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DEMAND ANALYSIS OF PARKING AT MACHAP NORTHBOUND REST AND SERVICE AREA

Muhammad Syimir Abd Wahab, Izzul Ramli, Sitti Asmah Hassan*, Mohd Rosli Hainin, Anil Minhans

Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

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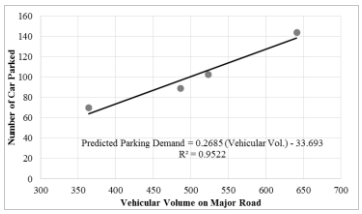
*Corresponding author
sasmah@utm.my

Graphical abstract



Abstract

Transportation planners need background information of parking generation in order to propose new developments and to predict changes in the parking generation. Most common factors on which the parking generation depends are gross floor area, number of staff employed at a facility, number of beds, etc. Unfortunately, in western as well as Asian countries including Malaysia, there is very little information on the parking generation for roadside rest areas. The parking generation of expressway rest area in Malaysia is believed to vary with time of the day, day of the week and depends on at least one or a few significant parameters. One of the factors influencing the parking demand is the prevailing vehicular volume on the major road, (North-South expressway). Therefore, this study was conducted to determine the effect of vehicular volume on major road on parking demand at Rest Area. The trend of parking demand was conducted at Machap Northbound Rest Area located at North-South Expressway for 4 different days to allow significant variations of traffic volumes. The guidelines of the parking generation by ITE were followed while collecting the parking demand data. The main parameter used in this study was the vehicular volume on the major road, North-South (expressway). The study was conducted on different days to allow significant variation of traffic volumes. It was found that the traffic volume on the major road can be used as a predictor to the parking demand at rest areas. The linear regression between vehicle volume on major road and parking demand showed significant relationship with R^2=0.9522. The finding obtained in this study was based on a constrained duration of study at one site, Machap Northbound Rest Area. Further investigation will be conducted at a few locations of rest areas for a better insight on the effect of the parameter to the parking demand.

Keywords: Vehicular volume, parking demand, rest area

1.0 INTRODUCTION

In these recent years, there is a rapid increase in the number of vehicles on road in Malaysia owing to high car ownership. If the same trend continues, the increase in number of vehicles on road will lead to congestion in the next few years. Besides that, as the vehicles on the road increases, the amount of parking demand also increases proportionately. Thus, the transportation planners and traffic engineers need to estimate the traffic volume attracted to or produced by these specific land uses.

The Institute of Transportation Engineers (ITE) is an international body representing the transport professionals from all over the world, has published Trip Generation Manual 2012 and Parking Generation 4th Edition 2010. The trip generation manual can provide useful information to transportation engineers and planners on estimating the trip produced by the specific land uses prevalent in the country. The 'Trip Generation Manual 2010' based on land use in Malaysia has been published by the Highway Planning Unit (HPU) of the Ministry of Works. Similarly, parking generation is used to estimate the parking demand produced by specific land uses types. Parking

generation represents the parking spaces required to accommodate the number of vehicle produced by the trips attracted to the area. Based on transportation engineering and planning practice, the required number of parking spaces for a facility depends on the parking generation rate which is from the trip rate estimation. Estimation of parking generation rate for a propose land used is essential in order to provide adequate parking space in the vicinity.

Current practices in Malaysia, parking requirements for any development in Malaysia are based on the non-statistical guidelines provided by the Malaysian Town Planning Department (JPBD) which are based on six different types of land uses—namely Residential, Commercial, Industrial, Recreational, Institutional and Disabled people facilities. It has been observed that this practise is often failed to estimate accurately parking requirements in almost all land-use type in Malaysia.

The ITE's Parking Generation though includes different 108 types of land uses but does not cover the land use type "Rest Areas" located by the Expressways. Rest and Service Area (RSA) or in Malaysian term '*Rehat & Rawat'* popularly known as Rest and Relax (R&R) is an important facility on highways and expressways that provide safety and comfort to the road users. This indicates a huge scarcity of information not only in Malaysia but worldwide in general.

