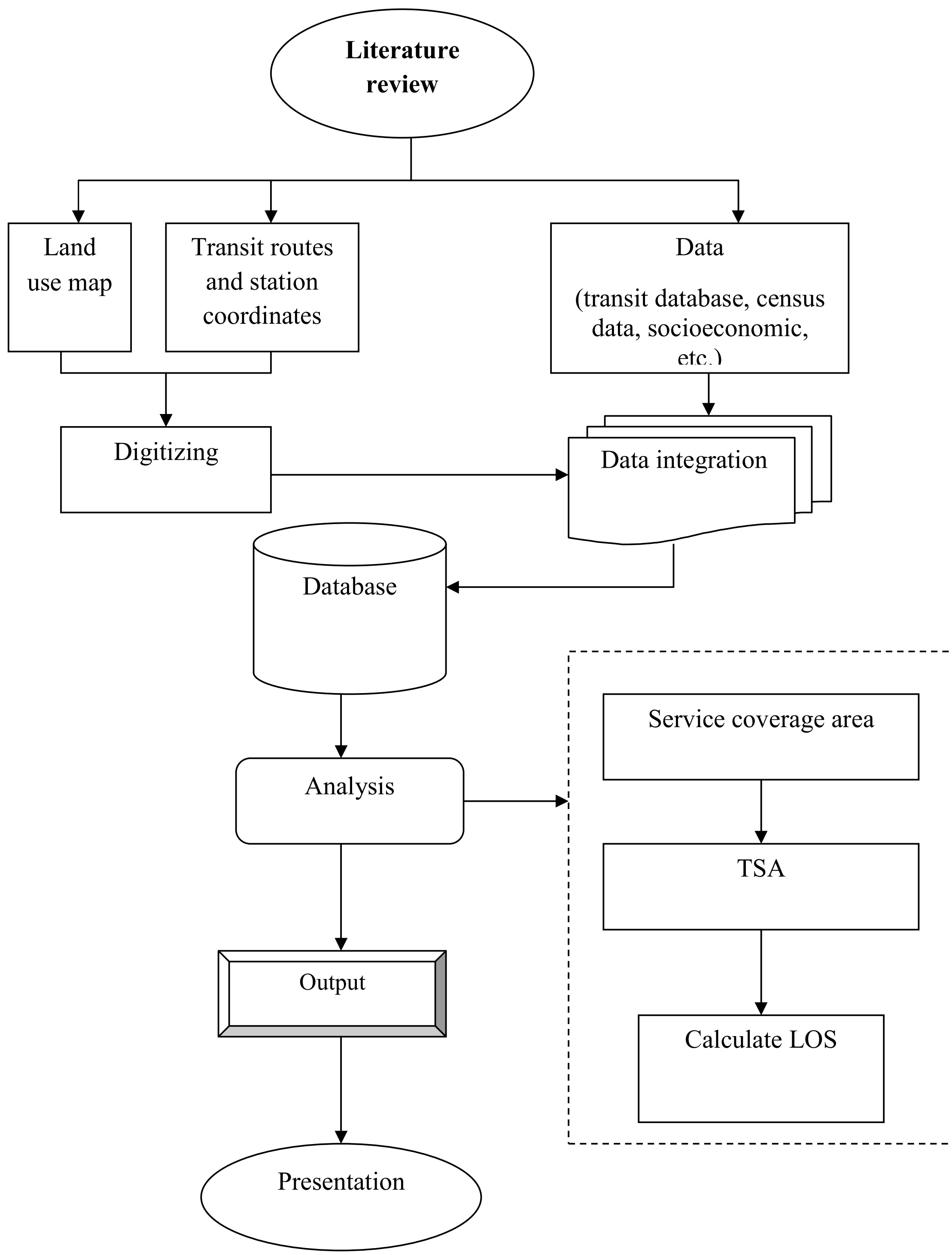


Figure 3.1. Research design

By splitting the service coverage measures analysis, it is able to demonstrate and explain the importance of each analysis in determining the significant number of ridership in a transit system by calculating the service coverage LOS of each transit system that is available in Kuala Lumpur.

3.2.1 Literature Review

The main objective of the study is to evaluate the service coverage LOS in the Kuala Lumpur transit system, which uses GIS as a tool to determine the quality of service of the transit system for transit planning. In order to achieve this objective, literature studies on the transportation planning, the transit performances, the quality of service, and the transit system have been carried out by referring to the previous studies, reports, local guidelines, international practices, and also experience of transit operators. After examining the related sources, the next step is to outline all the related transit services for analysis for the study area. The data that have been chosen in this study were absorbed from the *TCQSM* (2nd ed.) as a reference to determine the service coverage LOS in the Kuala Lumpur transit system. Table 3.1 shows the list of data that has been used in *TCQSM* and the data used in this study. Although *TCQSM* has used numerous data for service coverage LOS, this study only uses a part of data due to limitation and time constraint.

Table 3.1. Lists of data used in *TCQSM* and this research as reference

TCQSM (2nd ed.)	This Research
Transit lines	√
Transit station	√
Bus station	√
Bus line	×
Building	√
Lake	√
Volume of commuters	×
Walking distance	√
Time taken to reach station	×
Street	√
Employment	√
Household	√
Transit analysis zones	√

Transit services are owned by numerous agencies that meet the same government regulations, economic changes, environment, commuters, and social concerns. However, not all transit services are included in this research because the lack of data is the limiting factor. Because of this limitation, five transit services were selected and analysed: the LRT, the KL Monorail, the Keretapi Tanah Melayu (KTM), the Sri Petaling Transit Line (Sistem Transit Aliran Ringan [STAR] LRT), and the RapidKL bus transit.

Data pertaining to those transit services were obtained from the related government agencies as mentioned in chapter 3.2.2. All the data are in GIS format, except for the location of the RapidKL bus transit, which was observed using the Garmin GPS device.

In this research, ArcGIS v9.3 was used to perform the analysis. Some editing was performed before it could be used for the analysis. These data have gone through common tasks involved in preparing data for analysis, such as matching all the layers to their system or projections and assembling those layers using tools like "merging" and "clipping." Then came the procedure to produce the information for transit system for the transit agencies for planning purposes.

3.2.2 Data Acquisition

Data availability is very crucial in GIS application and thus in this study. The data collected were converted into GIS format (shapefiles). The data collected in hard copy were performed with manual digitising to convert them into the GIS format. The data are as follows:

- Transit routes and stations (Putra LRT, STAR LRT, KL Monorail, and KTM) - JUPEM (year 2009, shapefile)
- RapidKL bus stops-using Garmin GPS 76s
- Street, lake, and building maps-JUPEM (year 2009, shapefile)
- Census data (population, household data, socioeconomic data, employment, and industrial)-Department of Statistics (year 2008, shapefile)

These data were determined using the zone boundary in Kuala Lumpur with a total of 881 traffic analysis zones (TAZ).

According to Miller and Shaw (2001), "Traffic analysis zones (TAZ) is the unit of geography by census block information. Typically these blocks are used in transportation models by providing socio-economic data. States differ in the socio-economic data that they attribute to the zones. Most often the critical information is the number of automobiles per household, household income, and employment within these zones. This information helps to further the understanding of trips that are produced and attracted within the zone."

- The list of data in the census data are as follows:
  - Population
    - Gender: male, female, and total
    - Age: 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75+, and total
    - Ethnic group: Warganegara Malaysia-Bumiputera, non-Bumiputera, and total; Chinese, Indian, others, and total; Malaysian citizen, noncitizen, and total
  - Household Data
    - Number of persons in a house: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11–15, 16–20, > 20, and total
    - Number of vehicles: car-1, 2, 3, > 3, and total; motorcycle-1, 2, > 2, and total
    - Number of houses: living, vacant, and total
    - Ownerships: individual, government, private sector, lain-lain, unknown, and total
  - Industry
    - Agricultural, hunting and forestry, fisheries, mining, manufacturing, electric supply, gas and water supply, construction, trade, wholesale and retail trade, hotel and restaurant, transportation, storage and communication,

finance, real estate activities, renting and business activities, public administration and defence, education, health and social activities, community service activities, social and other private, private household with employed persons, organisation, and outside of the body

- Employment
    - Member of legislative council, senior official and managers professionals, technicians and semiprofessionals, clerical workers, service workers and shops and market workers, skilled workers, agricultural and fisheries, craft and related workers, machine operators and assembly plant, employment base (elementary), and unknown jobs

3.2.3 Preparing and Organising Data

ArcGIS Desktop is one of the most popular GIS software that can be customised to meet individual needs. ArcGIS Desktop contains a group of three GIS software systems: ArcView, ArcEditor, and ArcInfo. ArcView software consists of a set of three integrated applications: Arctoolbox, ArcCatalog, and ArcMap. By using these three applications, GIS tasks-such as mapping, reporting, data management, data editing, geoprocessing, and map based analysis-can be easily performed.

In this study, ArcMap v9.3 was used to facilitate the transit information system planning process. Some of the data were obtained in a different format. Since ArcMap v9.3 can only read data in shapefile format, these data were converted into the shapefile

(.shp) format. Some data, such as the location of the bus stops, were collected using a GPS, and the street maps were saved in .jpg format. This scanned map is opened in ArcMap v9.3, in which manual digitising can be performed.

The coordinate system is a vital part in the analysis to make sure that the data and the final results are in the correct coordinate system. In West Malaysia, the existing coordinate system used the rectified skew orthomorphic (RSO) system for mapping, which uses the Modified Everest ellipsoid as a reference with its origin fixed at Kertau, Pahang. Therefore, all the collected data are changed into this coordinate system in ArcMap v9.3. The Kertau RSO Malaya Meters coordinate system used in the analysis is presented in Appendix A.

3.2.4 Kuala Lumpur Transit System

The first step before the analysis is performed, the Kuala Lumpur transit system was determined to easy and quick access of the transit data and land-use data that are needed to analyse the transit system planning. The database is a system that combines all the information of the transit system for the study area, which were collected and gathered in GIS format.

The Kuala Lumpur transit system database consists of several data, which are listed as follows:

- Transit routes and stations (Putra LRT, STAR LRT, KL Monorail, and KTM)
- RapidKL bus stops
- Street, lake, and building maps

- Census data (population, household data, socioeconomic data, employment, and industrial)

All these data were input into the ArcGIS software to produce a complete Kuala Lumpur transit system in which all the related information regarding the existing transit system can be established in the database system.

3.2.5 Quality of Service Measures

The quality of service reflects the passenger's perception of transit performance. The performance measures used to describe this perception are different from both the economic performance measures and the vehicle-focused performance measures. The quality of service depends to a great extent on the operating decisions made by a transit system within the constraints of its budget, particularly decisions on in which transit service should be provided, how often and how long it is provided, and the kind of service that is provided. The quality of service also measures how successful an agency is in providing service to its customers, which has ridership implications.

The six measures of the quality of service for a fixed-route transit system has been identified in *TCQSM* and are listed in Table 3.2. The transit quality of service measures that is used in this study is the service coverage, which falls in the system availability category.

Service coverage considers both ends of a trip, for example, home and work. Transit service at one's origin is of little use if service is not provided near one's destination.

The options for getting from a transit stop to one's destination are more limited than the options for getting from one's origin to a transit stop.

Table 3.2. *TCQSM* fixed-route transit quality of service measures

	Transit Stop	**Route Segment**	**System**
Availability	Frequency	Hours of service	Service coverage
Comfort and convenience	Passenger load	Reliability	Transit-auto travel time

Source: *Transit Capacity and Quality of Service Manual*, 2nd ed..

3.2.5.1 Service Coverage Area

The first step in the spatial analysis is to apply the service coverage area in order to determine how completely the transit system serves areas with densities that can typically support transit. The calculation of the transit service coverage area can be performed relatively easily by the GIS software, using the software's buffering feature to draw appropriate-sized circles around transit stops. The transit service coverage area is defined as a 0.4 km (1/4 mile) radius around all bus stops, 0.8 km (1/2 mile) of rail station and railway. A 0.4 km (1/4 mile) to 0.8 km (1/2 mile) distance is considered the accepted "walking distance" as defined by the Federal Transit Administration.

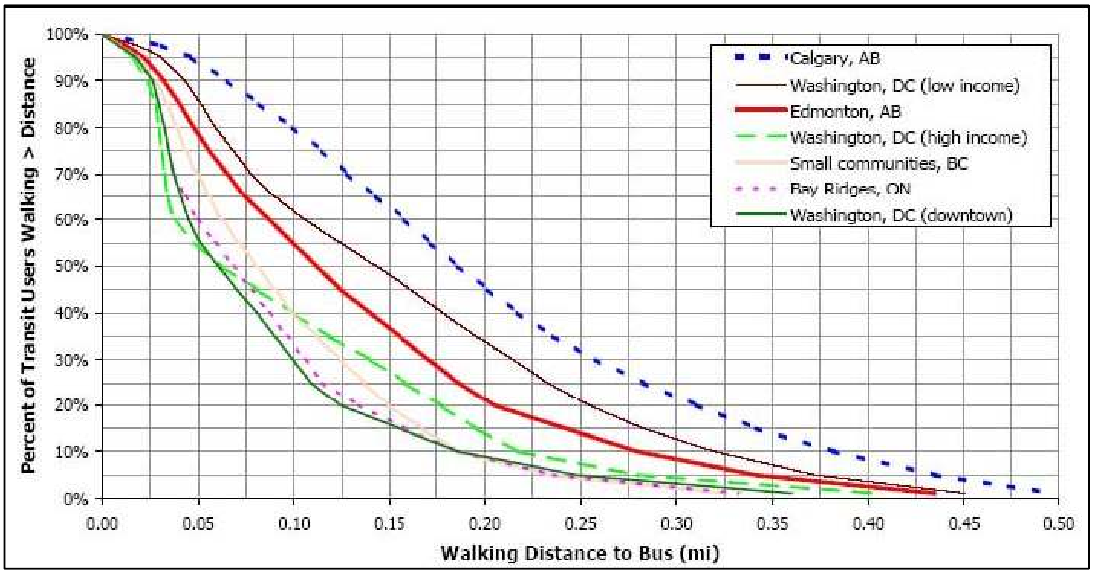
The buffering technique of the areas within 0.4 km (0.25 miles) of a bus stop and 0.8 km (0.5 miles) of a rail station and railway was generated using the GIS method. These values were used because a study on walking accessibility has shown that Jabatan Kerja

Raya agrees that a 500 m radius is acceptable for a person to walk from one destination to another destination (Mazlia 2008), whereas the *TCQSM* (2nd ed.) says a person is able to walk up to 800 m to reach their destination.

