

# Applying Shared-Parking Turn-Time (SPaTT) Model and Geographic Information System in the Supply and Demand Analysis of Parking Space

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## Abstract

Parking space is a basic and important public facility in urban areas. Problems of parking space are said to be always occurring in urban areas, especially in the city centre or busy commercial and services zones. In Malaysia, the common parking system adopted is shared-parking turn-time system, whereby members of the public share limited parking space in the city centre and have to take turns to keep their vehicle temporarily in parking lots. City centres are said to be suffering from insufficient parking space, forcing people to park their vehicles on road shoulders or outside the gazetted parking lots. This causes traffic congestion and arouses question of sufficiency of parking space in such areas. The basic task in addressing this issue is by carrying out supply and demand analysis of parking space. The objective of this study is to apply a spatial technique using the Geographic Information System (GIS) in modelling the supply and demand of parking space, taking Johor Bahru city centre as a study case. Maps of buildings, land cadastre, urban land use, and others such as road and street networks are digitally constructed to form a spatial database of supply and demand of parking space in the study area. Attribute data on building inventory, building characteristics, land use, space supply, and demand of parking space are obtained from the Johor Bahru City Council, private parking companies operating in the city, observational, as well as interview surveys in the study area. The shared-parking turn-time model – the “SpaTT model” – is developed to analyse spatial distribution of parking space supply and demand in the study area. The “SpaTT model” is then incorporated into ArcView 3.1 to determine parking space equilibrium across the study area. This, in turn, is used to determine zones with parking space deficit and, thus, which need additional parking lots. The study discloses that there is reasonable level of parking space equilibrium in the study area. In other words, there is no evidence of acute supply problem of parking space in the Johor Bahru city centre as perceived, although there are zones where additional on-street parking could be provided to add parking supply.

*Keywords: Parking space equilibrium, supply and demand, SpaTT model, Geographic Information System.*

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## 1. Introduction

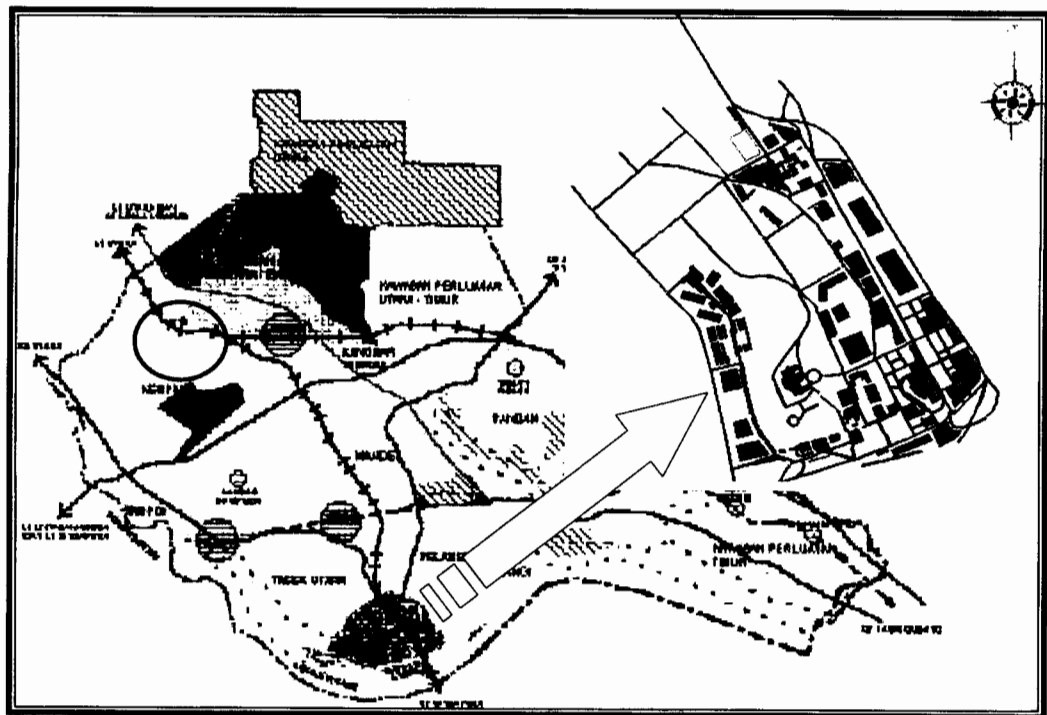
According to Weant (1978), provision of parking space is part of the overall need of transportation system with respect to vehicle movement and traffic flow in urban areas. People perceive that their movement or businesses are directly influenced by the conditions of a particular parking system in the urban area. For example, O’flaherty (1993) reports that between one-tenths and one-fifths of the general public avoid going to the town due to parking difficulties associated

with limited parking space. Brierley (1972) argues that increasing town population due to increasing trade and business activities leads to an increase in the vehicular traffic and this, in turn, increases the demand for parking space.

The city of Johor Bahru which has been developing and expanding for so many years is no exception in this case. With a population of about 1.2 million people, there has been public outcry over parking issues in this city for quite some time now (Berita

Is parking space really insufficient in the Johor Bahru city centre? How could we objectively measure parking space deficit or surplus in the area? In which zones of the city does parking space deficit occur if any and, thus, additional parking space is needed?

In answering these questions, this study has two objectives. Firstly, to develop a quantitative technique in estimating the supply and demand of parking space based on the shared-parking turn-time model (hereinafter called as the “SpaTT model”). Secondly, to integrate a Geographic Information System (GIS) with the SpaTT model with a view to identifying areas with parking space deficit in the city (Figure 1) and, thus, needing an additional supply of parking lots.



**Figure 1: The Study Area – the Johor Bahru City Centre**

urban area and helps identify spatial imbalances of parking resources and, thus, zones that need additional parking space. This can be a valuable input to urban authorities to improve their planning and management of urban land and facilities.

This paper is organised into five sections. The second section discusses the theoretical framework, the third section describes the data analysis procedure while the fourth section presents the results and discussion. The concluding remarks are given in the final section of this paper.

## 2. Theoretical Framework

### 2.1 Concept of Parking Space

Each transport system comprises three physical elements, viz., vehicle, road, and terminal (Everett and Homburger, 1994). A terminal is generically referred to as parking space provided on road shoulders or sides, in garage, at shopping complex, on private site, at bus and taxi stands, within vehicle loading zones, or inside purpose-built buildings.

By definition, parking space is a site which is specifically planned and allocated for short-time keeping of vehicle (JPBD, 2000). It is an economic commodity which is subjected to the fundamental laws of economics (O'flaherty, 1993). For instance, if demand for parking space is higher than its supply, parking fees will likely to rise. Rising parking fees, in turn, will discourage people to drive to the town centre or to park on the allocated lots.

Therefore, off-street and on-street parking planning has to be properly carried out. Off-street surface parking may take the form of roof parking, multi-storey car parking, mechanical parking, or underground parking. On-Street parking can be angular or diagonal' (30o, 45o or 60o, perpendicular (90o) or parallel' (180o) in nature (APAI, 2007; DoPO, 2007).

### 2.2 The Issues of Demand and Supply of Parking Space

There are a number of important issues in the supply and demand analysis of parking space. These issues relate to the factors that contribute to the increasing demand for parking space, the level of demand for parking space, the availability of parking space, supply and demand deficit, the spatial distribution of such deficit, and the suitable sites for additional parking space.

Generally, several factors contribute to the increasing demand for parking space. The growing population, better personal loan facilities, availability of variety of designs of vehicle at various price levels, increasing number of building construction in the urban area, increasing number of vehicles going to the town, and inefficient public transport systems are some of the main factors. There is also suggestion that associates personal status, position, lifestyle, self-esteem, and sense of respect with private ownership of cars as a factor that contributes to the increasing demand for

parking space (Mohd Nor Awang, 1992). Further, there is reason to believe that the larger proportion of the society prefer to use their own cars for work and leisure. It was suggested that the 'modal split' in the use of public bus and private cars in some Malaysian cities is about 30:70 (Mohd Nor Awang, 1992).

It seems that a good urban centre's parking space management (including sufficient parking space and reasonable parking fees) should be in place, especially in the congested urban commercial and service zones. In this context, the shared-parking system has long been in existence in many cities in Malaysia.