The Parking Generation of expressway rest area in Malaysia is believed to vary with time of the day, day of the week and depends on at least one or a few significant parameters. One of the characteristics influencing the parking demand is vehicular volume on major road (expressway). Vehicular volume on the major road (expressway) changes with different days and seasons. It has been observed that expressway rest areas in Malaysia at many times exceed the capacity of the parking spaces provided. Therefore, there is an extreme need that the local parking data in Malaysia are collected to estimate the parking demand characteristics for expressway rest areas. Keeping this aspect into consideration, this study was conducted to determine the effect of vehicular volume on major road on parking demand at Rest Area. The study was conducted at Machap Northbound Rest area at North-South expressway. To achieve the aim, the parking demand at the rest area was measured at different days to allow significant variation of traffic volumes (weekdays, weekend, and festive season) and then the relationship between parking demand at rest area and vehicular volume on major road was established.

This paper is structured in the manner that the problem statement and aim are presented in the Introduction followed by the background literature related to the study. Furthermore the methodology adopted in this study is described. The results and findings of this study are also described in later sections. The final section provides a summary and extends a few recommendations as per study outcomes. In this endeavour, this study provides some general guidelines for local authorities and developers in estimation of the parking space requirements of the rest area.

2.0 LITERATURE REVIEW

Previous study had developed a method to analytically derive parking and trip generation rates, and the method was found to be more accurate in calculating peak parking accumulations than parking occupancy counts in large parking lots [1]. A comprehensive study in Abu Dhabi, UAE addressed a re-look at the minimum parking standards for various uses in Abu Dhabi city and also introduces recommendations for maximum parking requirements [2]. It was found in the study that reduction in parking requirement can be applied under certain circumstances where shared parking and the existence of nearby complementary destination within walking distance. A survey of vehicle traffic attracted by shopping centres in the city of Rio de Janeiro, Brazil was conducted and it was found that the only point in common between ITE daily trip data and daily trips Brazil survey was the statistical correlation between the shopping centres' gross leasable area and the volume of vehicles attracted by them [3].

Ahmed, *et al*. [4] has determined trip generation rates at fast-food restaurants in ten locations in Johor Bahru town of Malaysia. Trip rates were found to be related to number of offered parking spaces and the gross floor area at the facility. However, the trip rates did not depend on the Number of Seats in the restaurants. The trip rates found in this study were lower than the ITE Trip Generation and higher than the Malaysia Trip Generation Manuals. A similar study was conducted on a comparison of deterministic and stochastic approaches for the estimation of trips rates from hypermarkets in Johor Bahru debates the adoption of currently available trip rates for nationwide application in Malaysia [5,6]. In many cases, the trip rates at the hypermarkets were underestimated which, if adopted, may result in the congestion of the neighboring network. Another study was conducted at Polyclinics in Johor Bahru, Malaysia found that the Number of Doctors is the most significant determinant factor of trips to Polyclinics in Johor Bahru, Malaysia and Gross Floor Area is not the best prediction parameters to estimate trip generated by the facilities [7]. It is logical since patients look for the quality of services provided by the polyclinics rather than the size of the building.

A relationship of multifamily residential parking demand and transit level of service in two urban centres in Washington State, USA was examined and it was found that parking demand is lower than the amount supplied in both urban centres, suggesting that parking is overbuilt [8]. It was found in this study that greater levels of transit service will yield a lower parking demand for multifamily residential developments in the urban centres. Based on assessment of alternative approaches to setting parking requirements, there were four types of parking requirement which were generic, area-based, flexible and form-based [9]. Generic parking requirements offer the least accuracy and correlation with long term policy objectives but are the easiest to implement. It contradicts to form-based requirements in which it has the potential to perform

well in terms of alignment with long term planning objectives, predictability, and ease of enforcement but requires a significant rewrite of existing zoning regulation and a corresponding institutional reorganization. Area-based requirements are well suited to policy-driven forward looking requirements in special planning districts, while flexible requirements generally do a better of job of reflecting the actual parking demand based on existing conditions at and around the site. A study on parking and vehicle trip generation for soccer fields and elementary schools was conducted and it was found that the presence of sport fields affects the number of trip generation on the elementary schools [10]. Most of soccer fields are located near elementary school sites and the parking demand of the sports events (and other after school-hours events) may impose higher provision of parking. The soccer field can be categorised into three purposes which are for practice, game or tournament and regional qualifying tournaments with non-local teams and each of these purposes have different parking demand.

Parking demand at rest area in Vermont was observed and the study has estimated that the highest levels of rest area usage occurred on weekend's holiday during summer and fall, particularly on Friday afternoons/evenings and Saturday mornings [11]. Assumptions can be made that travellers are more often travelling on weekends, which affect the parking demand at the facilities.