However, if the GIS software or accurate bus stop data are not available, this area can be approximated by outlining on a map all of the areas within 0.25 miles (400 m) of a bus stop. This approximation assumes reasonable bus stop spacing (at least six per mile or four per kilometre). Sections of a route where pedestrian access from the area adjacent to the route is not possible (because of a barrier such as a wall, a waterway, a roadway, or a railroad) should not be included in the service coverage area.

A GPS survey using Garmin GPS 76s was carried out to determine the exact latitude and longitude of RapidKL bus stops (accurate position of bus stops) at Kuala Lumpur, and the locations were uploaded into ArcGIS v9.3. Then these coordinates were overlaid on the existing transit lines (Putra LRT, KTM, STAR LRT, and KL Monorail) before the buffering was determined.

A bus service that emulates a rail transit, frequent service throughout much of the day, relatively long stop spacing, passenger amenities at stops, and so on, is expected to have the same walking access characteristics as a rail transit (e.g., a maximum walking time of 10 minutes). Figure 3.2 shows the percentage of transit users walking over distance to bus stops (*TCQSM*).



Source: *Transit Capacity and Quality of Service Manual*, 2nd ed., pp. 3–10.

Figure 3.2. Walking distance to bus stops

The roadway network provides near-universal access to the desired destinations. In comparison, transit service is only available to areas located close to transit stops and stations. Although the automobile and bicycle modes can access options under certain circumstances, most people access transit service by walking, and nearly all passengers must walk once the transit service delivers them to the vicinity of their destination.

3.2.5.2 Determine TSA

The definition of TSA as provided in the *TCQSM* is one where the housing density is at least 3 units per gross acre (7.5 units per gross hectare) or where the employment density is at least four jobs per gross acre (10 jobs per gross hectare). The area is considered to have adequate transit coverage if the supportive area is less than 0.25 miles from the bus service, provided there are adequate pedestrian connections to the transit sites from the surrounding area. TSAs are areas determined to be having a good potential for significant transit ridership. The supportive area in question is measured as either all or nothing, depending on the location of the transit service.

TSA was generated using the model builder tools in ArcMap in this study, in which the GIS method was used to produce the TSA areas. First, the areas of each TAZ should be converted to hectares or acres using the mathematical option in the ArcMap software. Then the number of households is divided by the TAZ area to obtain a household density in households per acre for each TAZ. The job density of each TAZ can be calculated similarly. Following these calculations, TAZs with a household density of 3.0 or more households per acre and/or a job density of 4.0 or more jobs per acre can be readily identified.

3.2.5.3 Compare Service Coverage Area to TSAs

By intersecting the service coverage layer with the TAZ layer, TAZs that are only partially served by transit are divided into two sections: a section completely served by transit and another section completely unserved by transit. Households and jobs can be allocated between the two sections based on their relative areas.

Next, all of the transit-supportive TAZs can be selected, and their total area determined, using the GIS software’s area calculation function. Finally, all of the transit-supportive TAZ sections served by transit can be selected and their areas added up. Dividing the second area into the first area gives the percentage of the TSA served.

3.2.5.4 Service Coverage LOS

Areas with a minimum density capable of supporting hourly service are referred to as TSA. For policy reasons, or simply to provide a route connecting two higher-density areas, an agency may choose to and likely will cover a larger area than that defined by its TSA.

Transit LOS is based solely on the percentage of the TSA served by transit. Higher LOS levels indicate a greater variety of origins and destinations that potential passengers can travel between.

Service coverage measures the number of people in TSAs that have access to transit. As defined by the Florida Department of Transit methodology, an area is considered transit supportive if it contains four or more employees (jobs) per acre or three or more dwelling units per acre. An area is considered to have access to transit if it is located within one-quarter mile of a transit route.

Service coverage LOS scores range from A (for 90% or more of TSAs with access to transit) to F (for less than 50% with access to transit). Table 3.3 shows the LOS based on the percentage of TSA served.

Table 3.3. The LOS based on the percentage of TSA

LOS	% TSA Covered	Comments
A	90.0%–100.0%	Virtually all major origins and destinations served
B	80.0%–89.9%	Most major origins and destinations served
C	70.0%–79.9%	About three-fourths of higher-density areas served
D	60.0%–69.9%	About two-thirds of higher-density areas served
E	50.0%–59.9%	At least one-half of higher-density areas served
F	< 50.0%	Less than one-half of higher-density areas served

Source: *Transit Capacity and Quality of Service Manual*, 2nd ed., pp. 3–34.

The service coverage LOS of each transit line-namely, Putra LRT, STAR LRT, KTM, KL Monorail, and RapidKL bus stops-were calculated using the method explained in chapters 3.2.5.1, 3.2.5.2, and 3.2.5.3. The LOS of each of these transits was categorised using the range shown in Table 3.3.

3.2.6 Visual Basic for Applications–Based Programme

Visual Basic for Applications (VBA) is already embedded within ArcMap and ArcCatalog. ArcGIS users can customise and extend the functionality of the interface using VBA, the programming environment included with the software. Moreover, Visual Basic is an uncomplicated programming language. As a result, this study uses VBA. Working with the ArcGIS interface, the customised application by VBA has been programmed to calculate the service coverage and LOS in ArcMap, focusing especially on the buffer zone and the percentage of TSAs served by the transit service.

The programming code used in this study is shown in Appendix B. These codes were used to derive the final output in determining the service coverage area and in calculating the LOS of each transit lines with RapidKL bus stops.

3.2.7 Presentation and Publisher

ArcGIS Publisher delivers the capability to easily share and distribute the maps and GIS data. ArcGIS Publisher is an optional extension that was installed in the ArcGIS Desktop. Publisher converts ArcMap (.mxd) and ArcGlobe (.3dd) documents into the published map format (.pmf) used with ArcReader. Published maps from ArcMap are two-dimensional, whereas those published from ArcGlobe are three-dimensional.

ArcGIS Publisher can be used for the following applications:

- To easily provide interactive maps to the users
- to protect the maps, including cartography and data, from inappropriate use
- To create rich interactive maps that meet the users' needs
- To provide efficient and controlled access to the enterprise GIS data
- To easily package the required data and maps for distribution
- To build custom versions of ArcReader for the audience viewing

ArcReader provides GIS users with a method to share electronic maps locally, over networks, and on the Internet. ArcReader preserves a live connection to data so the data view is dynamic.

A published map is the fundamental component that works within ArcReader. Maps help to visualise geographic data by showing where things are, by telling what they are, and by helping to understand why they are that way. Published maps serve a variety of purposes. Maps may be interactive and can be browsed or queried, whereas others are formatted for display and printing. Every map can have a unique look, including both its graphic layout and interface, tailored to those who will ultimately use the map.

CHAPTER 4

4.0 RESULTS

4.1 Introduction

This chapter presents the results of the analysis that have been applied based on the research design described in chapter 3. The initial process starts with the literature review, which concentrates on the service coverage measures to determine the quality of service in transit planning of each transit system in Kuala Lumpur. The spatial operations are performed using GIS functions, such as the buffering, merging, intersect, clipping, and overlaying of the map layers. The process calculates the service area from further analysis for transit coverage area. Then the TSAs were determined using the employment density and the household density in which the service coverage LOS can be identified with the existence of each transit system.

4.2 Application of the Data

After identifying all the data referring to *TCQSM* in evaluating the service coverage LOS in the Kuala Lumpur transit system, the processing and the programming are ready to be carried out for the purpose of transit planning. In order to achieve the objectives, the first step was to apply all the relevant data. The objective of this application was to screen the needed data for the transit system. Figure 4.1a shows all the map layers of the transit information data as discussed previously.

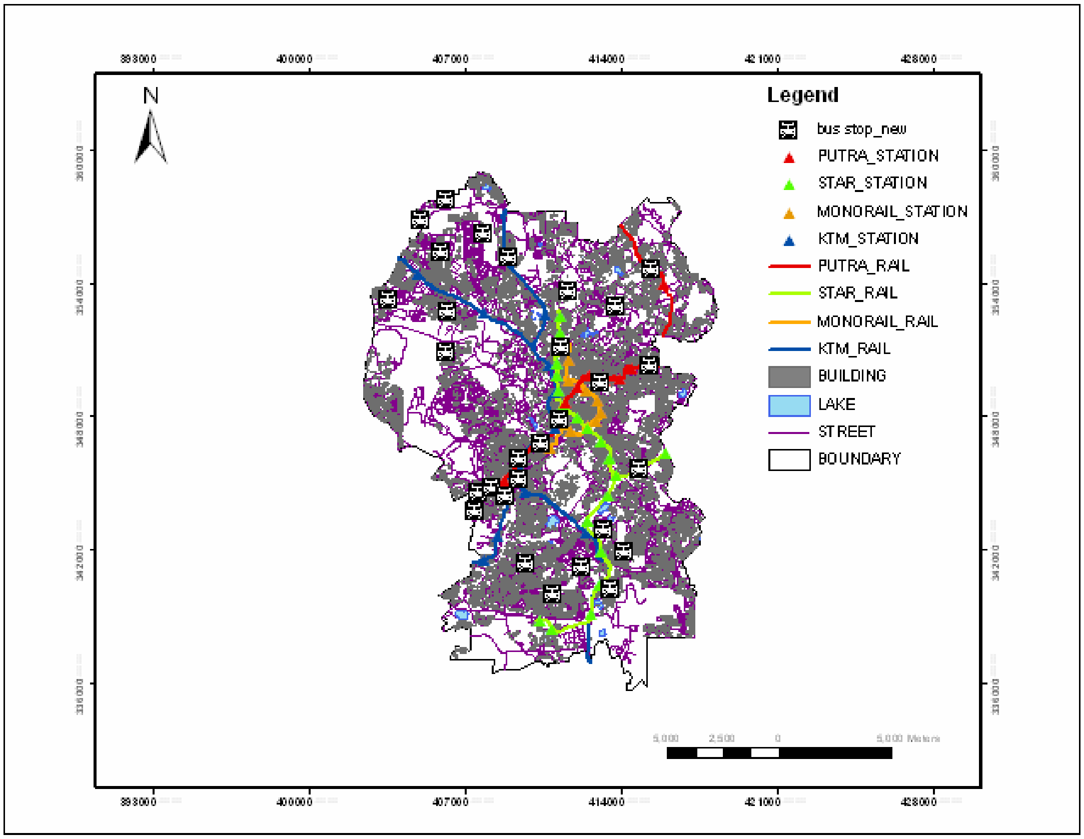


Figure 4.1a. Combination of all transit systems data with boundary

There were 12 data that have been collected to determine the service coverage LOS for the Kuala Lumpur transit information using GIS. The data include RapidKL bus stops, Putra LRT lines and stations, STAR LRT lines and stations, KL Monorail lines and stations, Keretapi Tanah Melayu (KTM) lines and stations, streets, commercial and residential buildings, and, lastly, a lake. All these data were chosen because these data facilitate a lot in determining the transit system in the city.

Figure 4.1b shows only the transit systems layers without boundaries, which have been chosen for the Kuala Lumpur transit systems in this study. The lake data are included in this map because the lake will be much affected in the transit system, especially when the commuters cannot access the transit systems. Buildings and streets do not affect the commuters to access the transit system as it could connect the commuters easily to reach the transit system.