For the purpose of parking space supply and demand analysis, the first issue to consider is the supply of parking space in a particular urban zone. What is the total available supply of parking space in that zone? What is the distribution of the parking space? Which zones are likely to be more congested and, thus, will have parking space deficit? Consequently, which zones do need additional parking space? These issues are addressed under Section 2.4.

### 2.3 Main Guidelines for Provision of Parking Space

All local authorities have their own policies, regulations, and guidelines pertaining to urban area's parking space. In our case, the guidelines for parking space are contained in the Guidelines and Standards for the Planning of Parking Space, Johor Bahru City Council (MBJB, 2000), and the Guidelines and Standards for the Planning of Parking Space, Department of Town and Country Planning Peninsular Malaysia (JPBD, 2000).

Parking space provision should aim at creating an efficient parking system in urban areas, that is, a parking system which is well-planned, designed, and managed (see TDM Encyclopedia, 2005). Kamus Dewan (1993) states that an efficient parking system must be productive and avoiding wasteful use of energy. Efficient must also be defined in terms of parking convenience and comfortability, namely, it is safe, is free from traffic flow disruption, protects users from adverse weather, and is economical.

Fundamentally, the siting of parking space should help the smooth flow and orderly situation of the urban traffic. It should have appropriate dimensions in order to support peak-time demand. The siting of parking space must be planned in zones with ingress-egress facilities. The area must be sufficiently safe

for the movement of people from parking lots to points of destination in the town. On-street parking may be provided along low-speed, low-volume-traffic one-way streets as a last resort should other alternatives are not possible. Other criteria need also be formulated by the authority in the management and planning of urban parking space.

#### 2.4 Supply and Demand Model of Parking Space

There are a number of supply and demand Model of parking space. One model is based on the concept of "Tempe Standard Shared Parking Model" (TDM Encyclopedia, 2005). Based on the currently available parking space, this model assumes a 0700-to-2400 week-day business-hour time duration of parking supply and demand. For example, for the banking business, the demand for parking space at 0900 is 93% while the demand for parking from 1000 to 1200 is 100% of the total full capacity of a parking area. This model has two main shortcomings: firstly, it assumes that the total current supply of parking space always sufficiently meets the demand and, secondly, it does not anticipate demand oversupply (Shoup, 1997).

In this study, we adopt the "shared-parking concept" with a simple, straightforward AUCoP model. ["AUCoP" stands for available space, space under construction, completed space, and planned space.] Thus, by definition, AUCoP model states that the total supply of parking space in a particular urban area,  $SS(T)_{ij}$  is based on the total space available,  $A_{ij}$  under-construction,  $U_{ij}$  completed,  $C_{ij}$  and planned  $P_{ij}$ , at any given time. It is expressed as follows (subscript for time is suppressed):

$$SS(T)_{ij} = \sum_{i,j=1}^{n,m} (A_{ij} + U_{ij} + C_{ij} + P_{ij}) \quad (1)$$

This is a comprehensive, potentially dynamic model that calculates total supply of urban parking space by considering the current as well as future needs. In fact, each of the sub-component of AUCoP model can form its own supply function. For example, the planned supply of parking space is a function of future urban expansion, land availability, population, construction, businesses, level of parking charges, and local planning requirements.

In this study, however, we have confined ourselves only to parking space that is currently available without attempting to include other supply components. The

supply model is then stated as follows:

$$S(A)_{ij} = \sum_{i,j=1}^{n,m} (SS(I)_{ij} + SS(E)_{ij}) \quad (2)$$

where  $SS(A)_{ij}$  is the total available supply of shared-parking space of type  $i$  at location  $j$ ;  $SS(I)_{ij}$  is the available supply of shared-parking space of type  $i$  at georeferenced in-building location  $j$ ; and  $SS(E)_{ij}$  is the available supply of shared-parking space of type  $i$  at georeferenced out-building location  $j$  (where  $i = 1, \dots, m$  dan  $j = 1, \dots, n$ ). Generally, according to this model, the total available supply of parking space in a particular urban area is made up of all parking space inside and outside all the existing commercial or office buildings.

Further, the demand for shared-parking space is based on the turn-time parking concept and, thus, an abbreviation "SpaTT" is suggested here. The SpaTT concept states that in a shared-parking system, a user takes turn to park on a given parking lot after the previous user leaves and the process of taking "turns" is assumed to continue for other users for the rest of the day depending on the maximum duration of daily business hours and business type. For example, the maximum time duration can be taken as 6 hours (0900 to 1500) for bank, 24 hours for hotel, 12 hours (1000 to 2200) for shopping complexes, and 12 hours (0800 to 1800) for street shops, etc.

In the SpaTT model, the number of clients or crowd size, customer's average parking time, building size, building occupancy, length of business hours, vehicle ownership, number of persons sharing a car are the pertinent variables of parking space demand in the commercial and service zones. These variables are used in the demand analysis of parking space at various levels of modelling complexity and what is discussed in this paper is only a simple model.

Let's take a simple example. A bank has an average of 300 customers per day and each customer consumes an average of 30 minutes of parking time. In an hour, there will be two parking turns for customers on a given parking lot. If the maximum time duration of banking business is 6 hours, there will be twelve 30-minute parking turns for customers, called parking turnover rate (see Shoup, 1999). Thus, the total customers' parking space required for one bank is  $300/(60/30 \times 6) = 25$  parking lots.

In general, the number of customers may be proportionate to the size of a particular business and,

thus, the number of customers per square foot of business space is an important parking space demand variable. The larger is the business the higher is the number of potential customers patronising it and the larger is the number of customers per square foot. Nevertheless, the number of customers per square foot of a given business type also depends on location, neighbourhood, situs characteristics such as attractiveness and accessibility of an area, etc. In the same way, parking turn-time is also likely to vary by commercial or trade zone or location. In a very busy and crowded zone, the average parking turn-time will be shorter than that in a less busy and less crowded zone.

With a number of demand parameters being rationalised on planning, physical, and market considerations, the model of parking space demand can be developed for each demand component based on the type of building use. For example, the potential number of employees needing parking space for a particular building can be estimated as follows:

$$S_{ij} = A_{ij} \times 1/100^* \quad (3-1)$$

$$S(a)_{ij} = S_{ij} \times S(op)_{ij} \quad (3-2)$$

$$S(c)_{ij} = S(a)_{ij} \times S(cp)_{ij} \quad (3-3)$$

$$DD(E)_{ij} = (S(c)_{ij} \times S(sc)_{ij}) \quad (3-4)$$

where  $DD(E)_{ij}$  = the potential number of employees needing parking space associated with a particular building  $i$  at location  $j$ ;  $S(c)_{ij}$  = proportion of employees of building  $i$  at location  $j$  owning private cars;  $S(sc)_{ij}$  = proportion of persons of building  $i$  at location  $j$  sharing a car;  $S(a)_{ij}$  = estimate of current number of employees of building  $i$  at location  $j$ ;  $S(cp)_{ij}$  = percentage of population owning cars;  $S$  = maximum employees population of building  $i$  at location  $j$ ;  $S(op)_{ij}$  = employee occupancy rate of building  $i$  at location  $j$ ;  $A_{ij}$  = building's net lettable area (sq. ft.). [\*each employee is assumed to need 100 sq.ft. of office space.]

Employee's parking space demand is then expressed as follows:

$$DD(EP)_{ij} = DD(E)_{ij} / (60/PT_{ij} \times H_i) \quad (4)$$

where  $DD(EP)_{ij}$  = employee's demand for parking space associated with building  $i$  at location  $j$ ;  $DD(E)_{ij}$  is as defined above;  $PT_{ij}$  = parking turn-time (in minutes) associated with building  $i$  at location  $j$  (Table 1);  $H_i$  = maximum duration of daily hours of business type  $i$ .

