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THE DEVELOPMENT OF MODEL ESTIMATION TO DETERMINE PARKING NEEDS AT LRT STATIONS IN SUBURBAN AREA

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Abstract: This study determines the most suitable independent variable for estimating the parking demand or parking supply model for suburban Light Railway Transit (LRT) station. This formula can be used to establish the number of parking bay to be provided to accommodate the parking needs at suburban LRT station. Linear regression method was use to develop the model. The analysis revealed that the most suitable independent variable for determining the parking demand formula is the daily average passengers. The regression equation established for this study found to have a high degree of coefficient of variation, $R^2 = 0.965$ for this independent variable. This shows that the equation established in this study have a high goodness of fit and can be used with a high level of confidence.

Keywords: parking supply, light railway transit (LRT), linear regression

1. INTRODUCTION

The saturation of private vehicles as a means of transport in urban areas has led to severe congestion and pollution. Valuable time and resources are wasted by urbanities in trying to cope with this stressful situation. A shift from private vehicles to public transport is seems to be one of the major solutions to this problem. Several measures had been recommended by local authorities to promote the use of public transport, such as the introduction of bus lane system to improve the existing bus services, construction of the commuter train and light railway transit (LRT) to cater the need of residents from suburban area to urban area.

The Light Rail Transit (LRT) system plays an important role in transporting residence from suburban area to urban area. LRT has a number of advantages over the traditional road based transport system. Although, the bus is well-suited transport system, it requires the used of road as major infrastructures. LRT in the other hand can provide higher carrying capacity, more energy savings, less pollution, better safety and more comfortable transport system. LRT operates on street, segregated at grade, elevated or in tunnels. The LRT has excellent performance that its capacities are between 20,000 and 30,000 passengers per hour per direction.

Kuala Lumpur first started to operate the light rail transit (LRT) in 1996. Since 1998, there are 2 LRT systems that operate in Kuala Lumpur, which are the STAR LRT and PUTRA LRT. As one of the policy to encourage residence from suburban area to use LRT to urban area, the park and ride concept has been promoted. The park and ride concept involves commuters driving to the public transport terminals, parked their vehicles and continue their journey to their destination by public transport. Even though park and ride policy is encouraging residents to use the public transport but the supply of parking space is seems to be one of the major issue to the public transport authority.