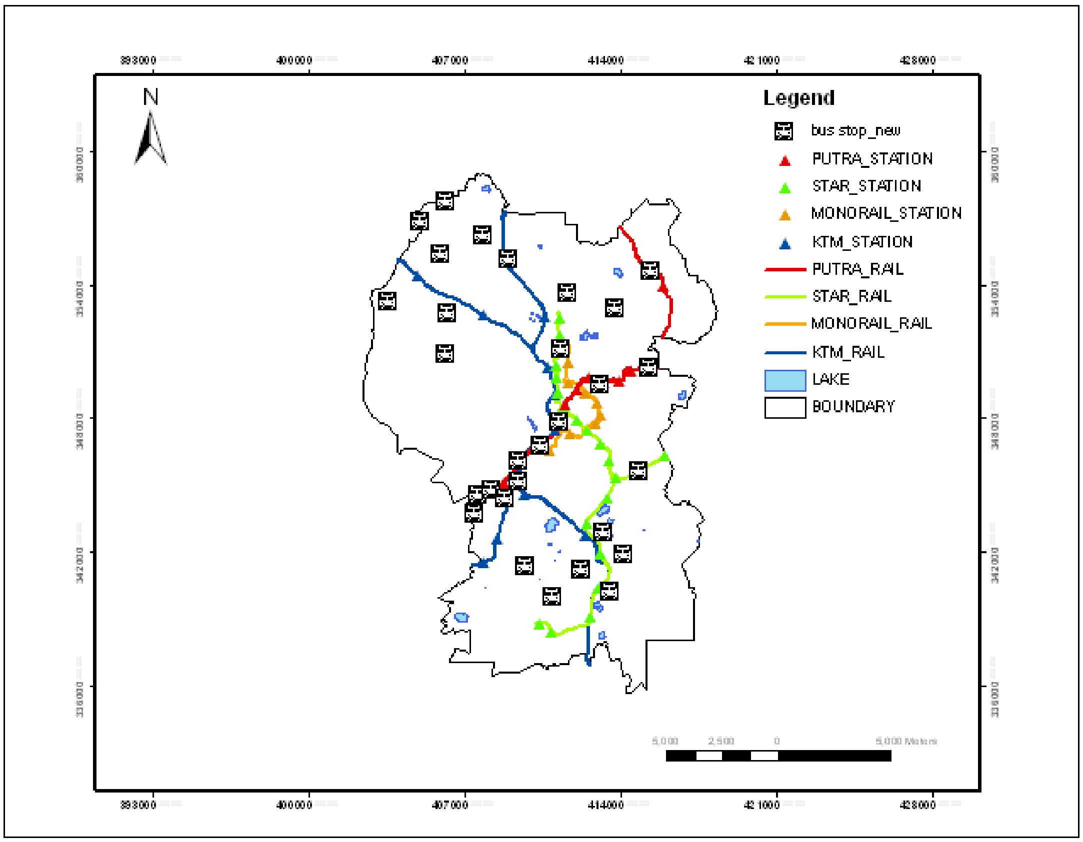


Figure 4.1b. Combination of all transit systems data without boundary

4.3 Service Coverage Area

Service coverage area is the initial analysis in the service coverage measures of transit quality of service. The service coverage area for each transit systems was determined as explained in chapter 3. The service coverage area measure identifies which areas in a city or region are capable of supporting at least hourly transit service and measures the proportion of those areas actually served by transit. It is a useful tool for identifying potential nonserved transit markets. When supplemented with demographic information, this kind of analysis has been used to identify potentially underserved neighbourhoods, which are the areas that currently receive some transit service but are capable of supporting additional service.

4.3.1 Application of Service Coverage Area from the Visual Basic for Applications

An application for generating service coverage area for every transit system has been created using the VBA programming language. This application is able to produce the service area layer (buffering) with the desired radius distance. Figure 4.2a shows the interface of the service coverage application, which was programmed using the VBA programming language. This application module is able to select the layer of the data needed to buffer, followed by the buffering distance, and finally the output of the buffering layer.

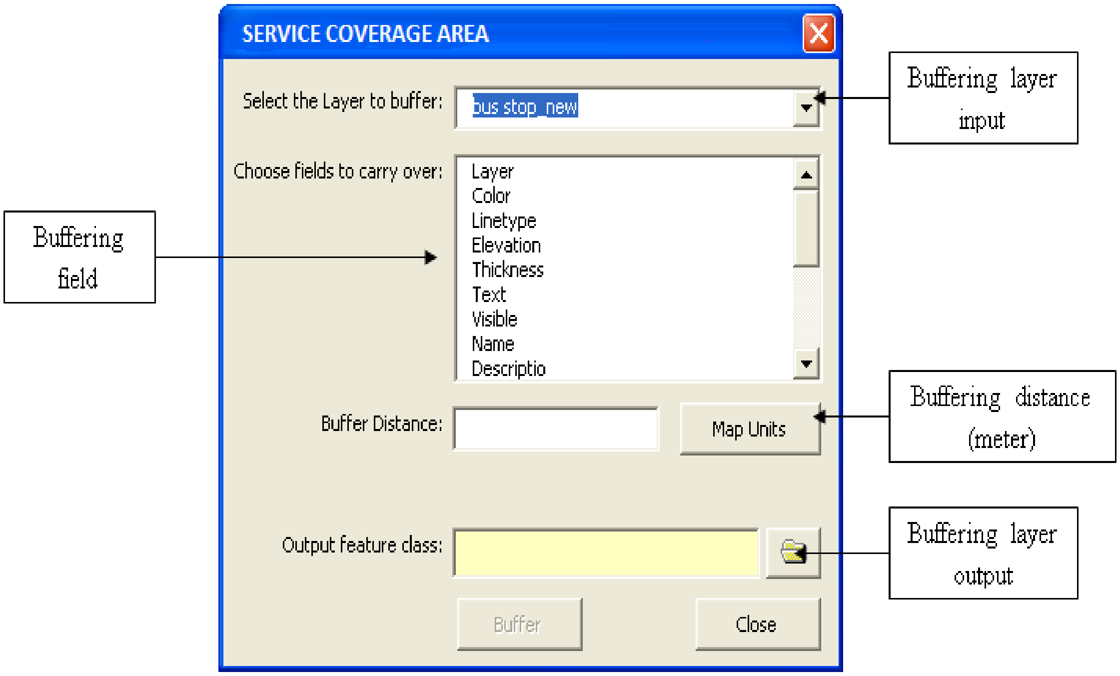


Figure 4.2a. Service coverage area from the VBA

Figures 4.2b to 4.2e indicate the service coverage area for Putra LRT, KL Monorail, KTM, and STAR LRT rails and stations together with RapidKL bus stops. All these three parameters were combined into one layer and intersect with the area data. The transit lines were buffered individually in order to calculate the total area covered by each of these transit services in Kuala Lumpur. The total area covered by each of the transit systems and RapidKL bus stops were calculated in hectares. Figure 4.2f shows the total area covered referring to the service coverage area in Figures 4.2b to 4.2e. As can be seen, the KTM line has the largest transit coverage area, with 30.1% coverage, followed by STAR LRT, which is 26.5%. The Putra LRT is the third largest, which covers 23%, and KL Monorail only covers 20.1%.

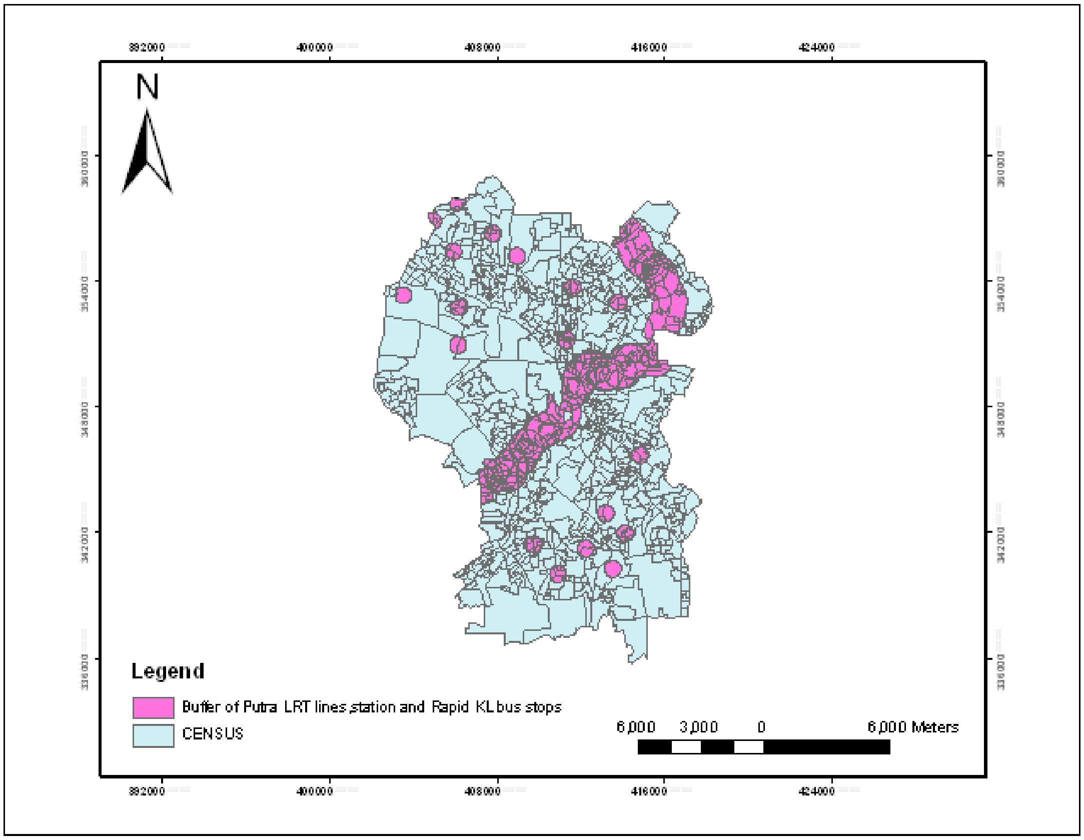


Figure 4.2b. Service coverage area of Putra LRT rails, stations, and RapidKL bus stops

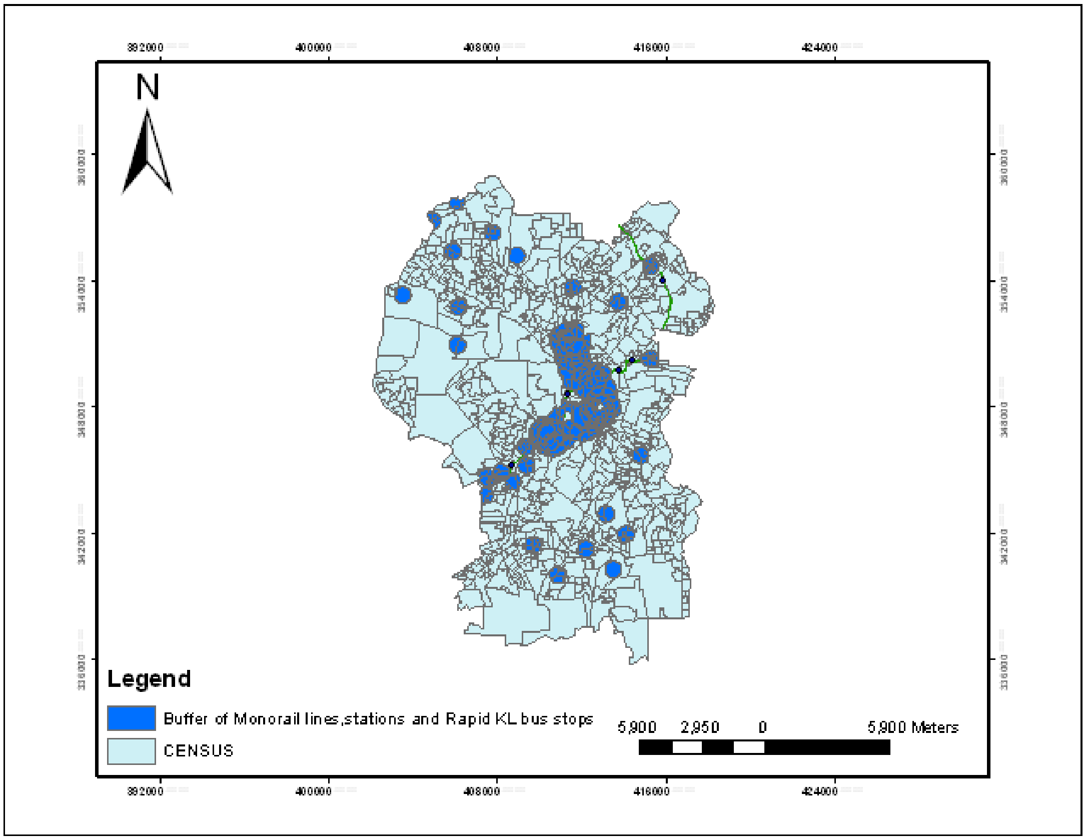


Figure 4.2c. Service coverage area of monorail rails, stations, and RapidKL bus stops