The potential number of customers needing parking space associated with a particular building can be estimated as follows:

$$\begin{aligned} DD(C)_{ij} &= N_{ij} \times S(cp)_{ij} \times S(sc)_{ij} \\ &= A_{ij} \times c_{ij} \times S(cp)_{ij} \times S(sc)_{ij} \end{aligned} \quad (5)$$

where  $DD(C)_{ij}$  = the potential number of customers needing parking space associated with building  $i$  at location  $j$ ;  $N_{ij}$  = potential number of customers of building  $i$  at location  $j$ ;  $S(cp)_{ij}$ ,  $S(sc)_{ij}$  and  $A_{ij}$  are as defined earlier;  $c_{ij}$  = potential daily customers per square foot of business space of type  $i$  at location  $j$  (Table 1).

**Table 1: Parking Turn-Time and Potential Daily Customers Per Sq. Ft. of Business Space**

	Government office		Private office		Hotel		Shopping complex		Individual shops		Other building uses	
	Em	Cm	Em	Cm	Em	Cm	Em	Cm	Em	Cm	Em	Cm
PT	480	30	480	30	480	960	480	60	480	30	480	30
c*	-	10-24	-	8-10	-	10-15	-	20-50	-	10-12	-	10-12

Note: Em = employee; Cm = customer. PT = parking turn-time, c = potential daily customers per sq. ft. of business.

\* In computing c, a middle figure is used for purpose of convenience.

Source: Observational survey and interviews with a number of building managers and business owners in Johor Bahru, 2005.

Customer's parking demand is then estimated as follows:

$$DD(CP)_{ij} = DD(C)_{ij} / (60 / PT_{ij} \times H_j) \quad (6)$$

where  $DD(CP)_{ij}$  = customers demand for parking space associated with building  $i$  at location  $j$ ;  $DD(C)_{ij}$ ,  $PT$ , and  $H$  are as already defined.

In the same way as indicated in equations (4) and (6), the total demand for parking space is made up of demand for all types of building under various uses. The general model can be expressed as follows:

$$DD(T)_{ij} = \sum_{i,j=1}^{n,m} DD(Gs_{ij}, Gc_{ij}, Ps_{ij}, Pc_{ij}, Hs_{ij}, Hc_{ij}, Ss_{ij}, Sc_{ij}, Cs_{ij}, Cc_{ij}, Os_{ij}, Oc_{ij}) \quad (7)$$

where  $DD(T)$  = total demand for parking space;  $DD(Gs)$  = demand for parking space by employees of government offices; and  $DD(Gc)$  = demand for parking space by customers of government offices;  $DD(Ps)$  = demand for parking space by employees of private offices;  $DD(Pc)$  = demand for parking space by customers of private offices;  $DD(Hs)$  = demand for parking space by hotel employees;  $DD(Hc)$  = demand for parking space by hotel customers;  $DD(Ss)$  = demand for parking space by shop employees;  $DD(Sc)$  = demand for parking by shop customers;  $Cs_{ij}$  = demand for parking space by employees of shopping complex;  $DD(Cc)$  = demand for parking space by customers of shopping complex;  $DD(Os)$  = demand for parking by employees of other building 'establishments' (e.g. Tenaga Nasional Berhad, Pos Malaysia);  $DD(Oc)$  = demand for parking by customers of other building 'establishments'; and  $i$  and  $j$  denote building  $i$  and at location  $j$ .

Based on equations (2) and (7), we can compute parking space equilibrium associated with any building  $i$  at location  $j$  ( $PE_{ij}$ ), which indicates the net

balance (parking space deficit or surplus) between parking space supply ( $SS(A)$ ) and demand ( $DD(T)$ ) associated with that building. The general model is expressed as follows:

$$PE_{ij} = SS(A)_{ij} - DD(T)_{ij} \quad (8)$$

However, the equilibrium concept needs to be based on the spatial mobility of parking choice with respect to the intended point of destination. This concept rules that insufficient shared-parking space at one point can be compensated by an additional space provided at other points within a conveniently accessible parking zone, with respect to the intended points of destination. In simple words, if a person could not park at one spot because parking is full, he can park at another spot so as to minimise the walking distance to the intended point of destination (e.g. office, shopping mall, police station, etc.).

Based on this concept, parking space equilibrium has to be computed within a 'conveniently accessible' buffer. From a random observational survey among car owners in the study area, it is assumed that the majority of customers would not be willing to park more than five-minute walk away from the intended point of destination. The average time of voluntary park-then-walk is estimated to be three minutes. Considering the pedestrian environment, climate, line of site and "friction" in the Malaysian cities, this represents a radial buffer of less than 100 m around the point of destination.

Therefore, the final model for estimating parking space equilibrium at location  $j$ ,  $PSE_j$ , is expressed as follows:

$$PSE_j = \sum_{i=1} PE_i / n \quad \text{for buffer} \leq 100 \text{ m} \quad (9)$$

where  $PE_i$  is parking space equilibrium associated with building  $i$ ; and  $n$  is the number of buildings within a 100-m radial buffer.

## 2.5 The Rationale for Applying Geographic Information System(GIS)

Geographic Information Systems (GIS) can be described in many ways including as a decision support system (Cowen, 1990); a functional or process-oriented system (Calkins and Tomlinson, 1977; Cowen, 1990); a toolbox (Tomlinson and Boyle, 1981; Cowen, 1990; Dangermond, 1990); a technology (ESRI, 1990b; Allen et al., 1994); and data (Goodchild, 1985). All of these views focus on one basic characteristic of a GIS, that it is designed for dealing with objects and phenomena where geographic position is an important characteristic or is critical to a particular analysis. In other words, GIS is a tool or more appropriately a system to process spatial data for spatial decisions.

In this context, one of the most important advantages of GIS is its capability to store and process both attribute and geographical data of an object. GIS can be used as a powerful analysis tool. The ability to identify demographic characteristics at any point in space is one example of this type of analysis. Correctly locating the occurrence of phenomena such as parking space deficit or surplus is the necessary first step in identifying locational process with regard to parking problems.

In any spatial analysis, GIS which permits disaggregation and reaggregation of sub-zonal data, offers a level of customisation and accuracy not otherwise possible using other types of information system. GIS is designed to overlay and compare different variables or types of data so that the relationships between important decision-making factors can be understood. Because of the spatial capabilities of GIS, its map display features are particularly well suited for understanding spatial processes such as why a particular area is exhibiting parking space deficit or surplus. However, since it requires another area of investigation, this "why" question is beyond the scope of this paper and, thus, needs to be further explored in future studies.

## 3. Data and Analysis Procedure

Having identified the issue (Section 1.0) and developed the parking space supply and demand model (section 2.4), the pertinent variables are included in the model and the database is constructed. This model is developed specifically for this study but it provides fundamental ideas for further development of the SpaTT concept and modelling.

Figure 2 shows the flow chart of this study which consists of three main stages. Firstly, supply and demand modelling of parking space is envisaged. Secondly, data collection is carried out to fulfill the modelling steps. Finally, supply and demand analysis is conducted to determine the state of parking space equilibrium (parking space deficit or surplus).