Another study in Jordan assessed vehicle parking demand for different land uses which are hospitals, office buildings, hotels, apartment buildings, restaurants and shopping centres [12]. The peak parking demands were investigated and the developed models have an exponential form, except for restaurants and shopping centres, which have a linear form. Compared with the standard values for developed countries, the parking demands for the investigated land uses in Jordan have lower rates. In another study by Van and Kinton [13], it was recommended that the required parking space for day-care facilities should be based on the number of students or size of the facility.

3.0 METHODOLOGY

The methodology adopted in this study can be described in Figure 1.

As shown in Figure 1, at first the survey on the suitable site was conducted. There are 24 Rest and Service Area (RSA) facilities along the North-South Expressway (E2) for both southbound and northbound administered under PLUS. This study was conducted at Machap Northbound Rest Area which is the first rest area from Skudai Toll Plaza, located at 74.6 kilometre from southbound expressway. One of the selection criteria of the rest area is the common type of shops, and services that are typical of those to Malaysian Rest and Service Areas. More importantly, such RSA type of land use category and pass-by trips does not appear to be fully addressed in previous study or handbooks. Total parking space provided at Machap Rest and Service Area is 120 spaces with 96 spaces for cars and 24 spaces for heavy vehicles. Machap Northbound Rest Area provides facilities and amenities such as food stalls, petrol stations, children playground, toilets, prayer halls, ATM machine and Kiosk.

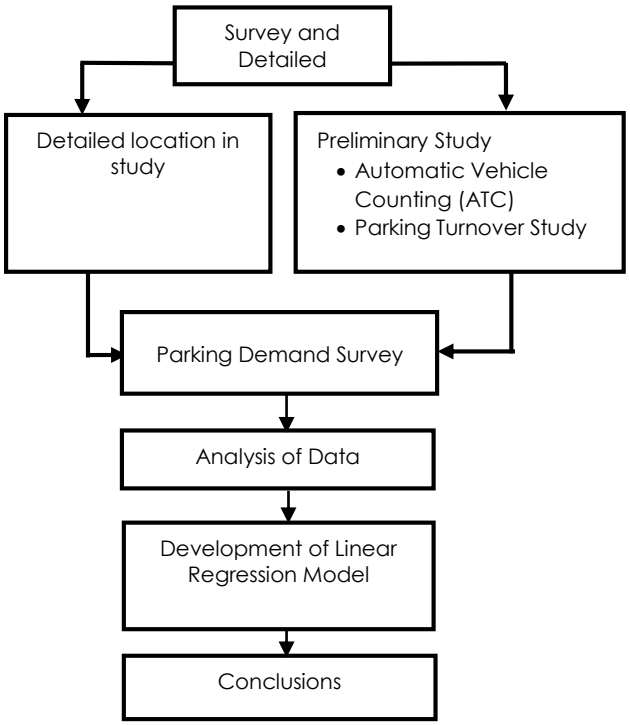


Figure 1 Flow chart of research study method

3.1 Preliminary Study

Preliminary study on the site was conducted to assess the needs in this study such as manpower, setting up the equipment, duration of the study and data collection procedures. Automatic Traffic Counter (ATC) was used to record traffic volume entering the rest area continuously for 7 successive days for 24 hours (rest area operational hours) from 19th to 25th June 2014, to determine the peak hour period of parking demand as shown in Figure 2.

Figure 2 Installation of Automatic Traffic Counter at the entry point of Machap Rest and Service Area

Calibration of ATC was conducted prior to data collection, to eliminate errors in the vehicle classification and volume. Then, turnover rate was determined in the preliminary study to determine the suitable time interval in parking demand study. Turnover rate is the ratio of number of vehicles parked in a duration to the number of parking bays available. This can be expressed as number of vehicles per bay per time duration.

Licensed-plate checks as in ITE were conducted to determine the parking turnover rate [14]. Vehicle plate number was checked for every parking bay. Only the last three digit of vehicle number plate were recorded on the license-plate check spread sheet as shown in Figure 3.