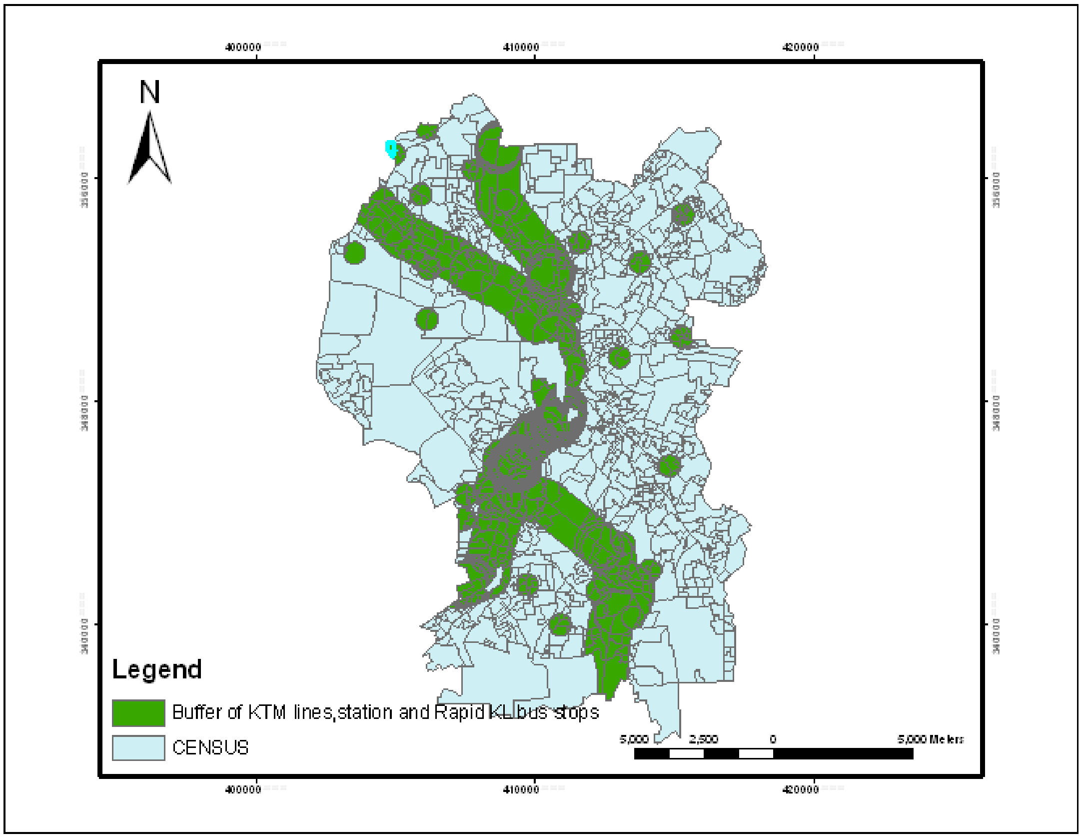


Figure 4.2d. Service coverage area of KTM rails, stations, and RapidKL bus stops

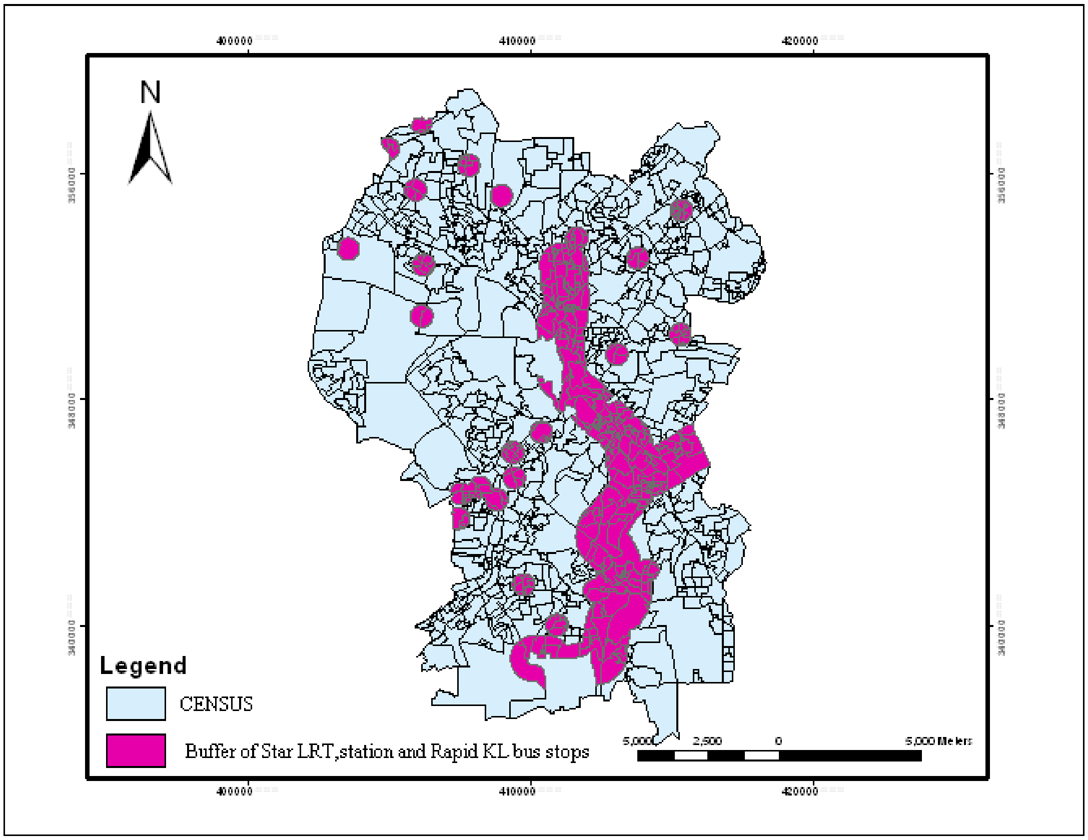


Figure 4.2e. Service coverage area of STAR LRT rails, stations, and RapidKL bus stops

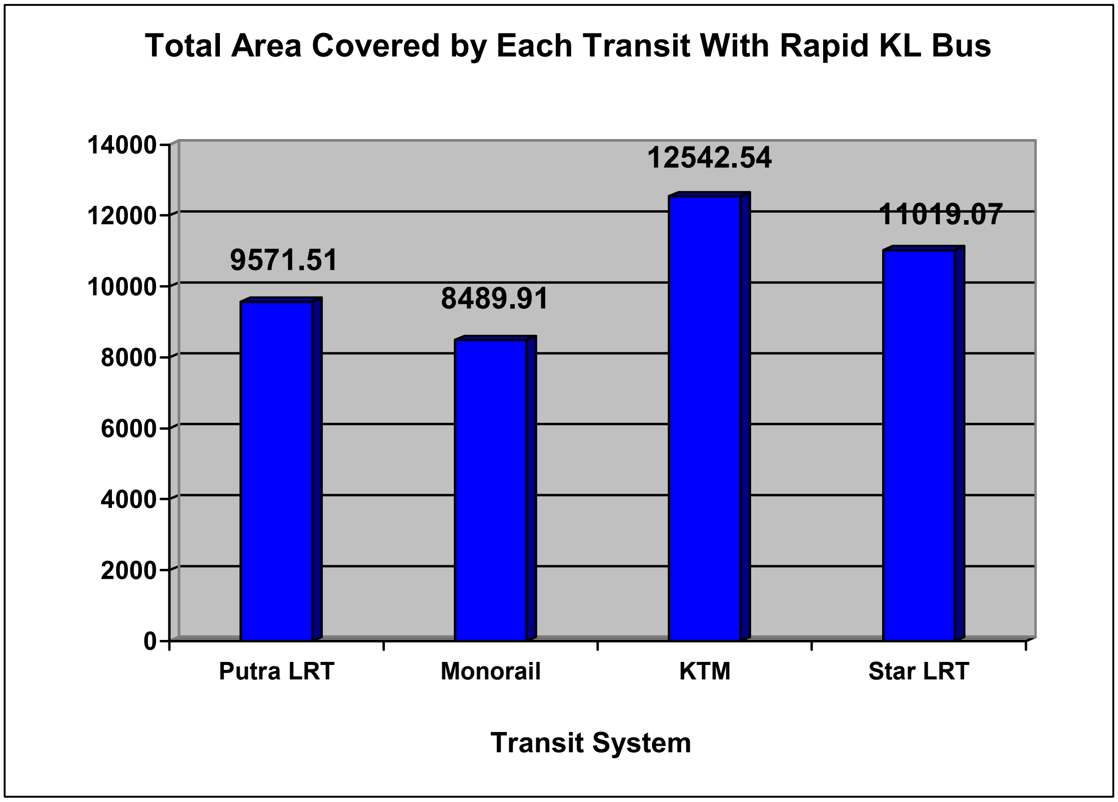


Figure 4.2f. Total area covered of each transit system with RapidKL bus stops

Figure 4.2g indicates the service coverage area for all the transit systems, namely, Putra LRT, KL Monorail, KTM, STAR LRT rails and stations, and RapidKL bus stops. All these parameters were combined into one layer and intersect with the area data to represent and generate the service coverage area. All the transit systems were combined to determine the efficiency of the total available transit system versus each transit system in Kuala Lumpur. The total transit-covered area combination of all the transit systems in Kuala Lumpur is 17,012.23 hectares. The overlay layers on the transit system have been eliminated in generating the covered area combination of all transit systems.

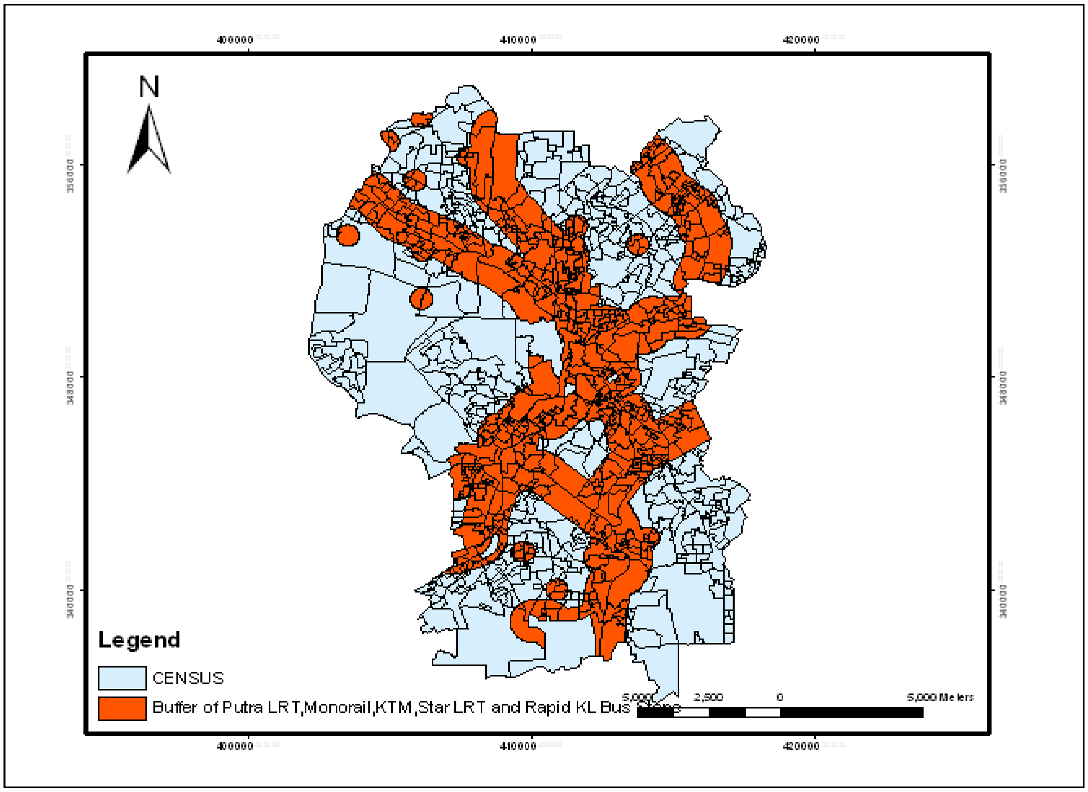


Figure 4.2g. Service coverage area of Putra LRT, KL Monorails, KTM, STAR LRT rails and stations, and RapidKL bus stops

4.4 Transit-Supportive Area

TSAs were determined from the methods that were explained in chapter 3. The two main data that are needed to determine the TSA for each of the existing transit system are employment and household data. The employment and the household density were generated using the GIS software to decide the TSA analysis. Figure 4.3a shows the range of employment density in hectares according to the zone covered for the whole area of Kuala Lumpur. The range shows that most zones have the range of employment density, which falls within 0 to 30 employments per hectare followed by 31 to 60 employments per hectare. The range of 2,001 to 5,000 employments per hectare has the lowest number of zones of employment density covered. This shows that almost all the residents in the area in Kuala Lumpur are working in the government sector or private sector or have their own business.

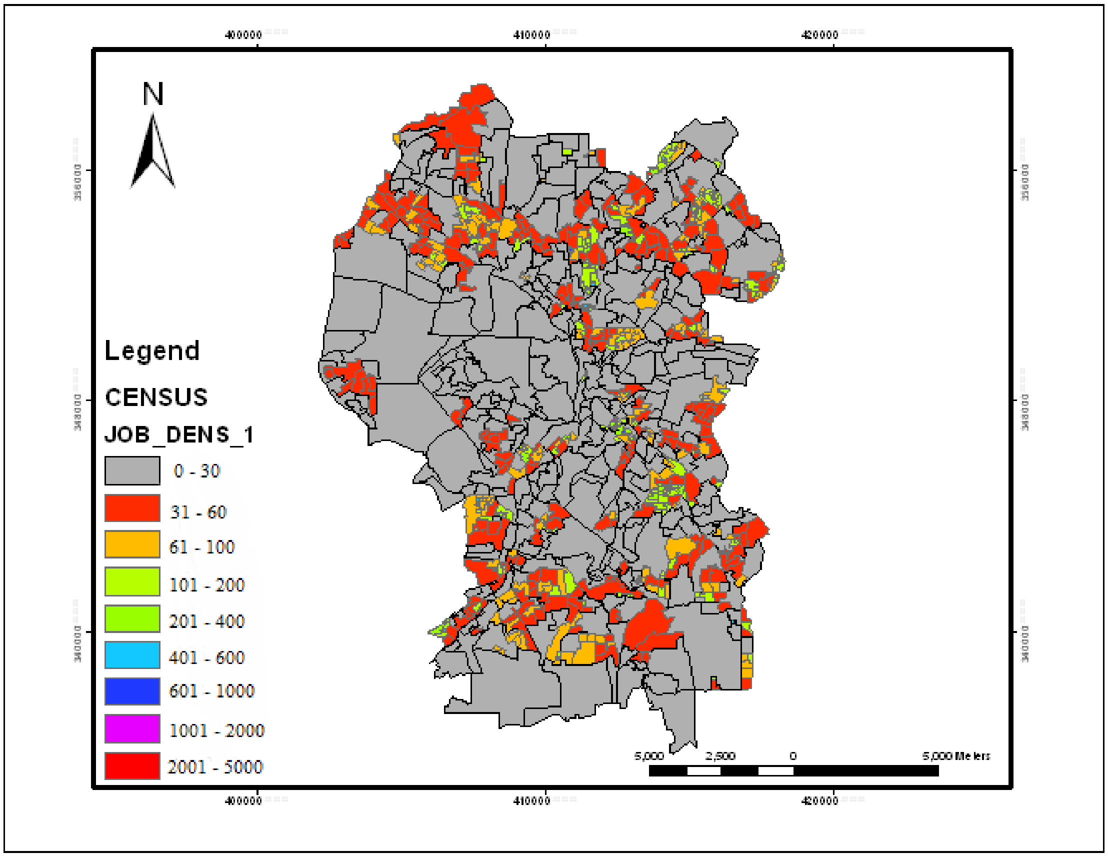


Figure 4.3a. The range of employment density according to zones for Kuala Lumpur area

Figure 4.3b shows the range of household density in hectares according to the zone covered for the whole area of Kuala Lumpur. The range shows that most zones have a range of household density that falls within 0 to 20 households per hectare followed by 21 to 30 households per hectare. The range of 901 to 5,000 households per hectare has the lowest number of zones of household density covered. This shows that most places in Kuala Lumpur have a minimum density of 15 people per hectare.