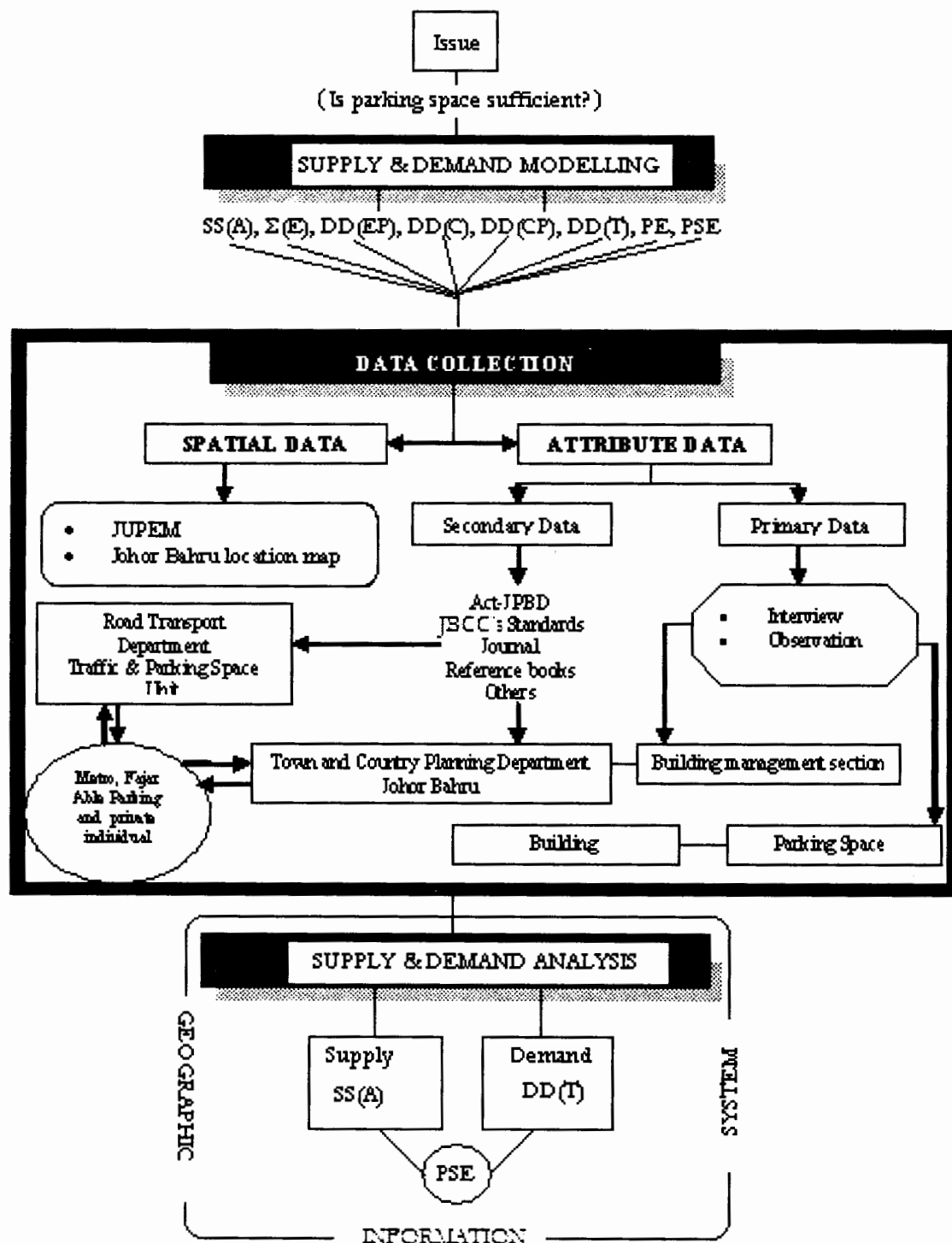


Figure 2: Modelling Flow Chart



**Table 2:** Turn-Time Shared-Parking Models' Variables and Source of Data

Label*	Definition	Source
SS(I)	Available supply of in-building parking space (sq.ft.)	Johor Bahru City Council
SS(E)	Available supply of out-building parking space (sq.ft.)	Johor Bahru City Council
DD(T)	Total demand for parking space (sq.ft.)	Calculated
DD(EP)	Employees demand for parking space	Calculated
DD(CP)	Customers demand for parking space	Calculated
DD(C)	Potential number of customers needing parking space	Calculated
DD(E)	Potential number of employees needing parking space	Calculated
DD(Gs)	Demand for parking space by employees of government offices	Calculated
DD(Gc)	Demand for parking space by customers of government offices	Calculated
DD(Ps)	Demand for parking space by employees of private offices	Calculated
DD(Pc)	Demand for parking space by customers of private offices	Calculated
DD(Hs)	Demand for parking space by hotel employees	Calculated
DD(Hc)	Demand for parking space by hotel customers	Calculated
DD(Ss)	Demand for parking space by shop employees	Calculated
DD(Sc)	Demand for parking by shop customers	Calculated
DD(Cs)	Demand for parking space by employees of shopping complex	Calculated
DD(Cc)	Demand for parking space by customers of shopping complex	Calculated
DD(Os)	Demand for parking by employees of other building 'establishments' (e.g. TNB, Pos Malaysia)	Calculated
DD(Oc)	Demand for parking by customers of other building 'establishments'	Calculated
S(c)	Proportion of employees owning private cars (%)	Calculated
S(sc)	Proportion of persons sharing a car (%)	Observation/interview
S(a)	Estimate of current number of employees of a building	Interview
S(cp)	Percentage of population owning private vehicle	Road Transport Department
S	Maximum employees population of a building	Calculated/interview
S(op)	Employee occupancy rate of a building (%)	Calculated/Interview
A	Building's net lettable area (sq. ft.).	Building manager
PT	Parking turn-time (in minutes)	Survey & observation
H	Maximum duration of daily business hours	Survey & observation
N	Potential number of customers of a building	Survey & observation
C	Potential daily customers per square foot of business space	Business owner
PE	Parking space equilibrium associated with a building	Calculated
PSE	Parking space equilibrium associated with a building within a 100-m buffer	Calculated

\* Spatial and/or categorical identification of the variables is suppressed for easy reading only.

### 3.1 Data Collection

As shown in Figure 2, data are categorised into spatial and attribute data. The main spatial data required are the cadastral map and urban land use map, obtained from the Department of Survey and Mapping Malaysia (JUPEM) and the Johor Bahru City Council, respectively. Other maps such as road networks are constructed using Autocad 2005 and ArcInfo 3.5 from the available road maps.

The main attribute data relate to the total supply of parking space in the study area. The data are obtained from the Johor Bahru City Council and private parking companies currently operating in the city of Johor Bahru. Other attribute data are collected from an observational as well as interview survey in the study area in March 2005. Table 2 lists the variables used in the SpaTT model of supply and demand of parking space.

### 3.2 Development of Database

The steps in the development of database for the SpaTT model of supply and demand of parking space are summarised in Figure 3. The whole process involves the conversion of analog maps into the ArcInfo 3.5 drawing (.dwg) files, AutoCad 2005 drawing (.dxf) files, cleaned-and-built ArcInfo 3.5 files (maps), and ArcView 3.1 shape (.shp) files. All of these software programmes are installed on the latest version of Windows XP.

To develop the database, building map of the study area (Johor Bahru city centre) is digitised from the existing hardcopy maps. To ensure integrity of the digitised maps, the cadastral maps from the Department of Survey and Mapping Malaysia (JUPEM) are used. All buildings in the study area including offices, shopping complexes, hotels, shops, religious places, stations, etc. are included. Also included are the major roads and streets.

Database development involves the generally accepted concepts of conceptual, logical, and physical designs (see for example Fariza Hanum et al., 2002; Rusli Abdullah et al., 2002; and Saadiah Yahya et al., 2000). The conceptual design has a basic purpose of creating entity relationships of mapping elements which are based on the analysis requirements and, which in turn, are based on the SpaTT supply and demand variables. The correct decisions on these entity relationships are vital since the subsequent

stages of database development are based on the internal structure of these relationships.

The logical design details out each data item for each map entity for which the specification of the database structure is determined (see for example Hamid, 2005). For the attribute data, details for field requirement, type, size, and decimal figures for numeric field are given. The data model derived from the conceptual and logical designs is then transferred and adapted to the selected software whereby the actual physical design of the database is implemented.

In this case, the final step in developing the database is choosing database storage and access passage consistent with the software's functionality. The determination of database storage structure depends on the supporting hardware, while the access passage depends on the selected database management system (Hecht, 1981). The access passage is determined based on the location of data in the computer storage system. This is important to ensure smooth running of the system. For this study, the physical design is basically based on the ArcInfo 3.5 and ArcView GIS 3.1 software programmes.

The SpaTT model's database uses a tabular structure available in Arc View 3.1 while Ms Access is used for managing (e.g. modifications, up-dating) the attribute information. The tabular structure such as this is crucial since the database management functions in Arc View 3.1 do not fully support database management system (DBMS). The attribute tables in Arc View 3.1 are linked to Ms Access' attribute data using an open database connector. Identity code (ID) is part of this connector.

Since this is only a small study for one single area, a local rather than global ID system is used. The latter system is more appropriate for a larger scale GIS. Example of table structure of attribute information for each spatial data layer is shown in Figure 3 (next page).