Space and Regulation	Time Circuit (Minute)													Remark
	0	5	10	15	20	25	30	35	40	45	50	55	60	
1	808	√	√	√	–	690	√	√	√	√	√	√	–	
2	80	√	√	√	√	√	√	551	√	√	√	√	√	
3	434	√	√	√	√	√	√	543	√	√	√	√	√	
4	388	√	√	√	–	727	√	√	√	√	√	√	√	
5	385	√	√	√	√	–	342	√	√	√	√	√	√	
6	4028	√	√	–	–	334	134	√	√	√	√	√	√	
7	973	√	√	√	√	√	810	√	√	√	√	√	√	
8	786	√	√	√	√	√	√	√	√	–	441	√	√	
9	524	√	√	√	√	√	√	√	√	–	2008	√	√	
10	867	√	√	800	√	√	√	√	√	√	√	√	√	
11	168	√	424	√	√	187	√	√	√	–	8043	–	799	
12	4008	√	385	√	√	√	√	√	√	√	√	567	√	
13	187	538	√	√	√	√	√	√	√	√	√	√	–	
14	781	√	√	√	√	432	–	846	√	–	497	√	√	
15	4034	√	√	–	–	–	111	√	√	√	√	√	√	
16	591	√	√	√	–	246	√	√	√	√	√	√	√	
17	433	√	√	√	√	√	√	√	√	√	√	799	√	
18	397	√	1069	√	√	√	√	√	√	√	√	930	√	
19	277	√	√	134	√	√	–	923	√	√	√	145	√	
20	487	√	√	706	√	√	√	√	937	√	√	√	√	
21	552	√	√	√	–	–	929	√	√	388	√	√	√	
22	224	√	√	√	–	–	–	–	–	318	√	–	–	
23	333	√	√	√	√	√	√	√	√	√	√	√	√	
24	727	√	√	√	√	√	–	272	√	√	√	589	√	

Codes: ###: Last three digits of license plate number for first observation of a vehicle
√ : Check mark for repeat vehicle from a prior circuit
– : Dash mark for empty spaces

Figure 3 Licence-plate check spread sheet for turnover study

In total, the license plate checks were conducted for 3 hours period on weekday (Wednesday, 19th June 2014) and weekend (Saturday, 22nd June 2014) with time interval of 5-minute. Initially, the parking utilisation in Machap Northbound Rest and Service Area can be assumed as short period parking which is 15 minutes, thus it is advisable to use 5-minute time interval for parking turnover study in this area. The turnover rate was obtained using Equation 1.

$$\text{Turnover rate, } T = \frac{\text{Number of Different Cars Park}}{\text{Number of Parking Spaces}} \quad (1)$$

The period for turnover study was selected randomly for the purpose of the study. Finally, parking demand survey was then conducted on various days and followed by analysis and development of linear regression models.

3.2 Parking Demand Survey

Then, based on peak hour period of parking demand and time interval obtained through turnover study in the preliminary study, the study on parking demand at Machap Rest and Service Area was conducted continuously throughout the period for different days. The objective of this survey was to count the number of vehicles parked at the time of peak parking demand and at various other times during the day. The selected days for parking demand data collection were: Weekday (3rd September 2014), Weekend (6th September 2014), Malaysian Day (16th –17th September) and Deepavali Day (22nd – 23rd October 2014). Each of these days has significant variation in the vehicle volume on major road thus the reason of conducting the study at this period. The parking demand data were collected on different days to study significant impact of the vehicular volume on the major road (expressway) to the parking demand at Machap Rest and Service Area. The parking demand survey was conducted based on the procedures outlined in the Parking Generation [15]. At the same duration of the parking demand survey was conducted, the digital video camera was installed at the entry point to the rest area to record the vehicular volume on major road (expressway. Continuous recording of the digital video camera during peak hour period of parking demand was conducted to determine both the number of vehicular volume entering the rest area and the number of vehicles on major road. So that, the vehicular count on the parking area and on the major road can be done simultaneously. Figure 4 shows the setup of video camera.