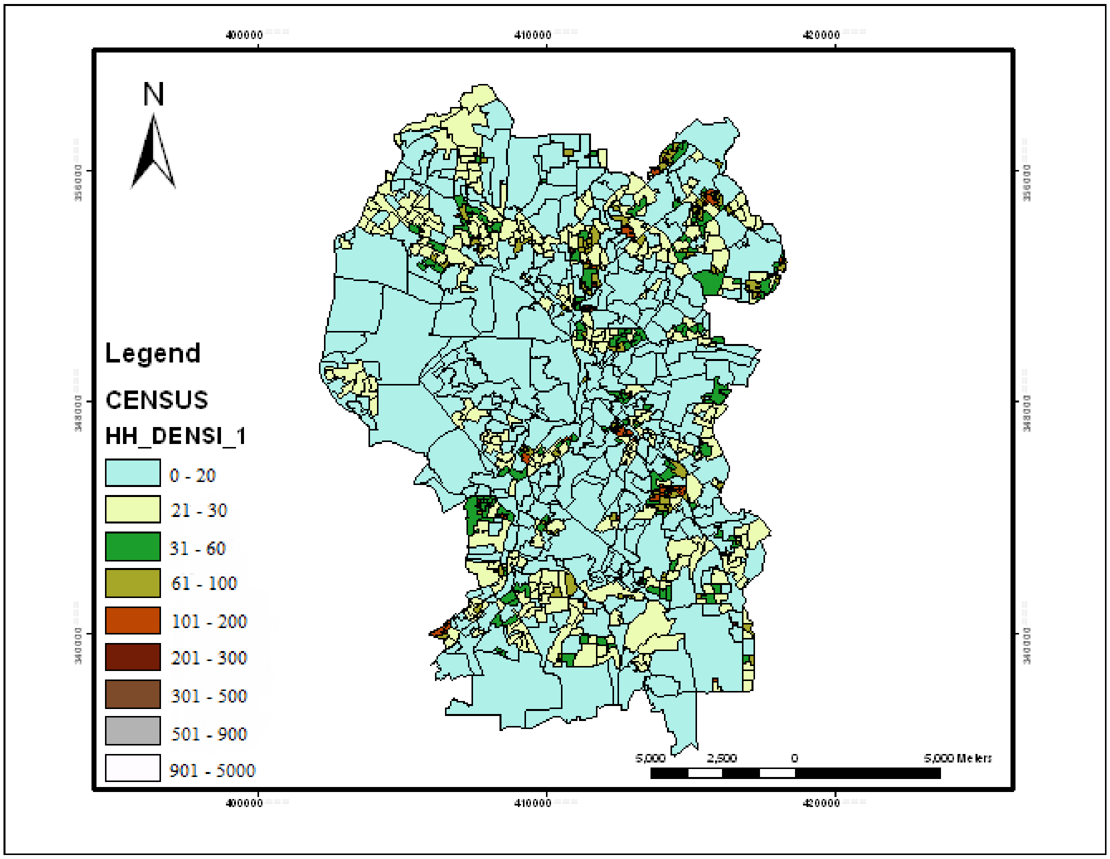


Figure 4.3b. The range of household density for Kuala Lumpur area

Figure 4.3c shows the TSA analysis output that shows the TSA and area that is not supported by a transit system. The total area covered was calculated in hectares. It is shown that 93% of the areas in Kuala Lumpur are TSAs, whereas the remaining 7% are areas not supported by a transit system. This means that almost all the areas in Kuala Lumpur should be served with any form of public transit system for the benefit of transit commuters.

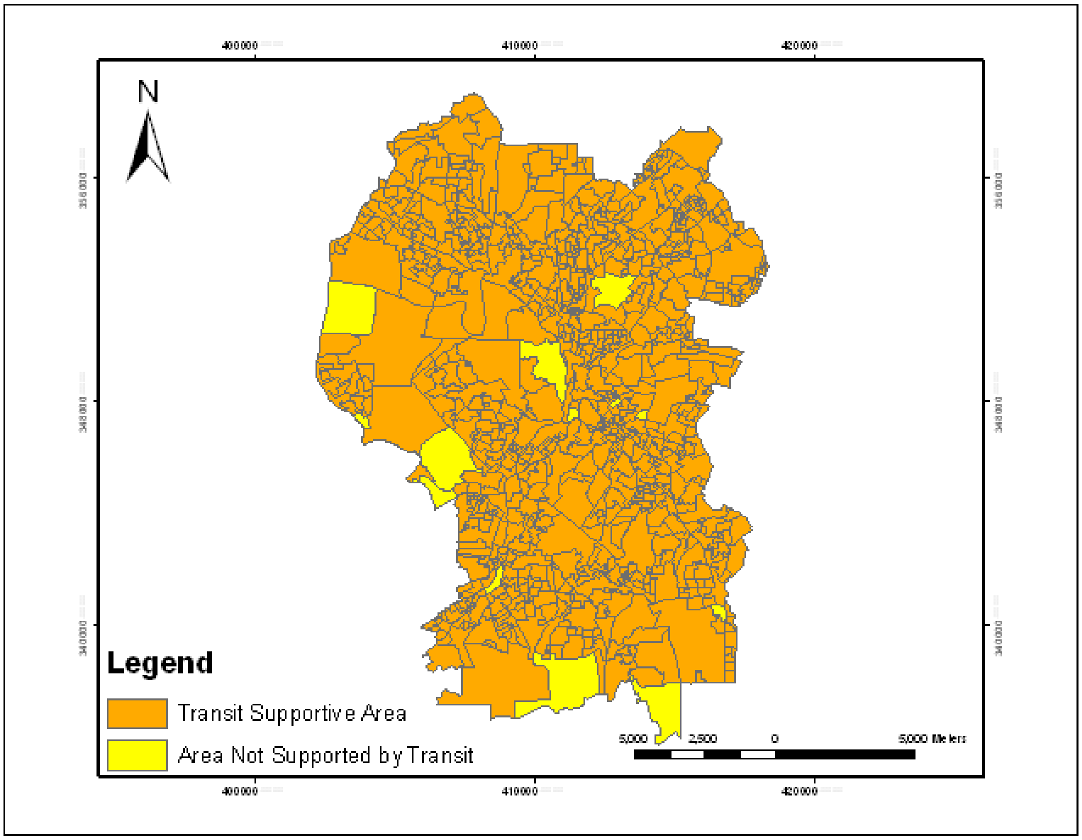


Figure 4.3c. TSA analysis

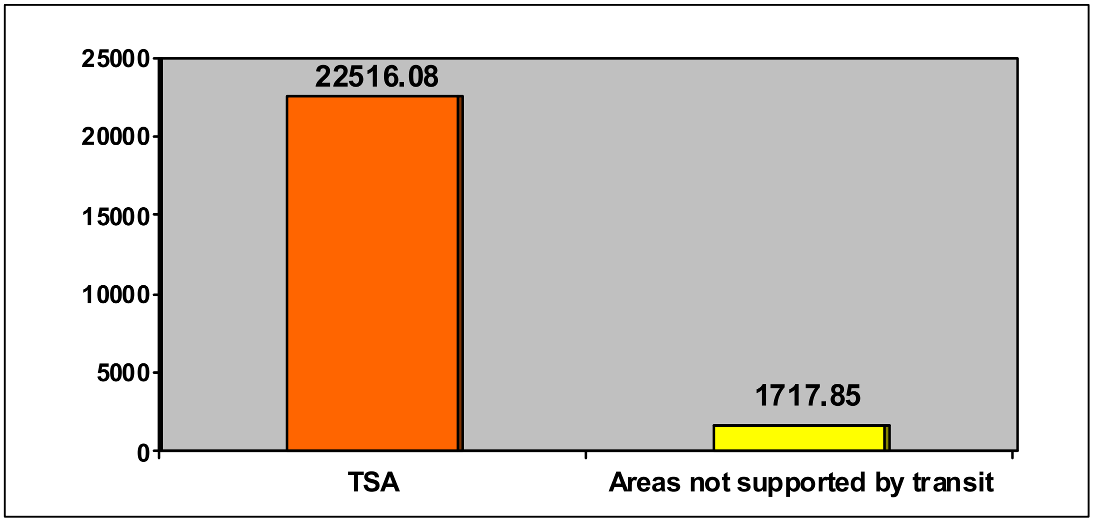


Figure 4.3d. TSA and areas not supported by a transit system

4.4.1 TSA Interface with Service Coverage Area

Figures 4.3e to 4.3h show the TSA that is served by transit for each of the transit lines and RapidKL bus. The TSA was generated for each of the transit systems to determine how efficient each of these transit systems is supporting the Kuala Lumpur area for transit users to use their transit system. The more area is cover the transit covers the transit supported area, the better it is for the transit users as well as for the transit agencies.