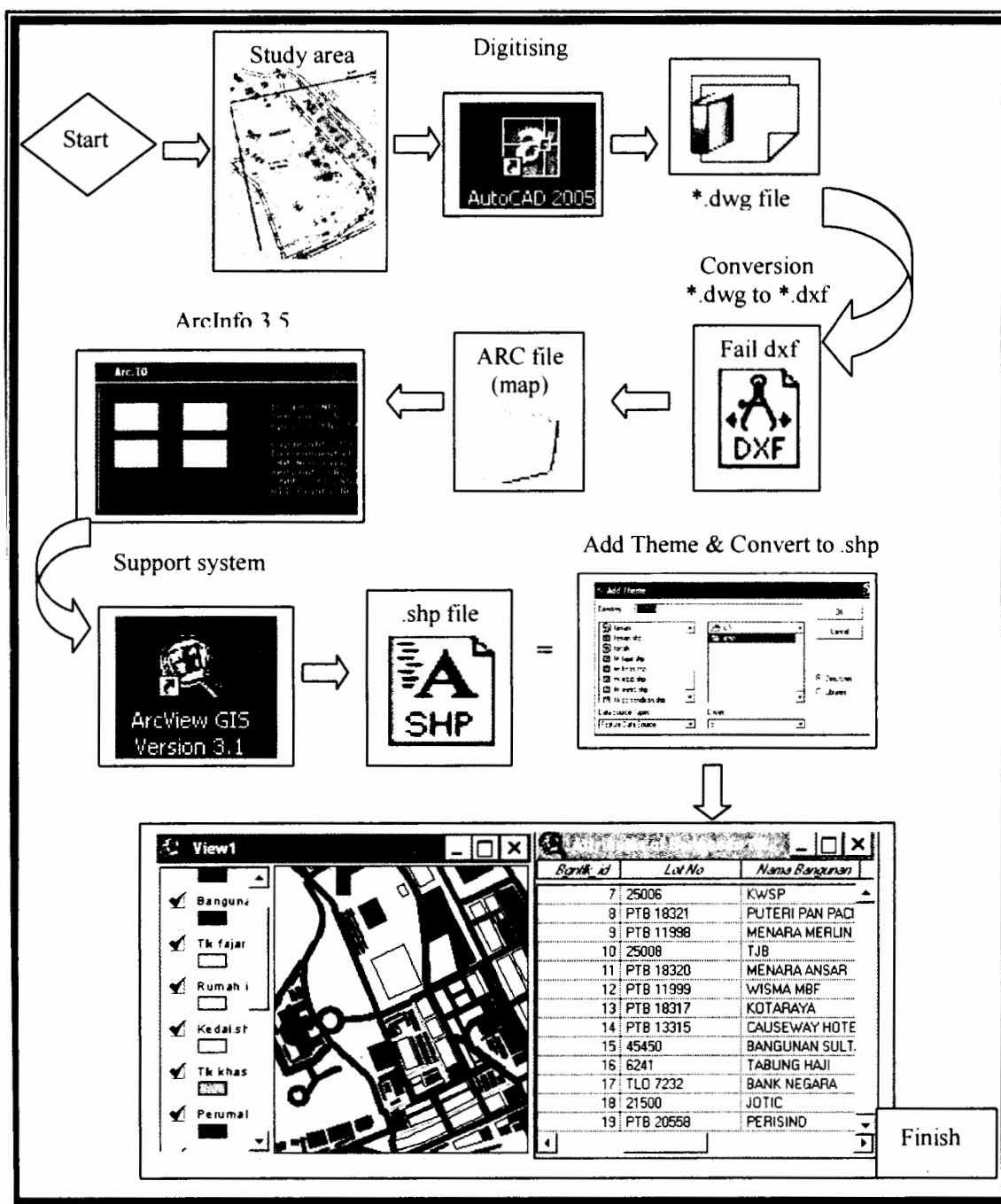


Figure 3: Database Development of the Turn-Time Shared-Parking Model

### 3.3 Data Analysis Method

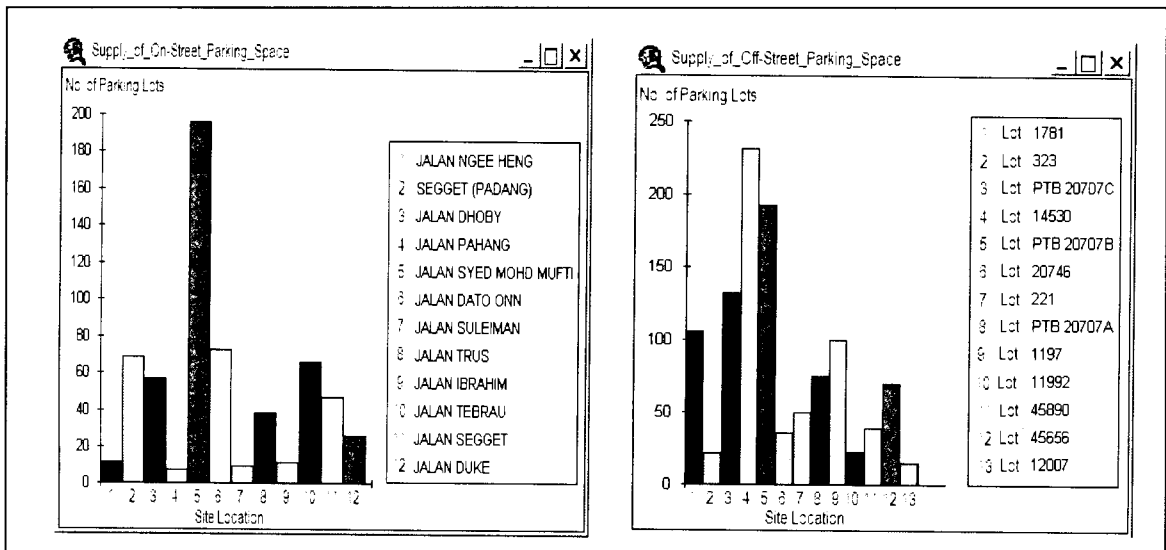
Having integrated the spatial and attribute information based on the specifications of equations (2) through (9), various spatial analysis components in ArcView 3.1 are used such as buffering, overlay, and theme intersection according to the required outputs. Besides, normal query and statistical functions (e.g., graph) are also used. Some display outputs, especially those related to the variables on the left-hand side of equations (2) through (9) are derived following arithmetic or algebraic operations of the respective variables on the right-hand side of the relevant equations.

Once the required variables are calculated, the resulting figures are added to the attribute tables for the intended spatial interrogations and analyses. Examples of such variables are parking turn-time (PT), parking space equilibrium associated with a building (PE), and parking space equilibrium associated with a building within a 100-m buffer (PSE).

## 4. Results and Discussion

### 4.1 Descriptive Analysis Using GIS

Bar graph is the simplest yet effective way of showing the profiles of total supply and demand of parking space in the study area. It helps us to quickly compare and contrast the levels of supply of parking space across the study area. For example, Jalan Syed Mohd Mufti has the most abundant out-building on-street and off-street parking space (Figure 4). In the same way, City Square has the highest level of in-building surplus of parking space. It still maintains its position even when both in-building and out-building parking space is considered (Figure 5).



**Figure 4:** On-Street and Off-Street Supply of Parking Space in the Study Area

Beyond the normal spreadsheet-like graphing, ArcView 3.1 has what is called built-in structured query language (SQL) to help users do simple and complex queries associated with any graphic or attribute element of a map. This can be done by identifying the required element on the map or by specifying the attribute criterion derived from the database.

Queries based on attribute can be performed to display the type of building, its name, its category of use, the

associated parking space, and other query variables. For example, Figure 6 shows the query on buildings (Bangunan tik.shp) with in-building parking space greater than 400 parking lots (table rows marked ✓). As shown, examples of such buildings are Menara Landmark, City Square, Kotaraya, and Tabung Haji.