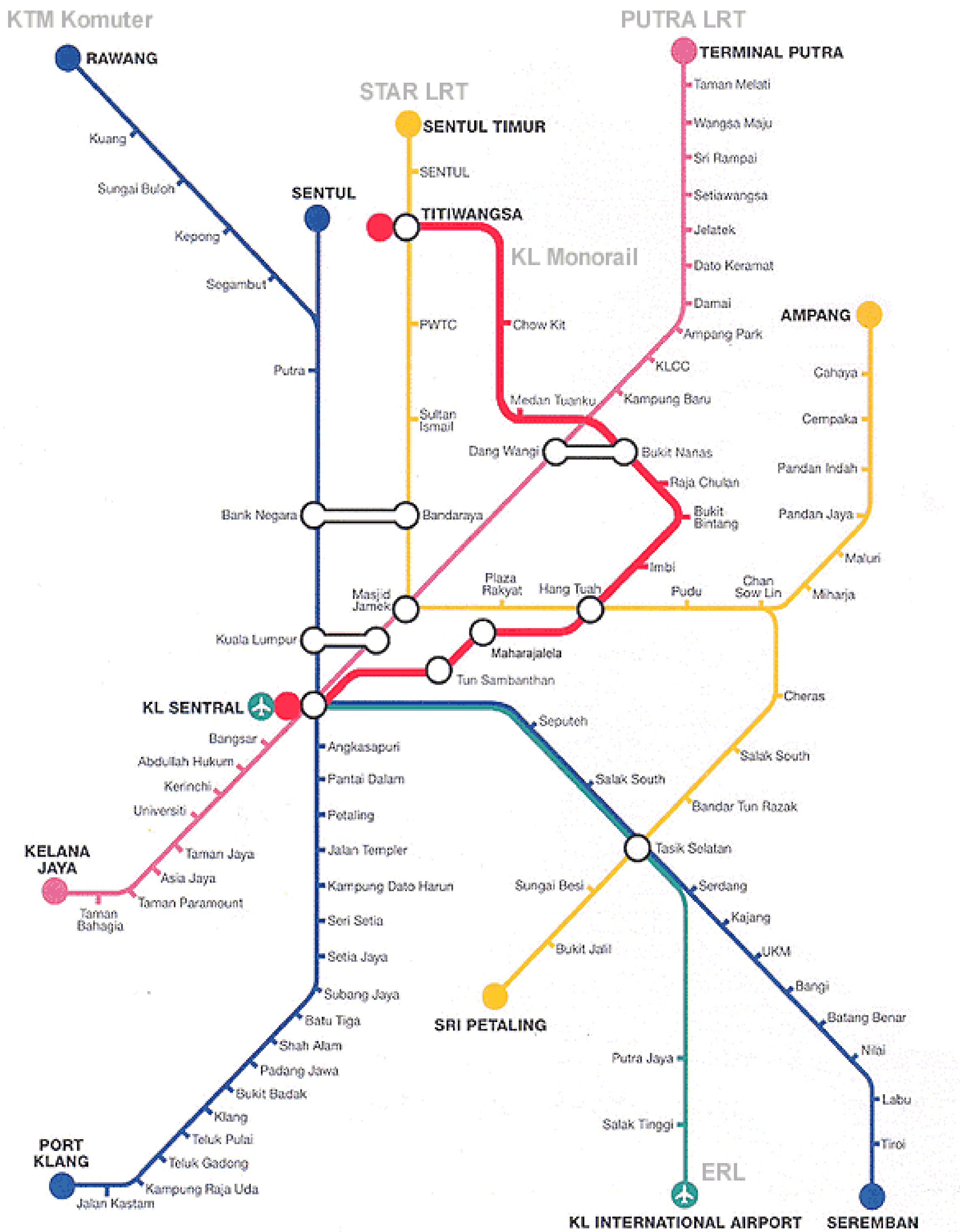

Figure 1: Integrated Urban Transportation System in Kuala Lumpur
(Resources: http://www.kiat.net/malaysia/KL/transit.html)

Figure 2(a): The STAR LRT in Kuala Lumpur

Figure 2(b): The PUTRA LRT in Kuala Lumpur

It has been found that most of the LRT stations in Kuala Lumpur area provides inadequate parking space, either too many parking spaces provided or lack of parking spaces. This has lead to illegal parking problem (due to lack of parking space) and wasting of land and resources (due to too many parking spaces provided) and the failure of the park and ride concept.

On conducting a detailed check at the local authority and the LRT service provider, it was found that there is no specific parking demand model that has been developed for estimating the number of parking space to be provided at LRT stations. Most of the parking spaces allocated at each station are based on free land available at each station. Hence, It is necessary to obtain a balance of parking supply and demand at LRT station. Therefore, it is important to develop a parking demand model so that the parking provision can be estimates to prohibit wasting of resources and optimize the maintenance of facilities.

1.1 Parking Supply And Parking Demand

Parking supply is the number of parking provided. Small city can provide predominantly off-street parking meanwhile large city and central business district can provide predominant parking lot or parking garage. Parking demand is depend on trip generation, trip purpose and land use. (John, 1992) Parking demands are not generated by the building space itself but it is generate by the number of residents in the area and its mode of transportation. Thus, there may be instances where an LRT station, because of its location (either at urban area, suburban area, or rural area and etc.), would have higher or lower parking requirements than indicated by the recommended standard, where such conditions are not likely to change with time, modification of the standard is in order. In such circumstances a specialized study needs to be undertaken to establish these parking requirements.

1.2 Parking Studies

Parking studies includes financial feasibility functional design, structural design, and demand studies. There are three major types of parking demand studies, which are comprehensive study, limited study and site-specific study. (John, 1992) Comprehensive study covers an entire area, such as central business district. Meanwhile, limited study are similar to comprehensive study but with reduced geographical coverage and fewer requirements. Site-specific study are geographically narrow but analytical extensive.

In comprehensive study, the future parking demand is estimated with the use of forecasting model, which include population growth, demographic, social and economics trends, as well as trends of local economy use of transportation modes. Analytic and comprehensive inventories of parking facilities are gathered along with detailed information on utilization patterns. From these, current deficiencies of the parking supply are identified.

Limited study is done with only one type of parking is investigated and the estimation of future demand may not be required. Site-specific study is mainly focus on site which includes existing, planned, or expanding hospitals, campuses, shopping malls, terminals, residential, office and industrial developments. Detailed inventories of existing supply and utilization are taken and future demands are forecast. In addition, attention is paid with regards to the various types of users of parking supply.

1.3 Objectives

The main objective of this study is to determine the most suitable independent variable that can be used to estimates parking needs at suburban LRT station for better planning on supplying parking spaces.

2. METHODOLOGY

The estimation of parking space required at LRT stations involves site selection, site surveys and data collection and finally data analysis. The process of data collection is subject not only to survey operations but is also subject to sample size considerations. In addition, the method of analysis primarily involves statistical analysis in the estimation of LRT stations.

2.1 Study Methodology

For developing the parking supply model, simple linear regression will be consider.