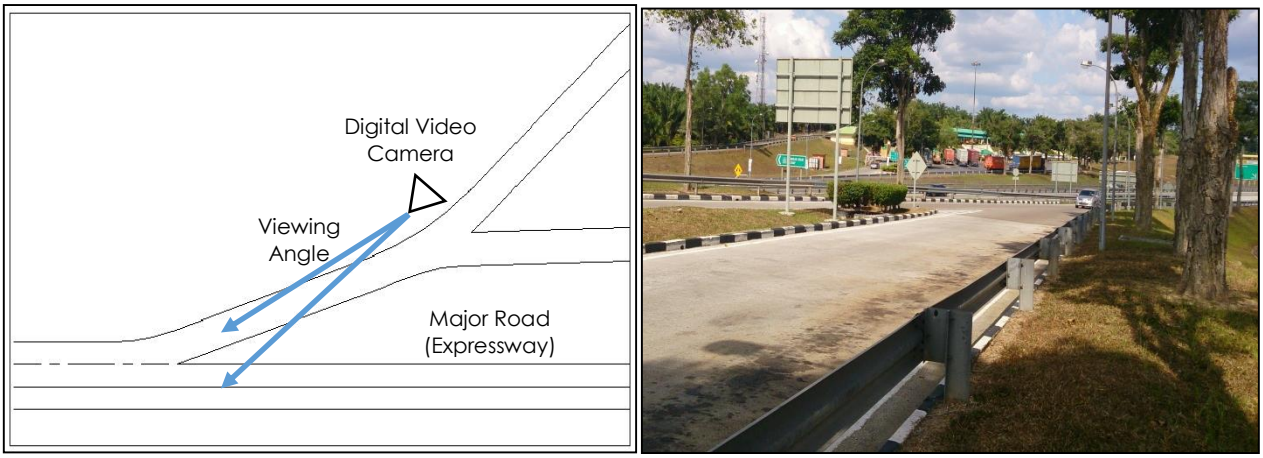


Figure 4 (a) The setup of digital video camera at Rest Area and b) real-time view of the camera at Machap Northbound Rest Area entrance

As seen in Figure 4, the video camera was positioned in such a way that it can record both the vehicle volume entering the rest area and vehicle volume on major road. The video camera was played continuously during peak hour period of parking demand that is based on the procedure outlined in Section 3.1. The recording was conducted during the day due to the limitation of the recording equipment at night.

During the recording, it was found that as the number of vehicles parked at the parking space increases, parking survey cannot be conducted effectively unless the parking area is divided into zones. Therefore, parking area at Machap Rest Area was divided into 3 zones for easier counting in the parking survey as shown in Figure 5.

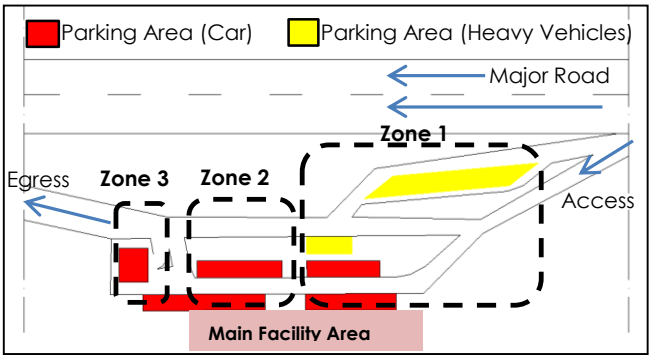


Figure 5 Zoning diagram for parking demand survey

Several considerations based on the basic guidelines by ITE in Parking Generation Manual for surveyor were made in this study, which are listed below [15]:

i. Heavy vehicle at loading docks that consume parking spaces should not be included in vehicle parking demand counts.
ii. Illegally parked vehicles such parking at non designated space that associated with the land use should be counted in parking demand survey.
iii. A vehicle that taking up two parking spaces should be counted as a single vehicle.
iv. A vehicle queued in drive-through zone or pick up and drop off zones should not be counted as a vehicle parking demand but should counted separately to provide information on this activity. However, if the vehicles park in parking facility spaces and conduct this activity they should be counted.
v. Delivery vehicles that park in the parking area which using the parking space should be counted, however if the delivery vehicles parked in truck loading areas or docks should not be count in parking demand. Separated form may be required if the delivery vehicles want to be counted.
vi. Motorcycles parked in vehicle spaces should be counted as a parked vehicles.
vii. Vehicles parked in accessible parking stalls should be counted in parking demand.
viii. Bicycle parking should be counted in vehicle parking observation but analysts or surveyor is encouraged to count them.

Parking demand survey data for designated parking and non-designated parking was counted separately. This was to ensure an efficient parking survey. Total parking demand data analysis consist of designated parking and non-designated parking which is also known as illegal parking such as curb parking. Heavy vehicles and cars were counted in separated spreadsheet. Both parking demand for vehicle and heavy vehicle were then sum up to obtain the total parking demand. The highest parking demand within the observed hour was then selected to plot accumulation curve as stated in ITE Parking Demand Survey [15]. Then, linear regression was

plotted between the peak hourly demand and total vehicle volume on major road during that same peak period.