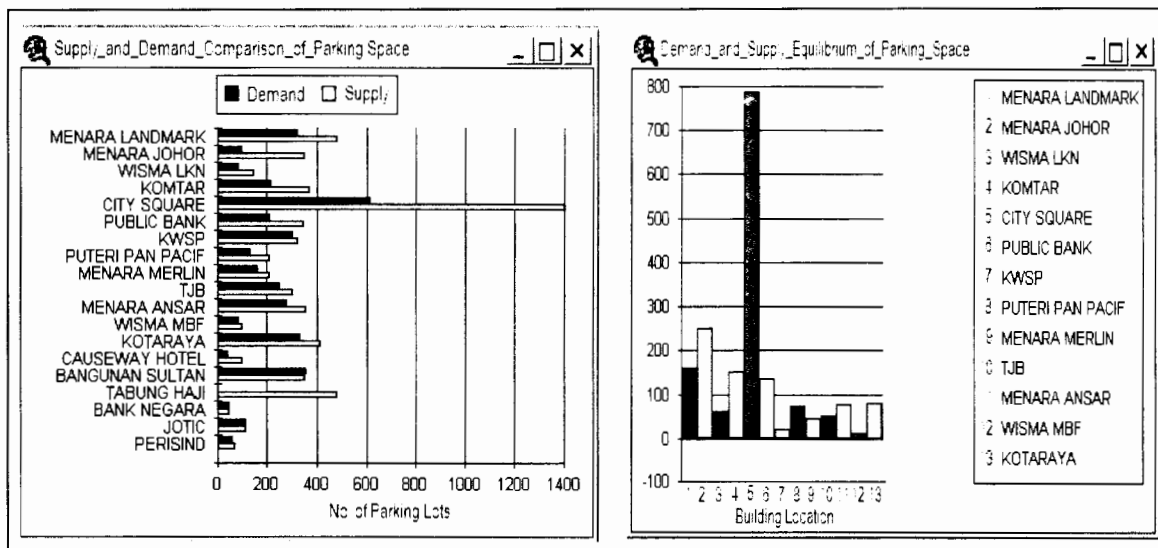


Figure 5: Comparison of Supply and Demand of Parking Space in the Study Area

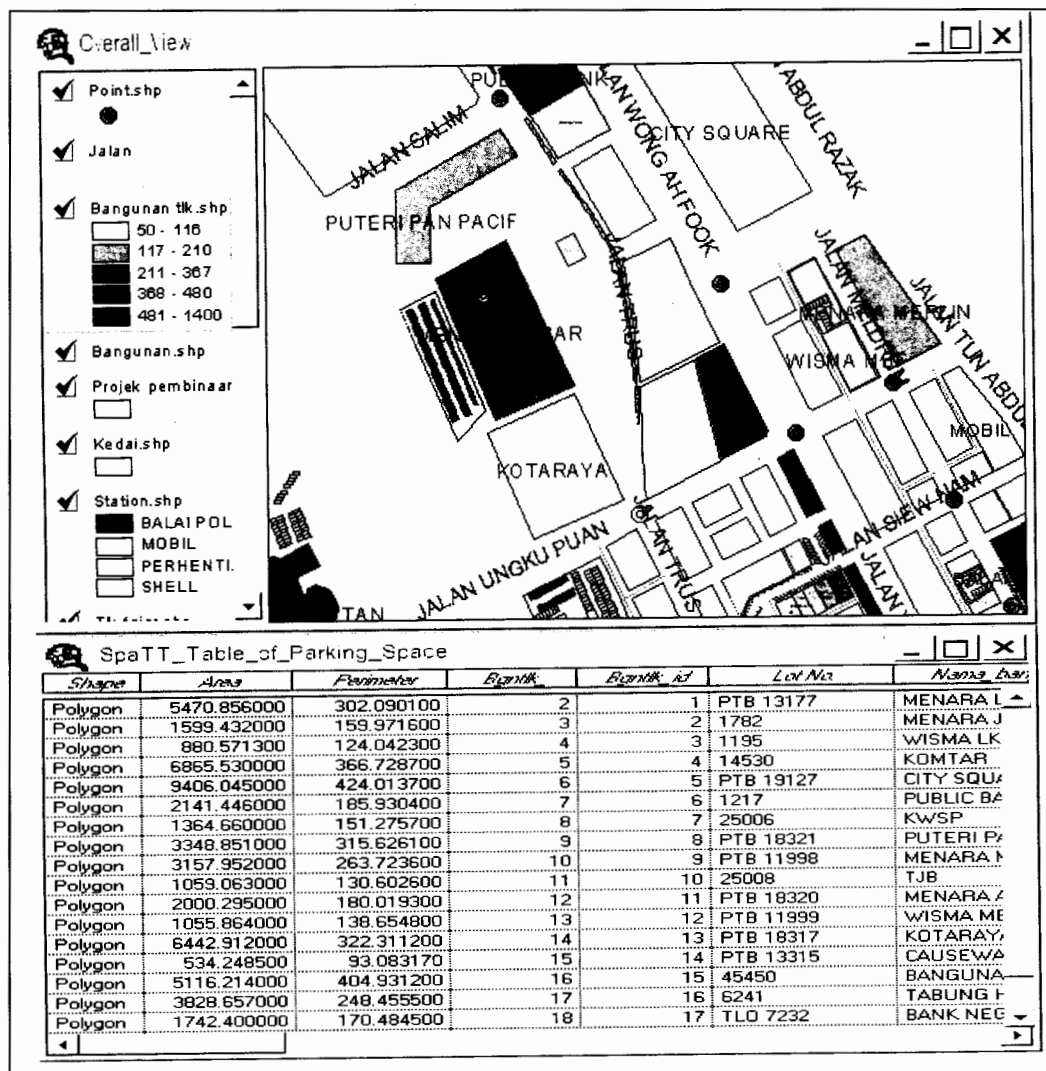



Figure 6: SQL on Map Attribute – Buildings with Parking Space Greater Than 400 Strips

Queries based on a particular entity on a map layer or theme can be performed using identify tool. For example, clicking  and then on 'Kotaraya', after activating Bangunan tik.shp theme, results in the display of the attributes of that building (Figure 7). As can be seen, the identify results display the

variables that are used in the SpaTT model. These are very important attribute information that is already integrated into the topology files and become the basis of various spatial analyses.