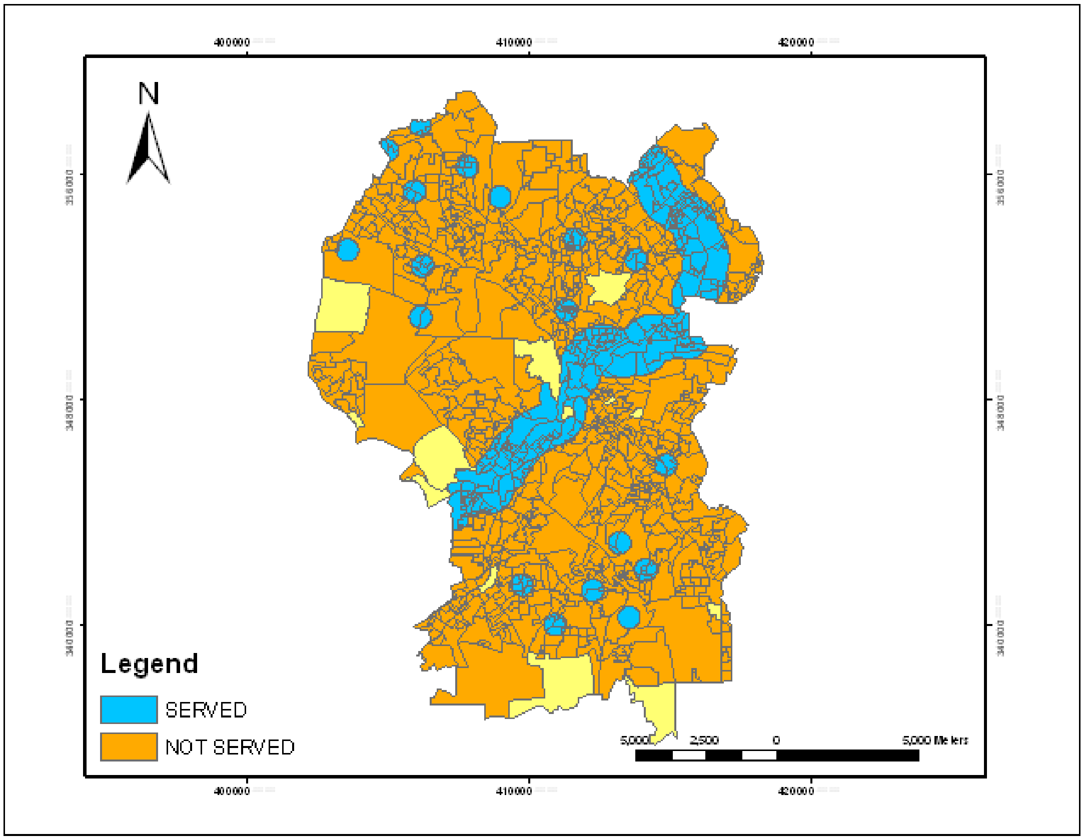


Figure 4.3e. TSA served for Putra LRT and RapidKL bus

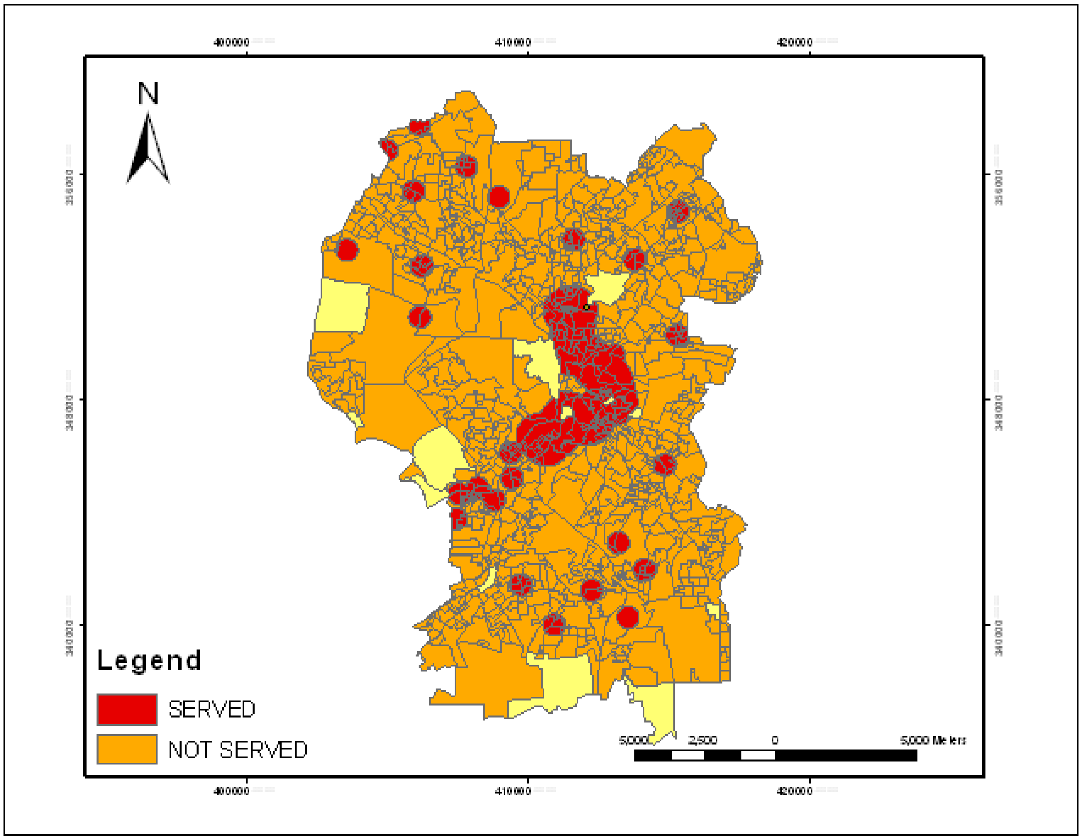


Figure 4.3f. TSA served for KL Monorail and RapidKL bus

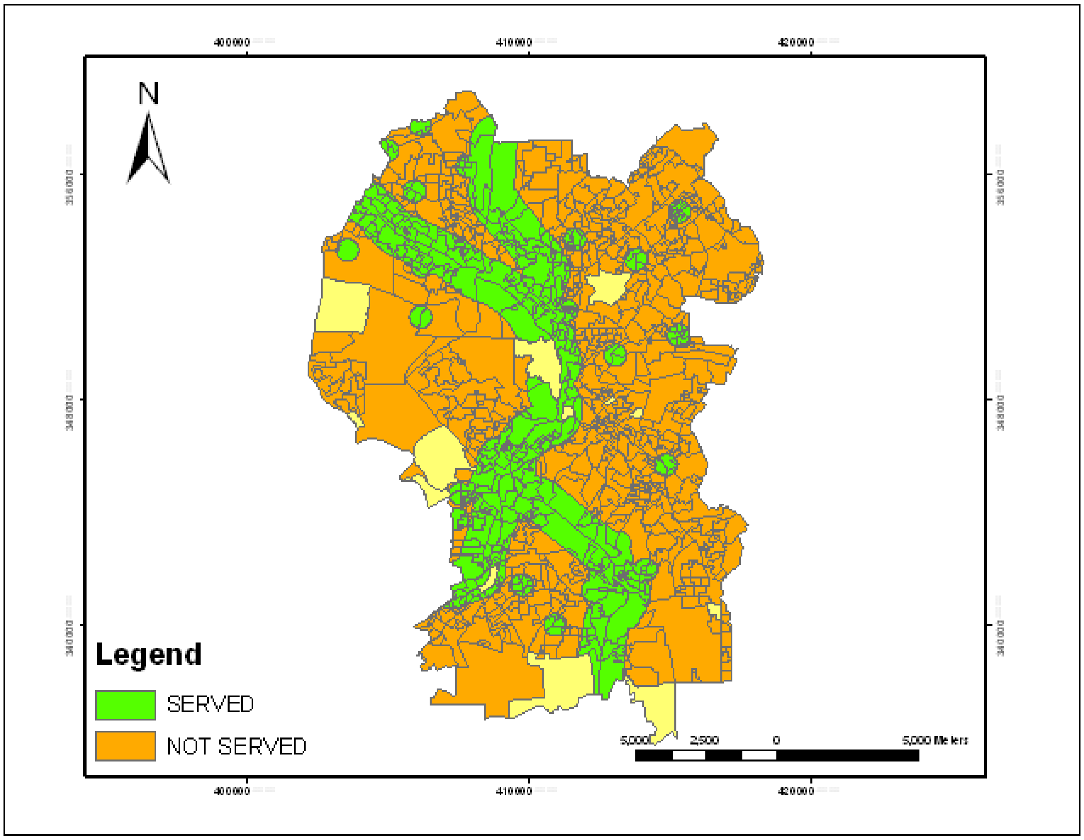


Figure 4.3g. TSA served for KTM and RapidKL bus

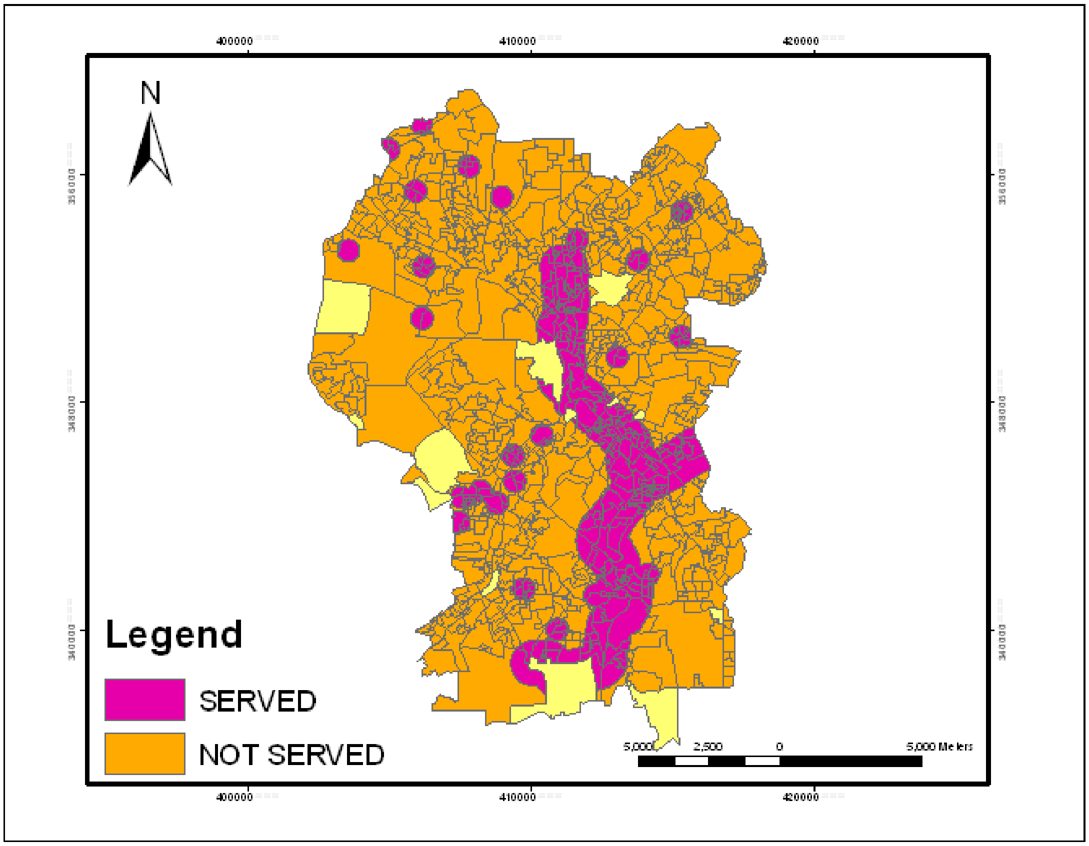


Figure 4.3h. TSA served for STAR LRT and RapidKL bus

Figure 4.3i shows the TSA that is served for a combination of Putra LRT, KL Monorail, KTM, STAR LRT lines and stations, and RapidKL bus stations. The dark-blue colour indicates the areas served by Putra LRT, KL Monorail, KTM, STAR LRT lines and stations, and RapidKL bus stations, while the orange colour indicates the areas not served by Putra LRT, KL Monorail, KTM, STAR LRT lines and stations, and RapidKL bus stations. The yellow colour indicates areas without any transit system at all. As seen in Figure 4.3i, there are a lot of orange areas.

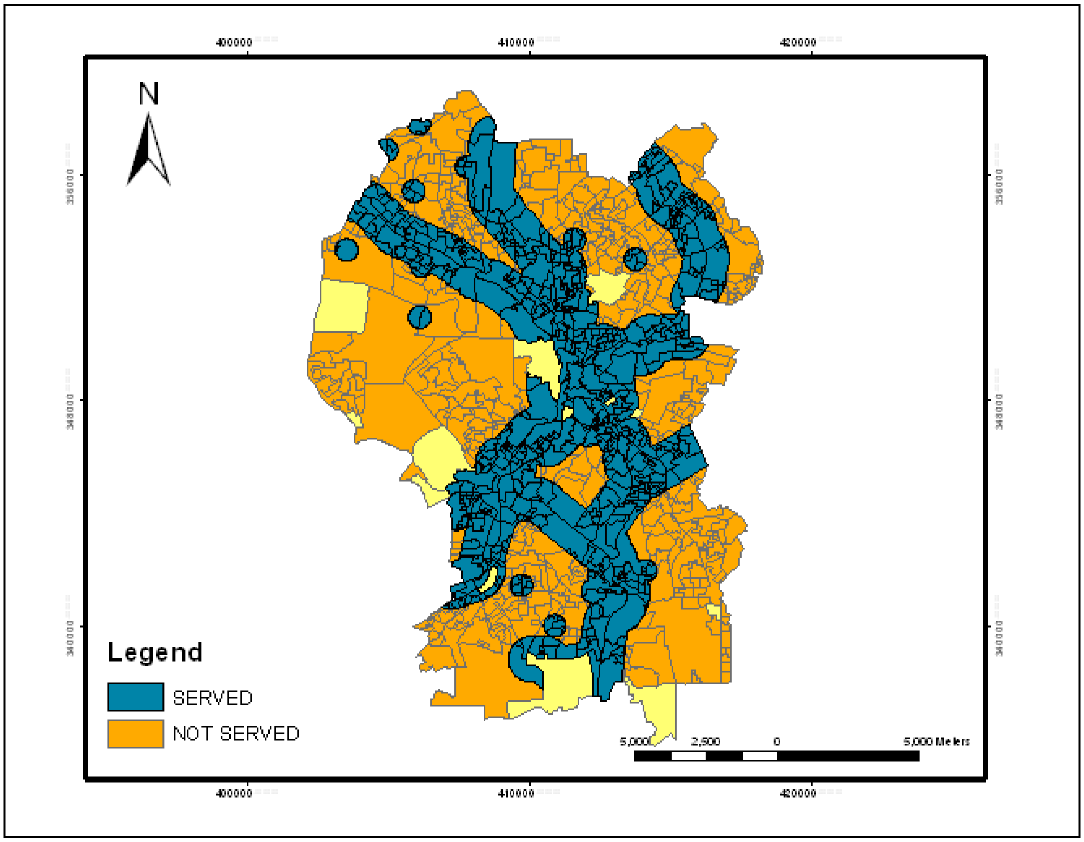


Figure 4.3i. TSA served for Putra LRT, KL Monorail, KTM, STAR LRT, and RapidKL bus

4.5 Service Coverage LOS Measures

An application was created to calculate the LOS using the VBA programming language. LOS is calculated with the percentage of TSA served by transit. Figures 4.4a to 4.4d show the transit LOS for each of the transit systems created using the application and the programming code in Appendix B. The LOS that were calculated for each of the transit systems is to compare the quality of service of each of the transit systems available in the Kuala Lumpur area for the public usage. When the percentage of the LOS is higher, the quality of service of the particular transit is very good, and a lower percentage shows that the transit system needs to be upgraded for better quality and quantity.