2.2 Site Selection

The selection of site was influenced by predetermined criteria such as below.

- The study location must be at suburban area because only suburban area is provided with parking facilities at the LRT stations.
- The LRT stations must have a provision of adequate parking space, which cater the

parking demand.
- The parking area is not linked to other land use categories.

Four PUTRA LRT stations and eight STAR LRT stations were selected as study sites. The PUTRA LRT stations selected was Terminal Putra, Setiawangsa, Jelatek, and Kelana Jaya. Meanwhile, the STAR LRT stations selected was Ampang, Cahaya, Cempaka, Pandan Indah, Pandan Jaya, Cheras, Bandar Tun Razak, and Tasik Selatan.

Table 1: Study Locations and Its Parking Information

No.	Stations Name	Total Legal Parking Space Allocated	Feeder Bus Service	Parking Charges
1	Terminal Putra	330	Yes	Yes
2	Setiawangsa	167	Yes	Yes
3	Jelatek	301	Yes	Yes
4	Kelana Jaya	482	Yes	Yes
5	Ampang	224	Yes	No
6	Cahaya	78	No	No
7	Cempaka	370	Yes	No
8	Pandan Indah	177	No	No
9	Pandan Jaya	226	Yes	No
10	Cheras	87	Yes	No
11	Bandar Tun Razak	25	No	No
12	Tasik Selatan	243	No	No

2.3 Site Survey and Data Collection

Two types of data collections were carried out at the LRT stations, which included,

(a) Passengers survey
In passenger survey, the number of passengers arrives in each half an hour is observed and the total number of passengers per day is taken. From this data, the peak hour based on passenger's arrival is observed. The average number of arrivals per hour could also be obtained. Data obtained from this survey include,

- Number of passengers arrive per hour
- Total number of passengers per day
- Mean, mode and median of passengers
- Average daily passenger

(b) Parking survey
In parking survey, the vehicle plate registration process is carry out in each hour to observe the parking time (duration of parking) of vehicles and highest parking demand could be obtained based on the total occupancy of parking space. Data obtained from this survey include,

- Number of car occupancy per hour
- Highest parking demand
- Total car entry per day
- Average daily car entry per day

- Mean, mode and median of parking time (Hour)
- Total parking lot at site

2.4 Modeling of Parking Demands

Simple linear regression was used to develop the parking survey model.

The initials parking supply model is believe to have relationship to the total number of residents population in the catchments area, the vehicle ownership of the residents in the catchments area, the average household income and the average travel distance from each resident to the LRT station.

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_4 \quad \text{---(1)}$$

where y = Parking supply
β = Coefficients of variations
x = Independent variable
x_1 = Total population in catchments area (within 5 km radius from LRT station)
x_2 = Average vehicle ownership per household in catchments area
x_3 = Average household income in catchments area
x_4 = Average travel distance from each resident to LRT station

Due to lack of resources and time constraints to obtain these data, the parking supply model has been regenerate,

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 \quad \text{---(2)}$$

where y = Parking supply
β = Coefficients of variations
x = Independent variable
x_1 = Daily average passenger
x_2 = Parking time
x_3 = Parking charges
x_4 = Feeder bus service

The parking supply is predicted has a positive linear relationship with daily average passenger and a negative linear relationship with parking charges and feeder bus service. The parking demand will increase if total number of passenger increase. Meanwhile, the parking time will affect the parking supply. If the duration of parking is usually long term, more parking spaces should be supply. If the duration parking is usually short term, may be less parking space should be provided in terms of economy.

Once parking is supply for free, it will encourage more commuters to park and ride but if parking charges is apply, it is for sure that this will discourage the commuters to park and ride. The feeder bus service is important in order to control the parking demand at LRT station. In this case, commuters are encouraged to use the feeder bus service to get to the LRT station and ride the LRT.

The new parking demand model is seems to be more realistic compare to the old parking demand model when considering on all types of data and the methods of data collection before modeling could be carry out.

3. RESULTS AND DISCUSSIONS

Twelve light railway transit station were selected for data collection, they are,

- Station Terminal Putra
- Station Setiawangsa
- Station Jelatek
- Station Kelana Jaya
- Station Ampang
- Station Cahaya
- Station Cempaka
- Station Pandan Indah
- Station Pandan Jaya
- Station Cheras
- Station Bandar Tun Razak
- Station Tasik Selatan

These sites were selected because the parking space provided at the LRT station has no sharing with adjacent building or land use. In the research, the parking demand survey was carried out. Parking survey was carried out to obtained highest parking demand (hourly), and means parking time. These studies were carried out every one hour from 6 a.m. to 12.00 a.m. during weekdays to record the registration plate of vehicle at the parking lots. No weekend study is being carried out because the weekend trips are usually non-regular trips.