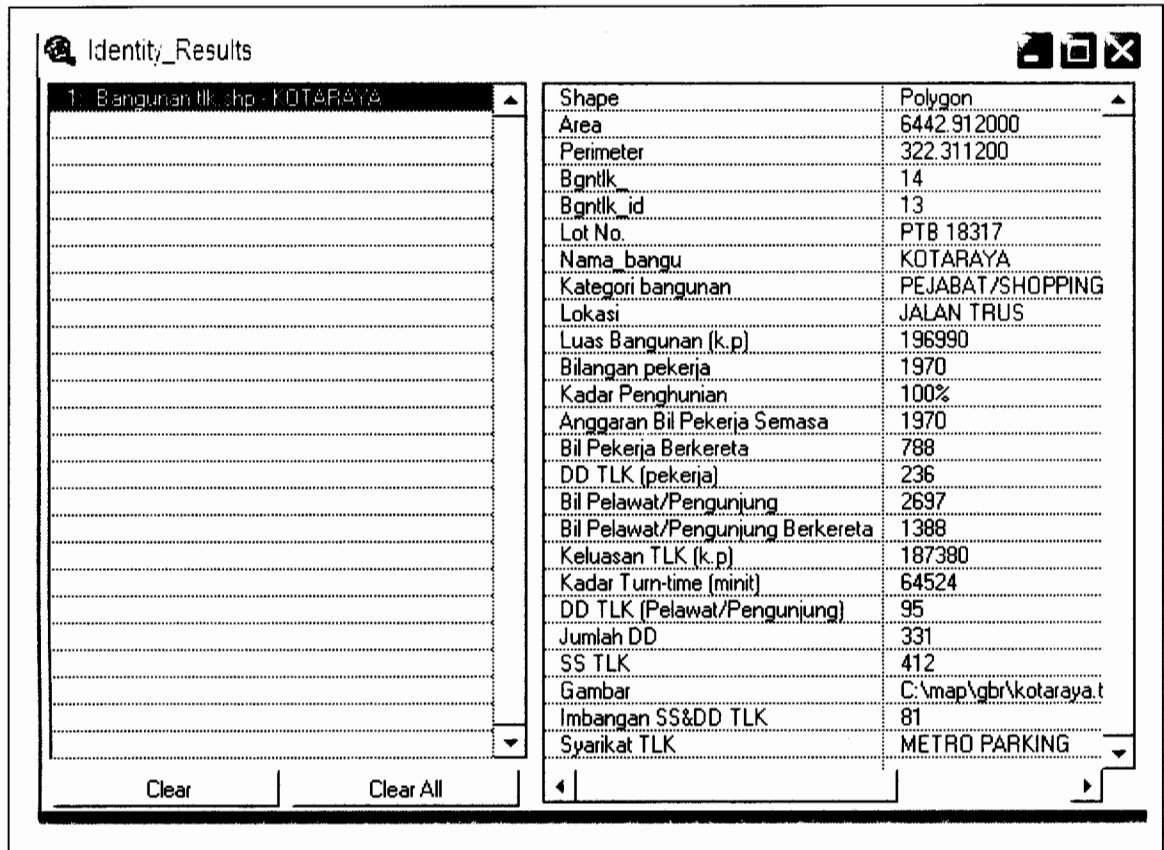


Figure 7: Identification of Selected Entity – Bangunan tik.shp – Kotaraya

#### 4.2 Analysing Parking Space Equilibrium (PSE)

The concept of spatial mobility of parking choice as mentioned in Section 2.4 necessitates the specification of a conveniently accessible buffer with respect to a particular point of destination. This is necessary in order for the SpaTT model to determine the balance between aggregate supply and demand of parking space within the specified region. As mentioned earlier, this conveniently accessible buffer is a 100-m radius around a particular point of destination.

Figure 8 shows an example of analysing spatial equilibrium of in-building parking space. Taking City Square, Kotaraya, and Tabung Haji as three main points of destination in the city centre, 100 m buffers

are drawn from the centre of each building. All spots within the 100-m circles are considered to be convenient zones that can provide alternative shared-parking space to the competing users. Figure 9 shows an example of analysing spatial equilibrium of out-building parking space. In the same way as Figure 8, assuming TJB Tower as the point of destination, a 100 m buffer is drawn around it to show the supply of parking space under the concept of spatial mobility of parking choice. PSE from equation (9) can then be calculated for such a zone.

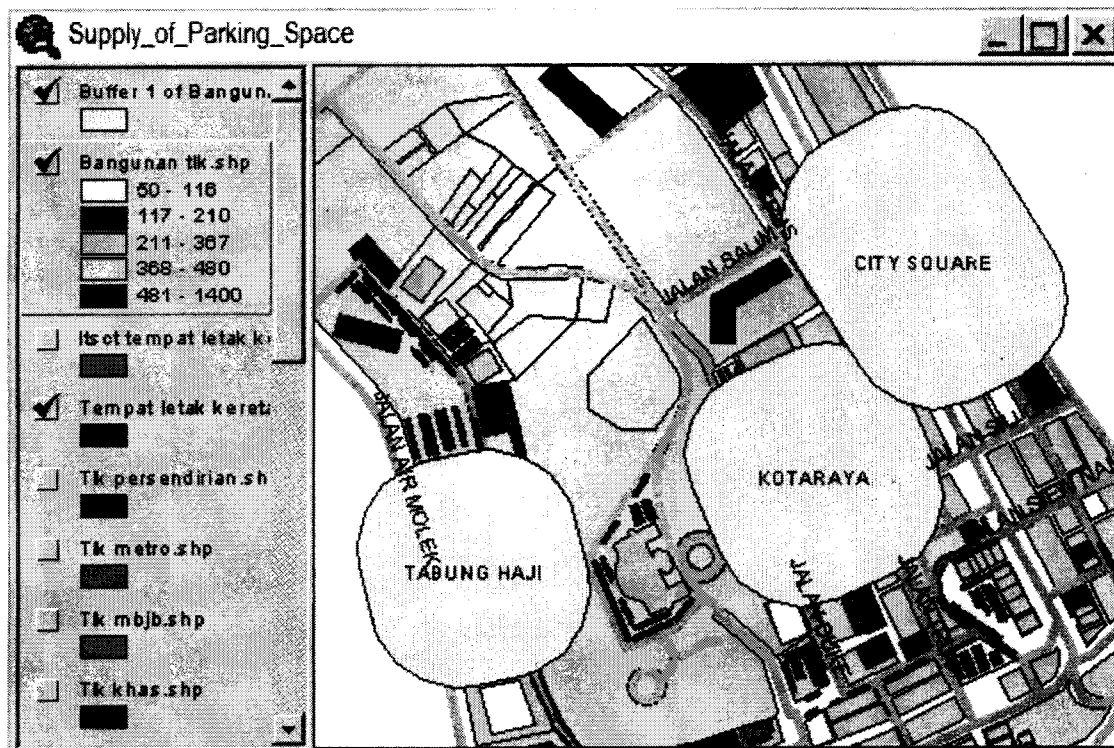


Figure 8 : 'Conveniently Accessible' (100 m Buffer) In-Building Parking Choice

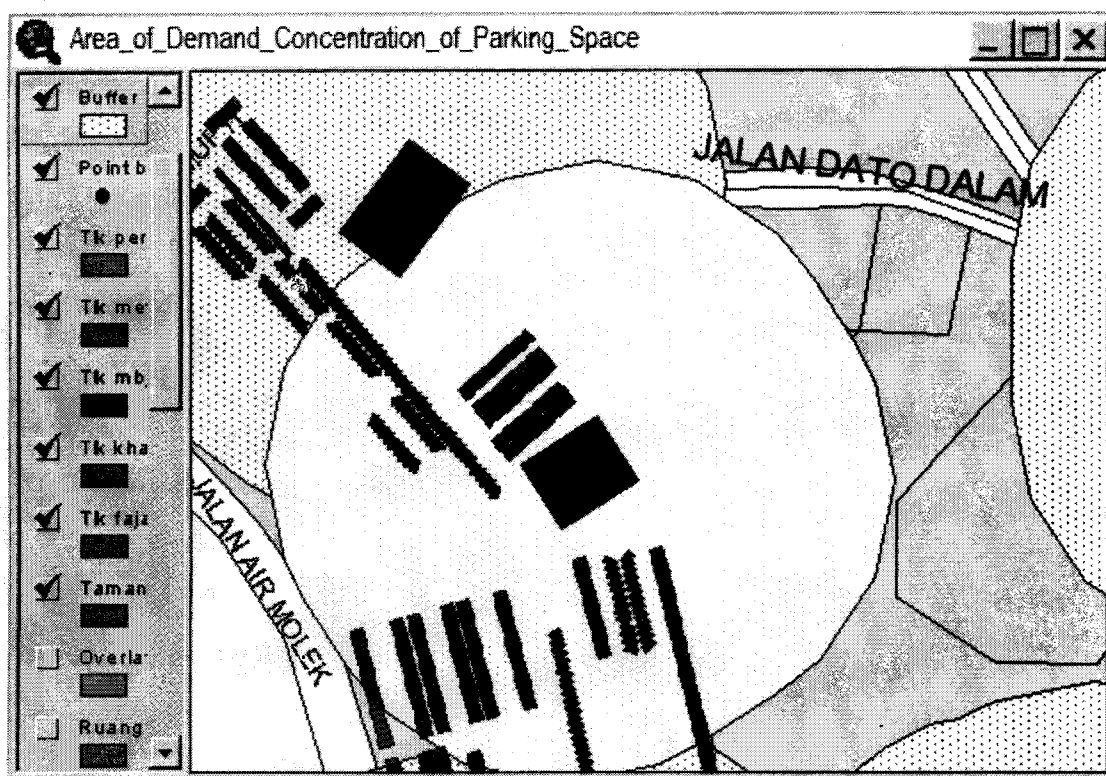
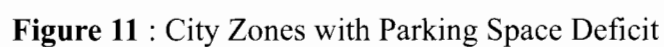
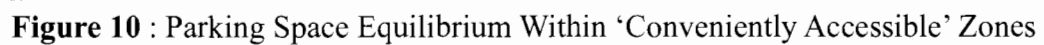


Figure 9 : 'Conveniently Accessible' (100 m Buffer) Out-Building Parking Choice







The results are shown in Figure 10. Figure 10 shows that City Square, Putri Pan Pacific, and Tabung Haji are examples of zones of the city centre that do not exhibit parking space deficit while zones around the Sultan Ibrahim and the Public Bank buildings are identified as among the city centre's "busy spots" with some shortage of parking space.