4.0 RESULTS AND DISCUSSION

4.1 Results of Preliminary Study

Automatic Traffic Counter (ATC) was used to record the traffic volume entering the rest area for one week continuously for 24 hours including weekends as shown in Figure 6. This procedure was conducted to determine the peak hour parking demand of the rest and service area.

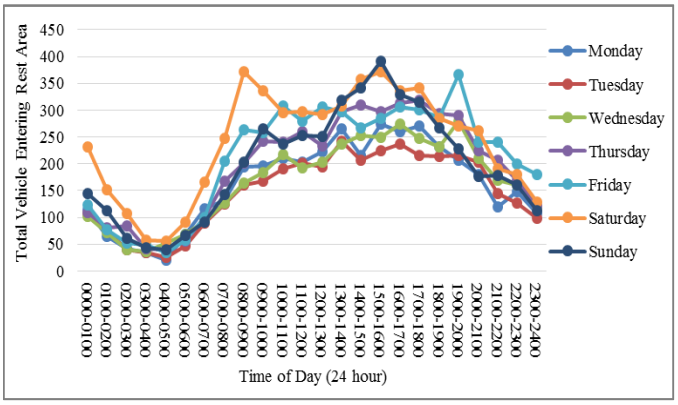


Figure 6 Hourly Vehicle Flow on Machap Northbound Rest Area for 7 days

As seen in Figure 6, for the whole seven (7) days, with the exception to Friday, the travel patterns of vehicles entering the rest area yield almost the same pattern. Most people visit the rest area from 9:00 am in the morning to 6:00 pm in the afternoon. Traffic flow entering the rest area started to increase at 9:00 am, and then it peaks at late afternoon. It revealed that more people travelling along the expressway in the late afternoon. The traffic hourly flow on weekend (Saturday) shows more traffic flow than weekdays. The results revealed that frequency of rest area used by traveller increases during weekends, so does the tendency for the travellers to transit at the rest area either for resting or using amenities (petrol fuelling, eating, etc.).

Based on the results obtained in Figure 6, parking demand survey at Machap Rest Area was conducted for 9 hours from 9:00 am to 6:00 pm, which indicate peak period using video camera. Although the rest area operates for 24 hours, the study was conducted until 6:00 pm due to the constraints of safety and limitations of collecting the data at night (due to glaring in the video recording image).

Then, the turnover study is conducted to determine the occupancy rate of parking space on the rest area and then it can be used to determine the suitable time interval to conduct parking study in the rest area.

4.1.1 Turnover Study

Turnover parking defined as the number of different vehicles parked in a specific area of facility in a given period of time divided by the number of spaces/bays. Turnover may be calculated during the course of an entire day or separately for daytime and evening parking. The purpose of turnover study was to determine the suitable time interval for parking demand data collection.

Table 1 and Table 2 show the parking turnover rate for each of the 3 hours for both weekday and weekend respectively.

Table 1 Turnover study on weekday

Time Period	Parking Supply	Parking Spaces Occupied	Number of Vehicle Parked	Turnover (veh/hr/bay)
10:00 - 11:00	96	72	158	2.19
11:00 - 12:00	96	72	140	1.94
14:00 – 15:00	96	72	152	2.11

Table 2 Turnover study on weekend

Time Period	Parking Supply	Parking Spaces Occupied	Number of Vehicle Parked	Turnover (veh/hr/bay)
10:00 - 11:00	96	72	175	2.43
11:00 - 12:00	96	72	160	2.22
14:00 – 15:00	96	72	172	2.39

Note: Parking supply = parking spaces provided on the facilities
Parking space occupied = total number of provided parking spaces that were occupied by vehicles
Number of vehicle park = total number of vehicles parked in the observation hour

It is observed in Table 1 and Table 2 that the highest turnover rate for weekday and weekend was 2.19 and 2.43 respectively. This indicates that generally, in one hour, the number of vehicles occupied each of the parking space is less than three vehicles. Therefore, it is appropriate to use 20-minute interval to conduct parking demand survey. However, it was observed that in a certain random occasion, the number of vehicles occupied one parking space in one hour duration was more than three vehicles, thus the 15-

minute interval was used in the parking demand survey in this study. If parking spaces in a facility are underutilised, the turnover rate will be very low [16]. On the other hand, turnover rate on Saturday revealed slightly higher compared to weekdays due to most of journeys are made during weekends compare to weekdays.