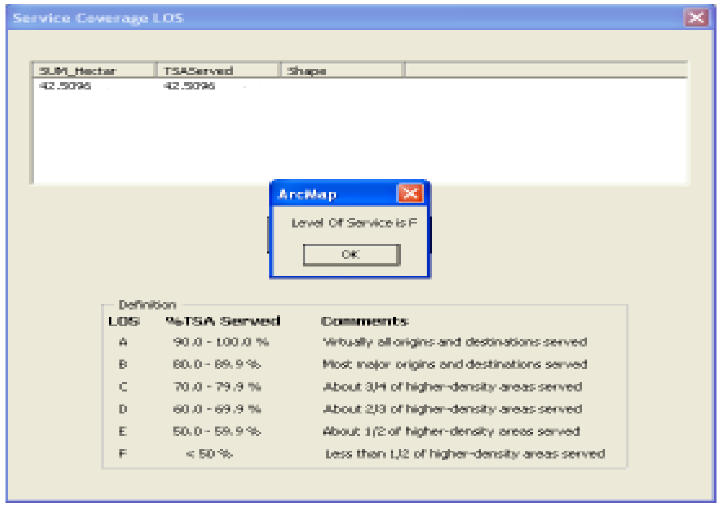


Figure 4.4a. LOS for Putra LRT and RapidKL bus

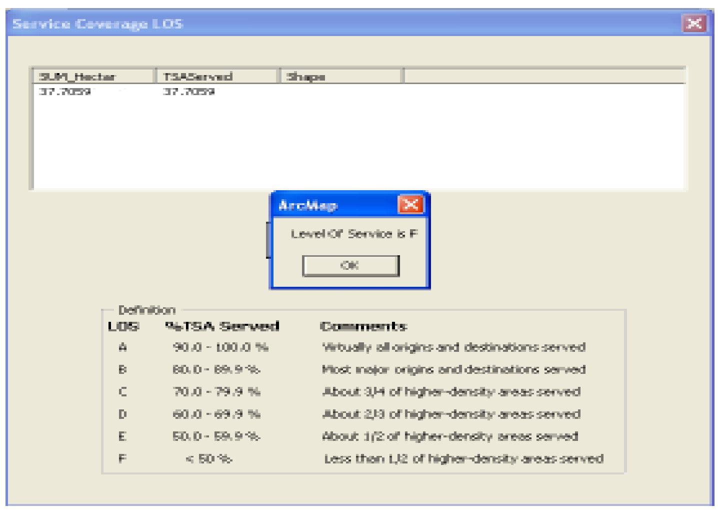


Figure 4.4b. LOS for KL Monorail and RapidKL bus

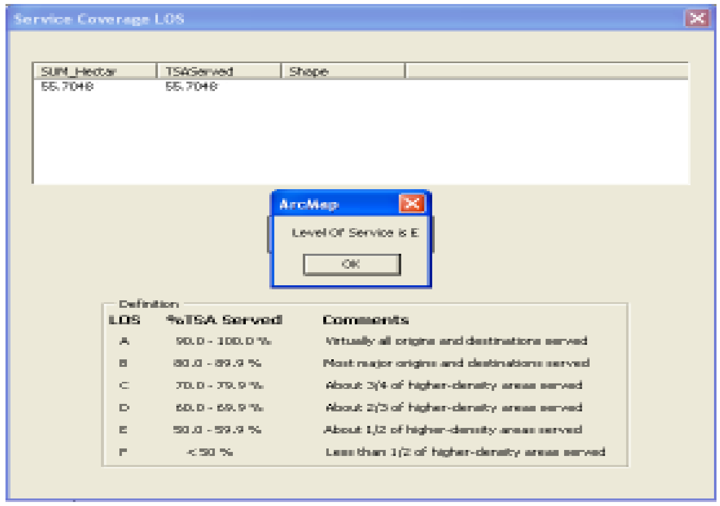


Figure 4.4c. LOS for KTM and RapidKL bus

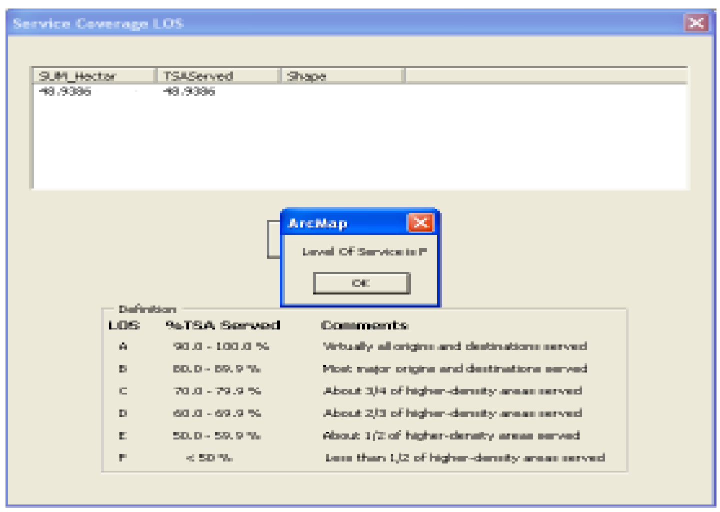


Figure 4.4d. LOS for STAR LRT and RapidKL bus

Table 4.1. LOS of each transit system based on the percentage of TSA

Transit System (Including RapidKL Bus)	% TSA Served	LOS	Comments
Putra LRT	42.5	F	Less than one-half of higher-density areas served
KL Monorail	37.7	F	Less than one-half of higher-density areas served
KTM	55.7	E	About one-half of higher-density areas served
STAR LRT	48.9	F	Less than one-half of higher-density areas served

Figure 4.4e shows the LOS for the Putra LRT, KL Monorail, KTM, STAR LRT, and RapidKL bus. The LOS for these systems is C, and the percentage TSA served by transit is 75.6%. Therefore, according to the LOS, about three-quarters of higher-density areas are served by transit with the existence of Putra LRT, KL Monorail, KTM, STAR LRT, and RapidKL bus. Therefore, the study shows that the existing transit system is not sufficient and has to be improved to fulfil the ridership of Kuala Lumpur. These are the main reasons in which the public prefer to use their own automobile rather than using the public transit because the public transit has not covered all the areas in the city.

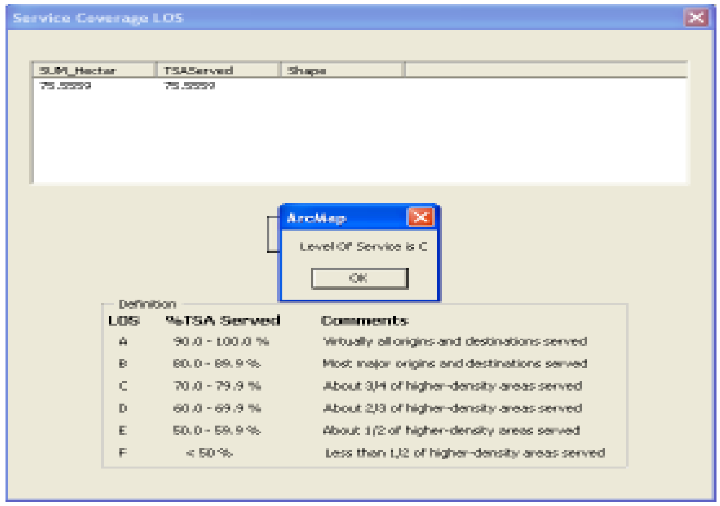


Figure 4.4e. LOS for Putra LRT, KL Monorail, KTM, STAR LRT, and RapidKL bus

4.6.1 Presentation and Publisher

The ArcGIS Publisher was used to deliver the map and GIS data for the public use. ArcGIS converts ArcMap (.mxd) documents into the published map format (.pmf) used with ArcReader. The data that were shown in published maps from ArcMap are two-dimensional. Figures 4.5a and 4.5b show the GIS data and map that were converted from the ArcMap to the ArcGIS publisher for the end user to view.

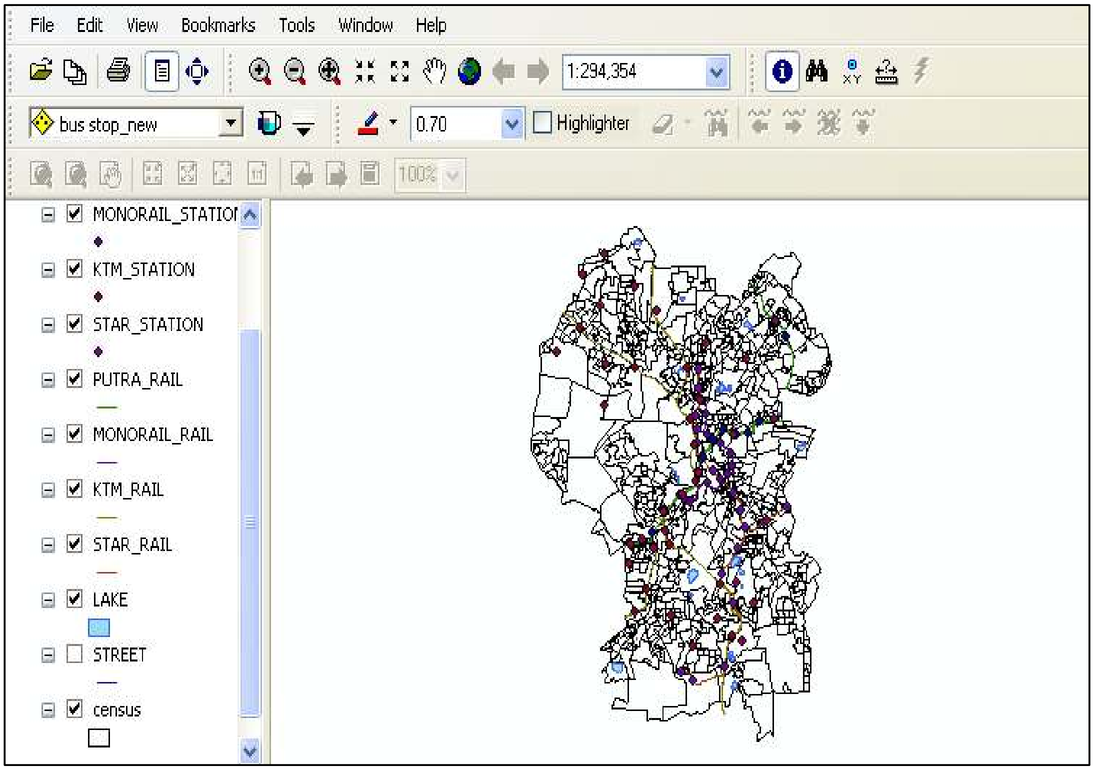


Figure 4.5a. Publisher map

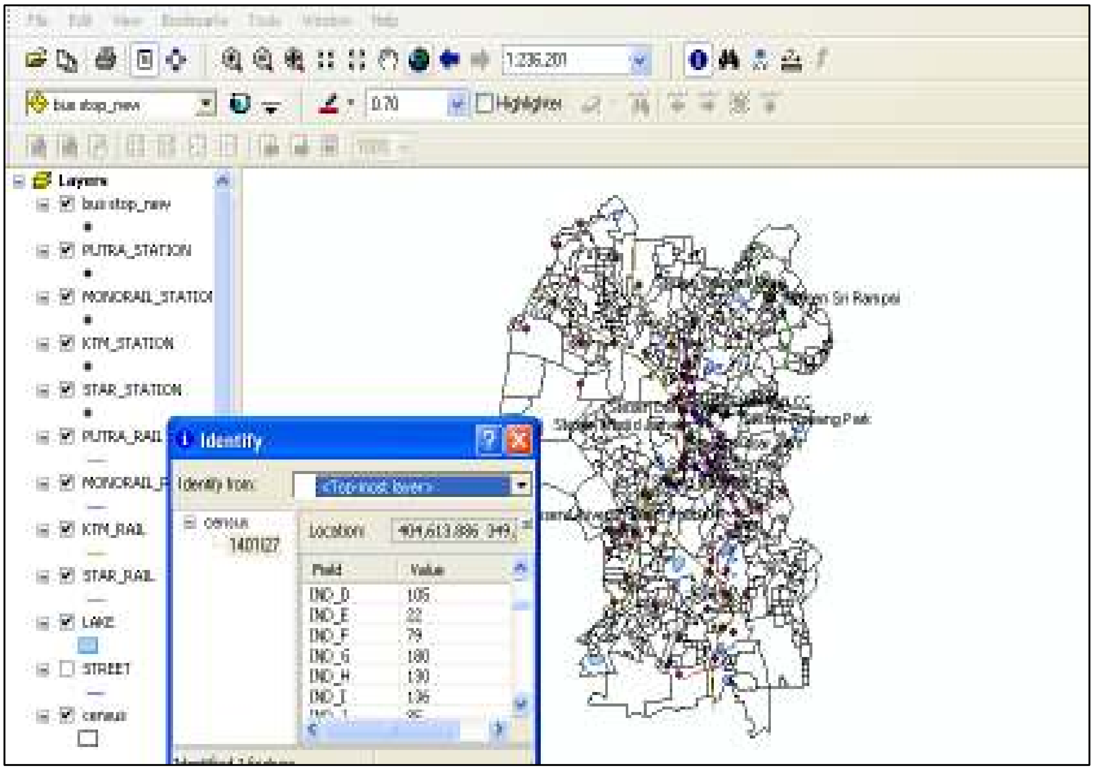


Figure 4.5b. Publisher map

Figures 4.5a and 4.5b show the map that has been converted into a publisher map with the desired parameters. Information on the transit system for all the transit—namely, Putra LRT, KL Monorail, STAR LRT, KTM, and RapidKL bus stops—can be accessed from this database system. The main purpose of publishing the map as shown in Figures 4.5a and 4.5b was to allow the users to view and analyse the data according to their preferences. Besides applying the service coverage LOS of transit quality of service for transit planning, the transit information system can also be obtained from this study for transit planning.

CHAPTER 5

5.0 DISCUSSION

5.1 Introduction

Transit line selection and data or information collection are the most important steps in the development of a transit information system. It requires numerous criteria, factors, and regulations to be considered; thus, the LOS calculation involves extensive effort to assess all those aspects before reaching a final decision. Applying this complex analysis in a conventional information processing approach would be expensive, tedious, and time-consuming. Furthermore, the analysis process might be repeated for several times until the best result is achieved and satisfies the interested parties. Therefore, with the help of modern computer technology, the complex procedures plus the involvement of numerous data can be easily evaluated.

There are three analyses that have been introduced in the study, namely, service coverage area, TSA, and service coverage LOS application. The spatial analysis is divided into two categories: the first is the analyses on the data involved in determining the suitable data for the transit system, and the second is the analyses involved in determining the service coverage LOS for the transit system for transit planning.

In this study, the GIS was used as a tool to calculate and determine the service coverage LOS in Kuala Lumpur transit system for transit planning. By using GIS, the service coverage LOS calculation procedure has been developed, in which the TSA were determined. This study shows that a combination of GIS and information data approach could be very useful in the calculation of service coverage LOS for every transit line in order to find the significance of ridership in the study area. The determination of ridership and information data of every transit system that exists is a major problem being faced by the local authorities and transit agencies; therefore, this study might be useful for them in order to determine the number of ridership of every transit system and the effectiveness of the existing systems to the public.