Statistically, zones around the Sultan Ibrahim and the Public Bank buildings have approximately 100-150 lots of parking deficit daily. This situation is in a stark contrast to areas in the vicinity of the City Square and the Putri Pan Pacific buildings which have up to 500 lots of parking surplus daily. There are some reasons for this phenomenon.

Despite abundant parking space in the City Square and the Putri Pan Pacific buildings, many parkers refuse to keep their vehicles in these basement car parks for various reasons. Firstly, to avoid paying higher parking fees. Secondly, some users spend only few minutes at points of destination and, thus, prefer to park at road sides or open parking space. Thirdly, some users perceive that the existing parking areas (such as the ones opposite Landmark mall and Menara Ansar) are quite far from the main clusters of commercial buildings, office buildings, and individual shops and, thus, are not willing to spend few minutes of walk to the points of destination. Some in-building parking ingresses and egresses such as those at the Komtar and the Putri Pan Pacific buildings are not perceived to be convenient for users. Fourthly, busy areas such as those nearby the Sultan Ibrahim building largely do not have in-building parking and, thus, tend to exert pressure on open-space parking in the nearby areas.

The calculation of parking space equilibrium as shown in Figure 9 can be modified to create a more generalised view of parking space equilibrium within a larger commercial and services zone. Smaller building-oriented zones which exhibit a general feature of parking deficit (Figure 9) can be combined into a single larger zone (Figure 10), using "intersect two themes" function in ArcView 3.1, to identify the spatial extent of public concentration in the study area. This is necessary to identify areas which need additional parking space, especially out-building parking. [It should be noted that many users prefer the latter category of parking facility.]

As shown in Figure 10, the existing out-building parking is concentrated in the Jalan Ibrahim-Jalan Dhoby-Jalan Trus zones. Areas such as Jalan Siew Nam and Jalan Siu Chin exhibit a shortage in parking

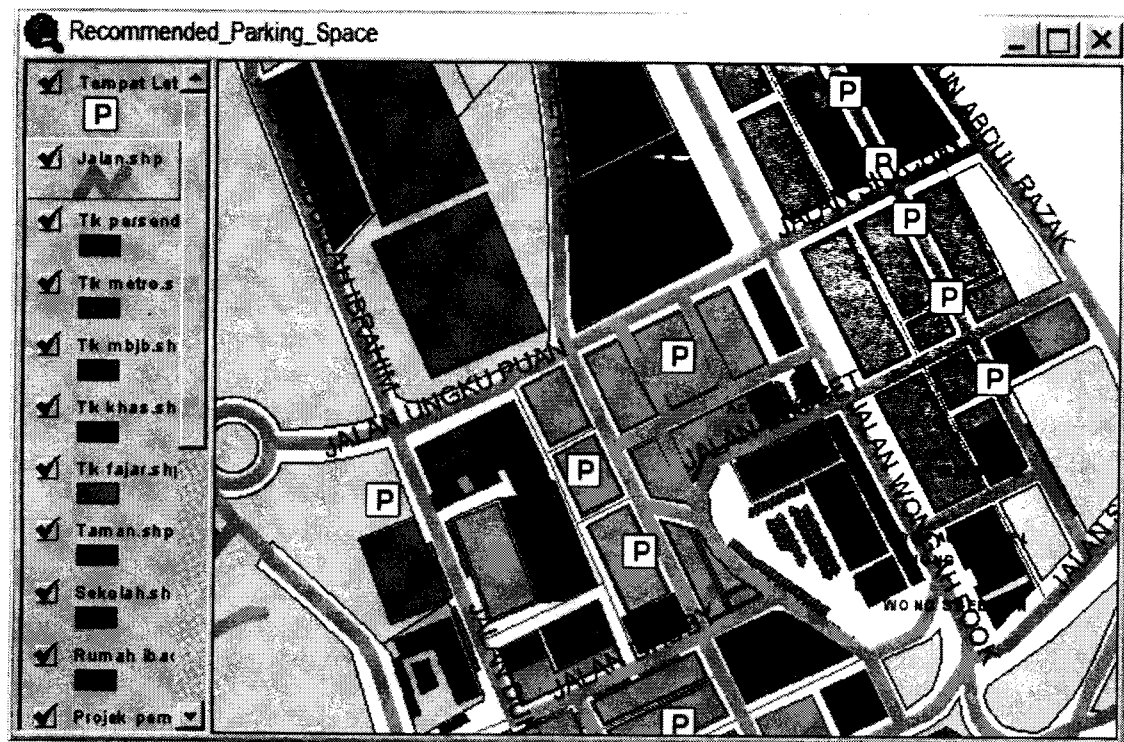
space. Therefore, it is important to identify areas which need additional parking space to alleviate the problem of parking space deficit.

### 4.3 Identifying Additional Parking Areas

Since land use competition is a main phenomenon of urban land and facilities management and planning, solving for parking space problem in the city centre is a difficult task. This is so especially because parking use has to compete with other highest-and-best use options such as trade and commercial (Koh, 1995). For example, office or shopping complex investment may be better alternatives to parking space business and, thus, are more economically enticing to investors and developers.

Notwithstanding this, plans can be drawn up to identify areas that can be used for providing additional parking space, especially on vacant sites belonged to the government and corporate bodies. Such areas must satisfy a number of criteria. Firstly, they must be areas with high parking deficit. Secondly, there must be sufficient amount of land area at the proposed sites. Thirdly, provision of new parking space must not cause unnecessary disruption to the current traffic flow. Further criteria which cover physical, design, economic, and other aspects must also be considered for each site. Therefore, further studies on all of these aspects should be welcome.

In this study, only the first and second aspects are considered. The purpose is merely to use GIS to show areas that can be identified as new parking sites. Further analysis has found that street parking, particularly in areas close to individual shop houses is much needed in the city centre. For example, Jalan Meldrum and Jalan Ibrahim need an additional on-street parking area. Figure 11 shows some examples of sites that need additional out-building parking space.



**Figure 12 :** Examples of Zones Needing an Additional Out-Building Parking Space

## 5. Conclusion and Closing Remarks

This study has demonstrated the use of a GIS and SpaTT model in the supply and demand analysis of parking space in the Johor Bahru city centre. The main advantage of this approach is its ability to combine spatial elements and their associated attributes for an integrated, visual spatial analysis of parking space equilibrium (PSE).

Overall, the study has achieved its objectives. Generally, there is still sufficient shared-parking space based on the concepts of turn-time parking and spatial mobility of parking choice in the city centre. However, certain busy commercial and service zones of the city centre need additional parking space, especially out-building parking, to increase supply of parking space. Though, this study does not suggest whether out-building parking is 'better' than in-building parking. However, based on random interviews with customers, there is reason to believe that on-street and open-space parking lots are preferred to in-building parking among the city dwellers and visitors.

This study has not explored into the reasons for parking deficit in some areas of the Johor Bahru city centre. Nevertheless, initial observations indicate that factors such as public attitude (preference for out-building parking), ingress and egress disadvantages of some existing in-building parking, lack of parking space in some busy spots, and perceived 'high' parking charges are among the factors responsible for parking problems in the city centre.

This study has not considered several other important aspects affecting the supply and demand of parking space in the study area. Peak-hours and peak-seasons parking shortage, long term changes in the size of crowd flocking into the city centre, future locational preference for shopping destinations, and future parking space planning are examples of factors that have not been included in the SpaTT model. As an example, the area around the Tabung Haji building may become congested in future as more office space in that building is taken up. Urban peripheral commercial development may change the trend in demand for parking space in the city centre. More multi-levelled in-building specialised parking space may be provided in future, especially in zones with parking space deficit.

Finally, more advanced GIS-based multi-model analyses of supply and demand of parking space are recommended, particularly to address specific issues of urban parking planning and management. The SpaTT model is introduced in this study only as a starting point for a more comprehensive approach to modelling parking space supply and demand in future.

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