Table 2: Summary of Data Collection at Twelve LRT Station

Station	No. of Parking Lot	Total Car Entry Per Day	Highest Parking Demand	Parking Times (Hour)			Passenger				Feeder Bus Service	Parking Charges
				Mod	Mean	Median	Total	Mod	Mean	Median		
Terminal Putra	330	528	372	11	8.5	10	5078	67	141	80	Yes	Yes
Setiawangsa	167	435	243	1	6.1	5	3087	42	86	71	Yes	Yes
Jelatek	301	192	130	11	7.3	9	4792	85	137	101	Yes	Yes
Kelana Jaya	482	1151	450	2	7.6	8	9454	268	263	168	Yes	Yes
Ampang	224	436	300	11	8.0	10	4096	83	114	83	Yes	No
Cahaya	78	52	35	10	6.8	7	1993	30	59	38	No	No
Cempaka	370	366	224	1	7.2	9	5497	107	167	103	Yes	No
Pandan Indah	177	131	66	1	5.7	4	2033	32	58	38	No	No
Pandan Jaya	226	248	147	1	6.5	6	4975	121	142	121	Yes	No
Cheras	87	143	82	1	6.1	8	2307	64	68	54	Yes	No
Bandar Tun Razak	25	157	45	1	4.2	3	4418	103	130	103	No	No
Tasik Selatan	243	363	207	1	6.7	6	6069	166	173	163	No	No

The following figures show the comparison of the data collected for twelve stations.