5.2 Preparing and Collecting Data

All input data required for the analysis were obtained from the related government agencies, except for the locations of transit routes and stations for Putra LRT, Star LRT, KL Monorail, KTM, and RapidKL bus stops, which were taken using GPS. Some of the data taken from these agencies were in digital format, in which its digitising accuracy cannot be determined. Because all these data came from different sources (e.g., Jabatan Ukur Dan Pemetaan and the Department of Statistics), data from one of them served as a reference in order to make some adjustments for the others. Furthermore, all the data from these two agencies are said to be latest data available.

In terms of applying the service coverage measures for a transit system, there are generally numerous criteria that should be considered. Major sitting considerations are environmental, economic, and social aspects. The criteria selected for this study are based on the guidelines set by the *TCQSM* as well as from related studies and international practices on developing a transit information system. However, although 13 factors are included in this study, there are still limitations surrounding the system. Not all factors are considered in this study due to the lack of data availability, such as the volume of commuters of every transit system, the walking distance, and the time taken to reach the transit system by every commuter. These examples are not included because of unobtainable of data in digital format and because more time is needed to prepare it. Because of the time constraint of conducting this research, these examples have been neglected. However, the result or the system could be more detailed and informative if these examples or other numerous criteria are taken into consideration.

5.3 Service Coverage

After outlining the parameters, the suitable buffer distances are examined. The buffer distances that were used as a guideline were taken from the *TCQSM* for every transit system. The buffering distance for all transit lines, stations, and RapidKL stops ranges from 400 to 800 m. The buffering should avoid the lake area and the major streets existing within the buffering distance. The buffering distances were considerable in Malaysia because it falls within a range where a commuter manages to walk from their destination to the transit system.

The first step of the presented analysis is the determination of service coverage area by every transit system available in Kuala Lumpur. Service coverage area was determined using the ArcGIS v9.3 software. The transit service coverage area is defined as a 0.4 km (1/4 mile) radius around all bus stops, 0.8 km (1/2 miles) of rail station and railway. An application for the service coverage was also generated using the VBA in ArcGIS. This application is able to generate the service coverage for the particular transit system within a few steps that is available in the programme. The application was generated to help transit agencies in their transit planning.

5.4 Transit-Supportive Areas

TSA was performed after determining the service coverage area and generating the application for the service coverage area. The calculation of the job and household density of every zone in the study area is one of the main steps in determining the TSA for Kuala Lumpur. There are a total of 881 zones in Kuala Lumpur according to the data that were obtained from the Department of Statistics. A mathematical calculation was performed to calculate the density area in hectares for every zone that is available. The area is considered a TSA if the housing density is at least 3 units per gross acre (7.5 units per gross hectare) or if the employment density is at least four jobs per gross acre (10 jobs per gross hectare).

In this process analysis, the GIS was used as a tool to calculate the TSA. This study shows that a combination of GIS and information data approach could be very useful in determining the TSA. The TSAs were calculated using a ModelBuilder in ArcGIS v9.3 software, which involves buffering, merging, clipping, and a few more steps before getting the output. The output of this analysis is divided into two areas, where there is a TSA and an area not supported by a transit system. The TSA shows that a particular area is able to support a transit system, and providing any type of public transit on those areas is recommended. The area that is not supported by a transit system is the area that is not recommended to provide public transit, in which the number of commuters is not enough to fulfil the transit system. This shows that TSA is one of the very important analyses for transit planning before determining the transit system in an area.

5.5 Service Coverage LOS

The last step that was used in this study is the creation of a LOS application using the VBA in ArcGIS. The programming codes were created in order to generate the LOS application for ease of use of the related agencies for transit planning. By using GIS, the service coverage LOS calculation procedure has been developed after the TSA was determined. The service coverage LOS was calculated for every existing transit system and a combination of all the transit systems available in Kuala Lumpur, namely, Putra LRT, Star LRT, KL Monorail, KTM, and RapidKL Bus.

The service coverage LOS of every transit system was determined by the percentage of TSAs covered by the transit system, which were ranked from A to F, in which A indicates that virtually all the major origins and destinations served are covered by a transit system and F indicates that only less than one-half of the higher-density areas are served. An overall output shows that most of the transit system falls in the F category, in which only less than one-half of the higher-density areas are served by a transit system. Meanwhile, the combination of the all the transit falls in the C category, in which about three-fourths of the higher-density areas are served by a transit system. This study shows that a combination of GIS and information data approach could be very useful in the calculation of LOS for every transit line in order to find the significance of ridership in the study area.

Finally, all the information on transit information system is made available for public use through the ArcGIS publisher, in which the users are able to view and analyse the information according to their needs. This information is published in map form and is very user-friendly. All the information needed for transit planning is available on the map.

5.6 Conclusions

There are two observations that can be made from this study: the TSAs were able to determine the most suitable area for a transit system and the service coverage LOS of the existing transit system. These two observations can help transit agencies with their transit planning for the existing transit systems and for the future development of transit systems. Because the determination of ridership and information data of every transit system that exists is the major problem faced by local authorities and transit agencies, this study might help them determine the number of ridership of every transit system and the effectiveness of the existing transit systems to the public.

GIS have proved to be a useful tool for the integration of different data sets and the creation of new ways for data visualisation. The study is limited and highly dependent on data collection and coverage. The presented approach and techniques in this study may be considered as a preliminary screening in applying GIS in the data input to the development of transit information systems in Kuala Lumpur.

CHAPTER 6

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study aimed to evaluate the LOS for service coverage measures in the Kuala Lumpur transit system using the GIS. The presented method is an efficient approach in a transit system for transit planning. The main objectives of this study as listed in chapter 1.2 were to determine the importance of the GIS application for the public transit on the quality of service using service coverage measures for transit planning in Kuala Lumpur, to apply the service coverage and TSA analysis, and, finally, to evaluate the service coverage LOS of each of the transit systems in Kuala Lumpur for transit planning.

The quality of service of every particular transit is very essential for the performance for every transit system. This study has used service coverage measures to calculate the LOS for every existing transit system in Kuala Lumpur. As explained in chapter 2, to compare with our existing transit system in Kuala Lumpur, this study has referred to the Florida Transit Information System standards and methods as discussed in the literature review.

From this study, we can conclude that calculating the service coverage LOS is also important in transit planning. Therefore, this study has chosen GIS as a tool in calculating the service coverage LOS of every transit system in Kuala Lumpur. As discussed in chapter 3, 12 types of data have been chosen to determine the service coverage LOS of every transit system.

The service coverage area of every transit system was calculated using the service coverage application generated by the VBA function. From the study, we can conclude that the total covered area of the combination of all transit systems is 17,012.23 hectares, in which the total covered areas for Putra LRT, KL Monorail, KTM, and STAR LRT are 9,571.51, 8,489.91, 12,542.54, and 11,019.07 hectares, respectively.

The TSAs for every transit system were determined, and the results showed that almost 93% of Kuala Lumpur is a TSA, and the remaining 7% are areas not supported by a transit system.

Finally, the service coverage LOS for every transit system in Kuala Lumpur was calculated using the LOS application, which was generated using the VBA application. On the basis of the results, the LOS of each transit system falls below the B level, in which the ranks of LOS for Putra LRT, KL Monorail, KTM, and STAR LRT were F, F, E, and F, respectively. The percentage values of TSA served by Putra LRT, KL Monorail, KTM, and STAR LRT were 42.5%, 37.7%, 55.7%, and 48.9%, respectively. The service coverage LOS of the combination of all transit systems is C, and the percentage of TSA served is 75.6%.

Therefore, we can conclude that the application of service coverage LOS for each transit system available in a particular area is essential to determine the transit performance of a transit system for better ridership and indirectly for the transit agencies. The study has also shown that it is possible to increase the transit service performance while continuing to provide suitable access to transit services for people who are being currently served.

6.2 Recommendations

The following recommendations are suggested for future research:

1. For future studies, it would be useful to incorporate more data into the GIS-based analysis. For example, the Florida Transit Information Systems considered more than 13 map layers during their development of a transit information system. This would increase, no doubt, the relevancy of the final output.

2. In a comprehensive study, a broad knowledge of parameters must be used for analysis. The incorporation of parameters from each of the environmental, sociopolitical, engineering, and economic aspects is necessary for a precise conclusion to be made.

3. Performing an analysis in a three-dimensional view can provide a greater impact of visualisation in presenting the outcome of the system. It can provide a clearer view of the site location and its surrounding areas as well.

4. Service coverage is one of the qualities of service measures that has been applied in this study for transit planning; thus, for future research, it is recommended to use other qualities of service measures—such as transit auto-travel time, hours of service, frequency, passenger load, and reliability—for better performance and output towards transit planning.

5. Develop a web application using the ArcGIS server to help related parties to view and analyse their work scopes.

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APPENDIX A

Kertau RSO Malaya Meters Coordinate Systems

Projection

False Easting	: 806471.299774999960000000
False Northing	: 0.00000000000000000
Scale Factor	: 0.999839999999999950
Azimuth	: -36.974209437118013000
Longitude of Center	: 102.250000000000000000
Latitude of Center	: 4.000000000000000000
XY Plane Rotation	: -36.869897645844020000

Geographic Coordinate System (GCS_Kertau)

Angular Unit	: Degree (0.017453292519943299)
Prime Meridian	: Greenwich (0.000000000000000000)
Datum	: D_Kertau
Spheroid	: Everest_1830_Modified
Semimajor Axis	: 6377304.063000000100000000
Semiminor Axis	: 6356103.038993154700000000
Inverse Flattening	: 300.801699999999980000

APPENDIX B

<u>Codes used to calculate and generate the Level of Service (LOS) and Service Coverage Area Application using Visual Basic Application in ArcGIS</u>

```
Private Sub CommandButton1_Click()

TSA = InputBox( _

"Enter the Percentage Value", _

"Percentage of Transit Supportive Area Served", _100#)

If TSA >= 90 And TSA <= 100 Then

MsgBox "Level of Service is A"

ElseIf TSA >= 80 And TSA <= 89.9 Then

MsgBox "Level Of Service is B"

ElseIf TSA >= 70 And TSA <= 79.9 Then

MsgBox "Level Of Service is C"

ElseIf TSA >= 60 And TSA <= 69.9 Then

MsgBox "Level Of Service is D"

ElseIf TSA >= 50 And TSA <= 59.9 Then

MsgBox "Level Of Service is E"

ElseIf TSA < 50 Then
```

```
MsgBox "Level Of Service is F"

End If

End Sub

Private Sub Frame1_Click()

En Sub

Private Sub Label1_Click()

End Sub

Private Sub Label3_Click()

End Sub

Pivate Sub Label5_Click()

End Sub

Private Sub UserForm_Initialize()

Dim pMxdoc As IMxDocument

Dim pMap As IMap

Set pMxdoc = Application.Document

Set pMap = pMxdoc.FocusMap

Dim pFeatureLayer As IFeatureLayer

Dim pFeatureClass As IFeatureClass

Dim pFields As IFields
```

```
Dim pField As IField

Dim i As Long

Set pFeatureLayer = pMap.Layer(0)

Set pFeatureClass = pFeatureLayer.FeatureClass

Set pFields = pFeatureClass.Fields

Dim pFSel As IFeatureSelection

Dim pSelSet As ISelectionSet

Dim pFCursor As IFeatureCursor

Set pFSel = pFeatureLayer

Set pSelSet = pFSel.SelectionSet

Dim Col As ColumnHeader

For i = 0 To (pFields.FieldCount - 1)

Set pField = pFields.Field(i)

Set Col = ListView1.ColumnHeaders.Add()

Col.Text = pField.Name

Next i

Dim newitem As ListItem

Dim pFeature As IFeature

Set pFCursor = pFeatureLayer.Search(Nothing, True)
```

```
Set pFeature = pFCursor.NextFeature

If pFeature Is Nothing Then

MsgBox "No matching records", vbInformation

Exit Sub

End If

Dim iTaxPinField As Integer

added the listitem

Do While Not pFeature Is Nothing

Set newitem = ListView1.ListItems.Add

For i = 0 To (pFields.FieldCount - 1)

Set pField = pFields.Field(0)

If pField.Type <> esriFieldTypeGeometry And pField.Type <> esriFieldTypeBlob Then

iTaxPinField = pFeature.Fields.FindField(pField.Name)

newitem.Text = pFeature.Value(iTaxPinField)

End If

Next i

For m = 1 To (pFields.FieldCount - 1)

Set pField = pFields.Field(m)
```

```
If pFField.Type <> esriFieldTypeGeometry And pField.Type <> esriFieldTypeBlob Then
 iTaxPinField = pFeature.Fields.FindField(pField.Name)
newitem.SubItems(m) = pFeature.Value(iTaxPinField)
End If
Next m
 Set pFeature = pFCursor.NextFeature
Loop
 Dim mn As Integer
 For mn = 1 To ListView1.ColumnHeaders.Count
 If mn = 1 Then
 ListView1.ColumnHeaders(mn).Width = 0
 ElseIf mn = 2 Then
 ListView1.ColumnHeaders(mn).Width = 0
 End If
 Next mn
End Sub
```

LIST OF PUBLICATIONS

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M.A. Mohd Din, M.R Karim, **S. Paramasivam (2009),** The Aspect Of Walking Accessibility In The Development Of GIS-Based Transit Information System Modelling In Kuala Lumpur, Crowne Plaza Mutiara Hotel, Kuala Lumpur, 10 – August 2009

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M.A. Mohd Din, M.R Karim, **S. Paramasivam**, **(2013),** Evaluating Level of Service (LOS) for service coverage in Kuala Lumpur Transit System using GIS, Journal of Public Transport, ISSN 1613-7159, (Sent for publication) (*ISI-Cited Publication*)

<u>Presentations</u>

Speaker, 8th International Symposium and Exhibition on Geoinformation (ISG 2009) at Crowne Plaza Mutiara Hotel, Kuala Lumpur, 10 – August **2009**