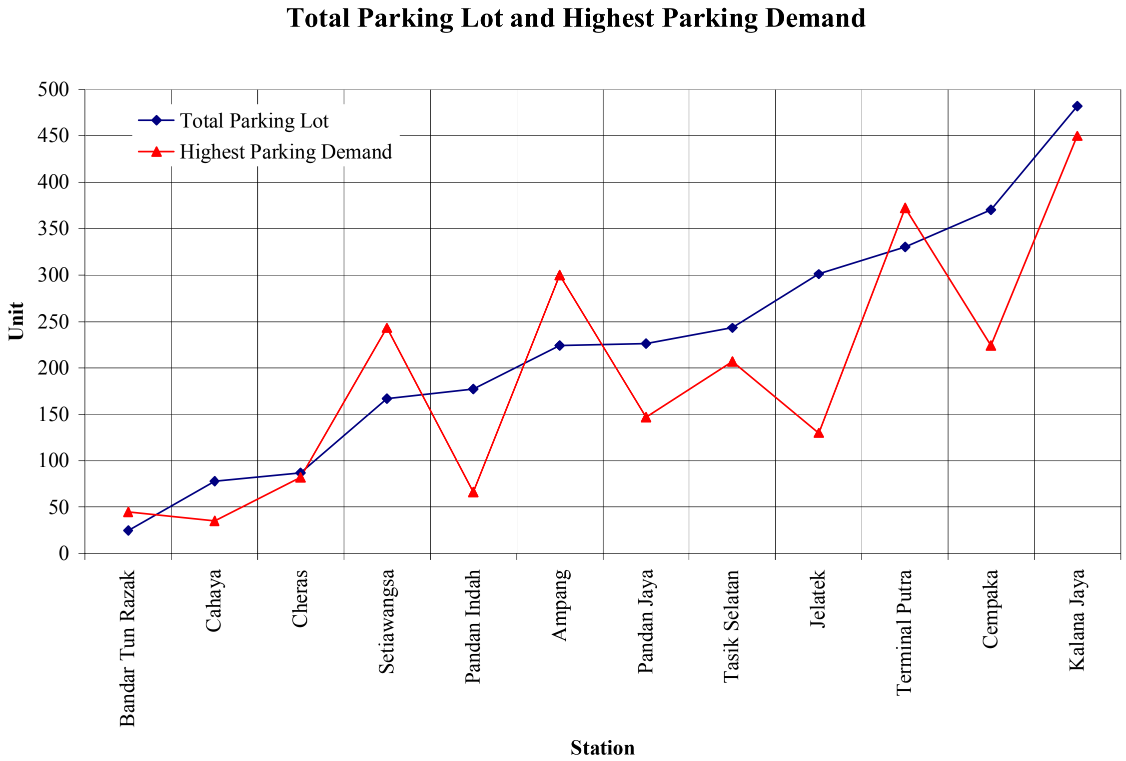

Figure 3: Total Parking Lot and Highest Parking Demand

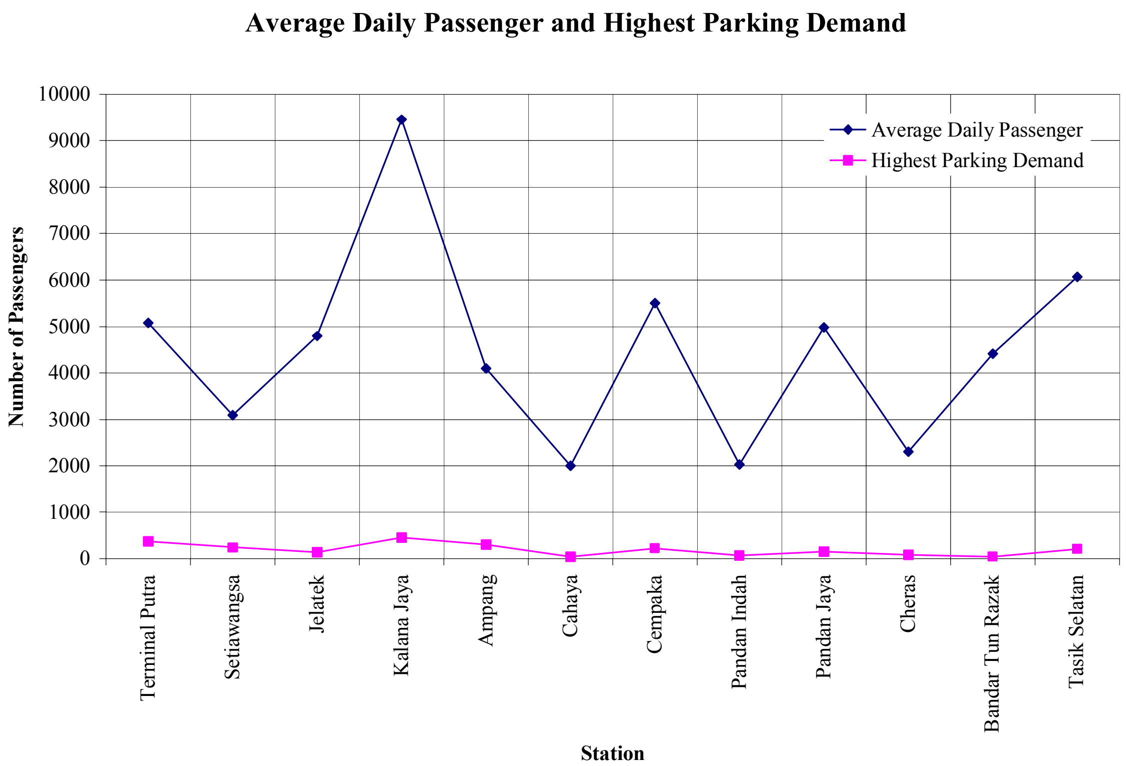

Figure 4: Average Daily Passenger and Highest Parking Demand

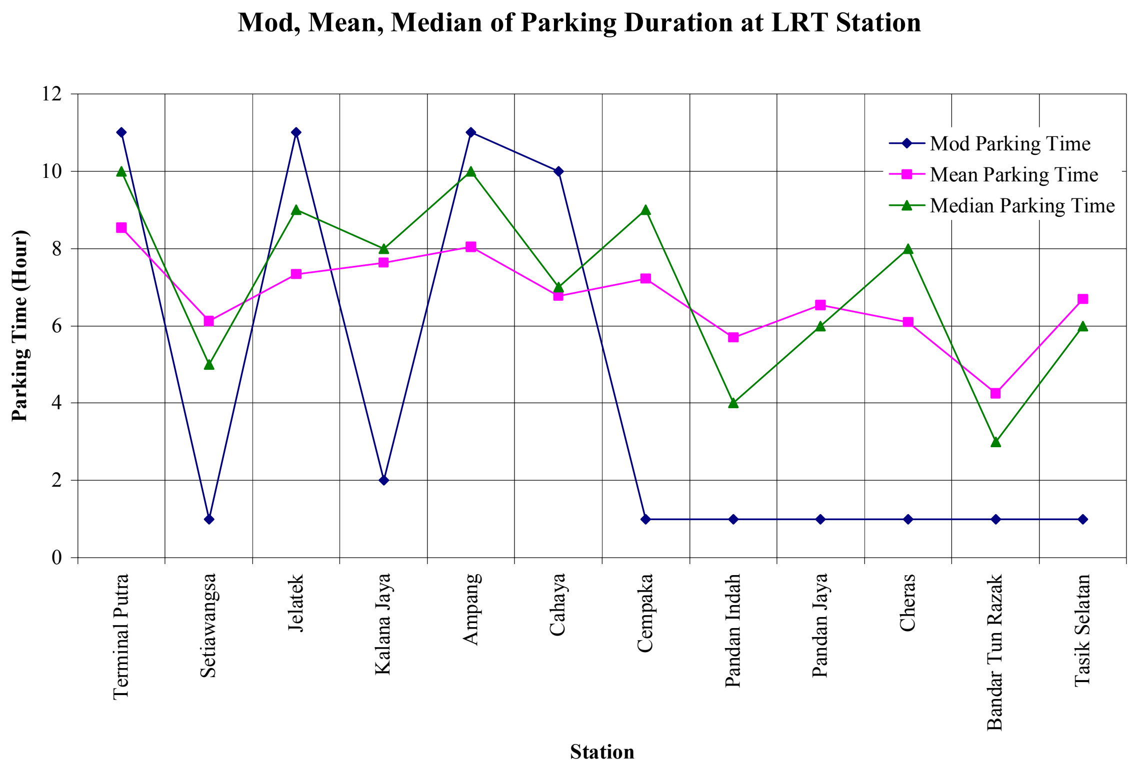

Figure 5: Mod, Mean, and Median of Parking Duration at LRT Station

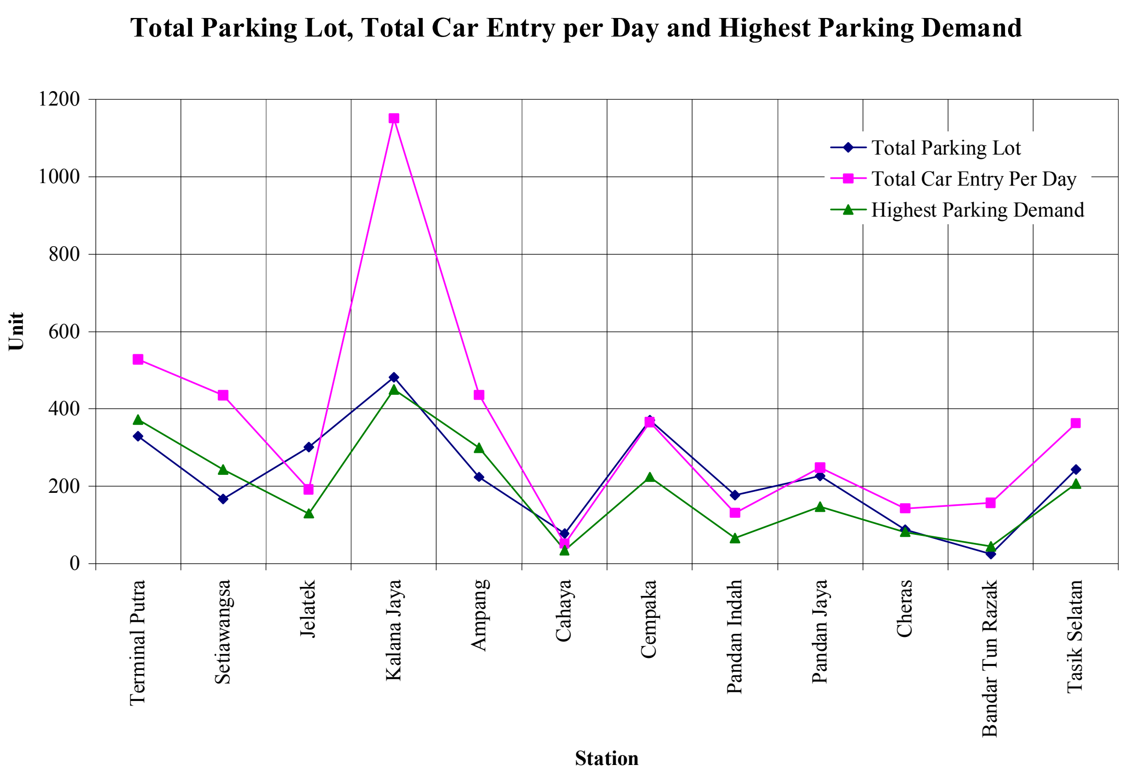

Figure 6: Total Parking Lot, Total Car Entry per Day and Highest Parking Demand

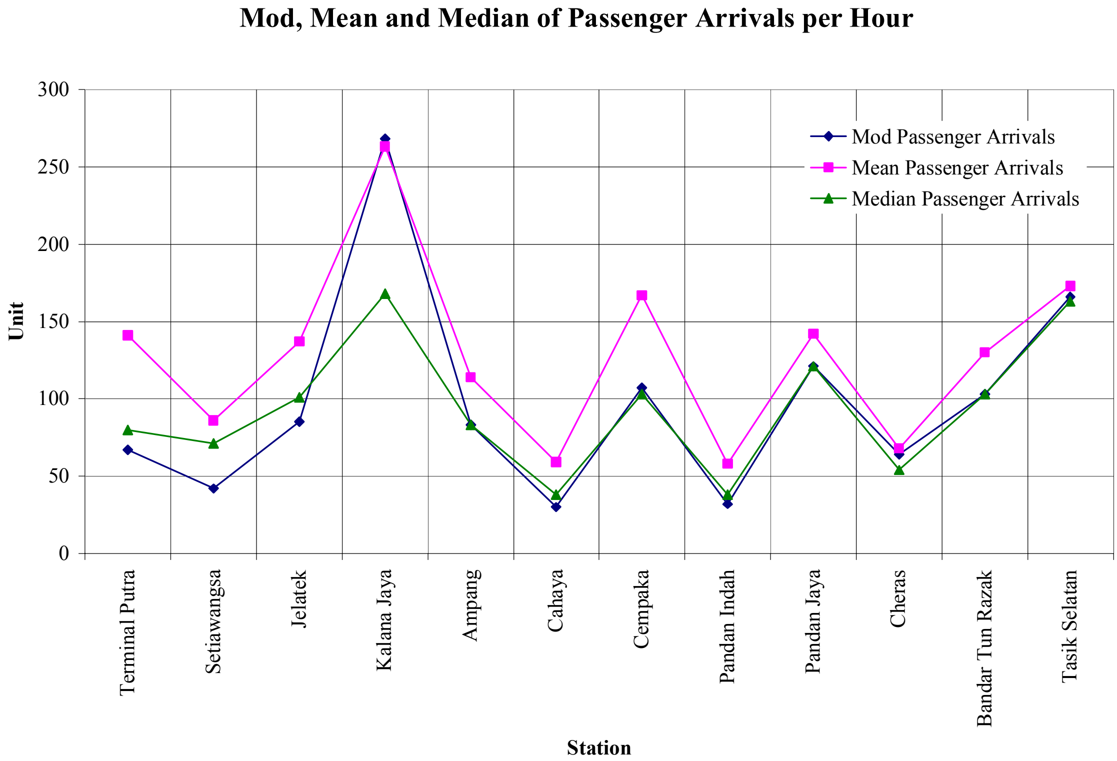

Figure 7: Mod, Mean and Median of Passenger Arrivals per Hour

3.1 Parking Demand Modeling

The following data shows the summary of data collection at twelve LRT station for parking demand modeling.

Table 3: Summary of Data Collection at PUTRA and STAR LRT Station for Modeling

Station	Highest Parking Demand (y)	Daily Average Passenger (x_1)	Mean Parking Time (x_2)	Parking Charges (x_3)	Feeder Bus Service (x_4)
Terminal Putra	372	5078	8.5	1	1
Setiawangsa	243	3087	6.1	1	1
Jelatek	130	4792	7.3	1	1
Kelana Jaya	450	9454	7.6	1	1
Ampang	300	4096	8.0	0	1
Cahaya	35	1993	6.8	0	0
Cempaka	224	5497	7.2	0	1
Pandan Indah	66	2033	5.7	0	0
Pandan Jaya	147	4975	6.5	0	1
Cheras	82	2307	6.1	0	1
Bandar Tun Razak	45	4418	4.2	0	0
Tasik Selatan	207	6069	6.7	0	0

Notes:
* Mean parking time in table is in hour.
* Parking charges, 1 for parking charges apply, 0 for no parking charges apply.
* Feeder bus service, 1 for feeder bus service provided, 0 for no feeder bus service.

It is predicted that parking demand will decrease if feeder bus service is provided and parking charges is apply at the LRT station. Meanwhile, the parking time will also affect the number of parking space to be provided. If high demand is needed for short parking time, i.e., just parked for one hour, it is not economical to provide more parking spaces.

Before the analysis is carried out, it is important to find out whether the independent variables selected for the parking demand modeling have high degree of association with the car parking demand at each site. The table below tabulates the correlation matrix between the chosen independent variables.

Table 4: Correlation Analysis for Twelve LRT Station

	y	x_1	x_2	x_3	x_4
y	1				
x_1	0.73309672	1			
x_2	0.71643136	0.38633829	1		
x_3	0.59416905	0.39585915	0.42012058	1	
x_4	0.57473361	0.30233102	0.56554694	0.5	1

Since the correlation between the independent variable is not significance, some data should be add or remove. In this case, data for four stations has been remove, which are, Terminal Putra, Setiawangsa, Jelatek, Ampang, and Bandar Tun Razak.

Table 5: Correlation Analysis for Seven LRT Station

	y	x_1	x_2	x_3	x_4
y	1				
x_1	0.97535212	1			
x_2	0.78804460	0.79894802	1		
x_3	0.86392966	0.77599044	0.64968687	1	
x_4	0.46533538	0.42663068	0.37587108	0.35355339	1

After removal of five sets of data, the correlation between the independent variables seems to be more significant, therefore, parking demand modeling is carry out with SPSS.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4$$

The following table shows the summary of curve estimation for the independent variable (x) with dependent variable (y).

Table 6: Summary of Curve Estimation

Dependent	Independent	Model	R Squared
y	x_1	Linear with constant	0.951
	x_2		0.621
	x_3		0.746
	x_4		0.217
	x_1	Linear without constant	0.965
	x_2		0.700
	x_3		0.615
	x_4		0.619

Using SPSS, parking modeling with simple linear regression analysis is done using both models with two methods, which is the "Enter" and "Stepwise" method. The following shows the summary of the models.

Table 7(a): Linear Regression With Constant Using Enter Method

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-23.0559	204.5262		-0.11273	0.920541
	x_1	0.038499	0.009844	0.74825	3.910704	0.059601
	x_2	-0.59766	34.62439	-0.00271	-0.01726	0.987795
	x_3	99.62348	55.82344	0.266326	1.784617	0.216252
	x_4	14.00952	27.50095	0.052965	0.509419	0.661102

a Dependent Variable: y
R square = 0.982

Table 7(b): Linear Regression Without Constant Enter Method

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	x_1	0.039033	0.007066	0.94869	5.524107	0.011686
	x_2	-4.45096	4.517987	-0.13712	-0.98516	0.397183
	x_3	100.6997	45.05057	0.175445	2.235259	0.111451
	x_4	14.10805	22.51428	0.04916	0.626627	0.575346

a Dependent Variable: y
b Linear Regression through the Origin
R square = 0.994

Table 8(a): Linear Regression With Constant Using Stepwise Method

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-58.7605	26.77029		-2.19499	0.079595
	x_1	0.050183	0.005077	0.975352	9.884038	0.000181

a Dependent Variable: Y
R square = 0.951

Table 8(b): Linear Regression Without Constant Using Stepwise Method

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	x_1	0.040422	0.003134	0.982443	12.89905	1.34E-05
2	x_1	0.034326	0.002369	0.834282	14.49102	2.82E-05
	x_3	125.4825	33.04468	0.218623	3.797359	0.012663

a Dependent Variable: y
b Linear Regression through the Origin
R square = 0.965 (Model 1)
R square = 0.991 (Model 2)

3.2 Discussions

If 95% confidence interval is taken, it is seems that the Enter method did not give good results on the parking supply model. This can be seen when comparing the last column of table 7(a) and 7(b). The significance value is very much higher than 0.05, therefore, both model estimates from Enter method has been rejected. Comparing both the Enter and Stepwise method, the stepwise method is more accurate. The linear regression estimates for the parking demand are,

Linear regression with constant (Stepwise Method),

$y = -58.7605 + 0.050183x_1$ --(3)

Since the t-value for the constant is not significant (i.e. more than 0.05), therefore, this model is rejected.

Linear regression without constant (Stepwise Method),
Model 1:
$y = 0.040422\, x_1$ ---(4)

Model 2:
$y = 0.034326x_1 + 125.4825\, x_3$ ---(5)

When parking charges is apply, $x_3 = 1$, else, $x_3 = 0$

Both t-value for model 1 and model 2 is significant, therefore, both models can be accepted. Model 1 is seems to be more friendly than model 2 as once the parking charges is apply at LRT station, the minimum parking supply should be 125 parking lots which is not so economical.

4 CONCLUSION AND RECOMMENDATION

The main objective of this project is to determine the most suitable independent variable for estimating the parking demand formula for suburban LRT station is obtained. The parking study involved existing site surveys, which provided the actual on site demand apart from highlighting the highest existing parking volumes on selected LRT stations.

In this research, the daily average passengers have high degree of association with parking supply.

$$y = 0.04x_1$$

or

$$y = 0.034x_1 + 125x_3$$

where y = Parking supply/demand
x_1 = Average daily passenger
x_3 = Parking charges, 0 for no parking charges and 1 if parking charges apply

The first model is much prefer, as it is well to define the parking needs at suburban LRT station. The second model could also be used but it is not so economical compare to the first model. If a new LRT station will be located at suburban area and parking facilities will be provided, the above formula could be one of the guides to estimate number of parking space to be provided. The number of daily passenger is affected by number of population or density in 5 km distance around the LRT station.

The main recommendation for future study is a more comprehensive data collection should be carried out to develop a better model. This comprehensive data collection may include house-to-house survey to obtain the population in catchments area, vehicle ownership per household and total household income. With this data, hopefully a more comprehensive parking supply model can be develop to estimate parking needs at suburban LRT station for residents in suburban area.

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