4.1.2 Preliminary Study: Relationship between Vehicle Trip Entering the Rest Area and Vehicular Volume on Major Road

Based on peak hour parking demand obtained in section 4.1, vehicles entering the Machap Northbound Rest Area and vehicular volume on major road (expressway) were recorded continuously using video camera during peak hour period, 9am to 6pm. The vehicular volume was computed as cumulative per hour. The vehicular volume on the major road includes the number of vehicles entering the Machap Northbound Rest Area. Figure 7 shows the proportion of vehicle entering the rest area from the major road.

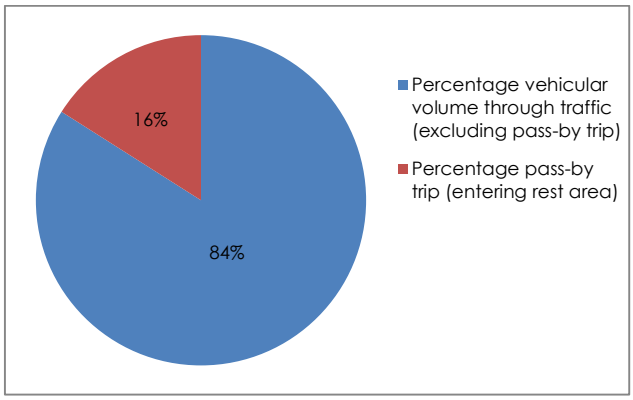


Figure 7 The proportion of pass-by trip from vehicular volume on major road

The percentage of vehicle entering the rest area shown in Figure 7 is based on average value from every one hour during the observation period. Based on the finding, it shows that 16% from the total vehicles on the major road enter the rest area during the observation period. It was also observed that not all vehicles entering the Machap Northbound Rest Area used the parking supply. Some of the vehicles were found to just drive through the parking area to the petrol station.

Then, traffic data in mid-weekday (Wednesday) were used to determine relationship between total vehicle entering the rest area and total vehicles on major road. This is only a preliminary study to look at whether there are relationships exist between these two variables hence the selection of data for mid-weekday only. Table 3 shows the hourly traffic volume on Wednesday for both pass-by trips and major road for the duration of 9:00 am to 6:00 pm.

Table 3 Hourly traffic volume on Rest Area and Major Road

Time of day	Vehicular Volume Entering Rest Area (veh/h)	Total Vehicular Volume on Major Road (veh/h)
09:00 – 10:00	184	1258
10:00 – 11:00	217	1458
11:00 – 12:00	193	1387
12:00 – 13:00	203	1359
13:00 – 14:00	237	1376
14:00 – 15:00	253	1493
15:00 – 16:00	249	1524
16:00 – 17:00	275	1589
17:00 – 18:00	260	1580

Based on hourly traffic data as shown in Table 3, a relationship between vehicular volume entering Machap rest area and vehicular volume on major road was established as shown in Figure 8.

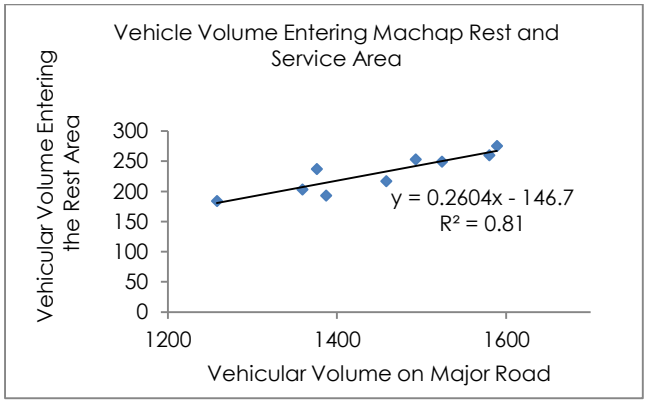


Figure 8 Relationship between vehicles volume entering the rest area and vehicle volume on major road

Based on the scatter plot obtained in Figure 8, the value correlation coefficient, R^2 equal to 0.81 was closes to 1.0 which can be considered as better correlation between vehicle volume entering the rest area and vehicle volume on major road. It shows that the number of vehicles on major road is a predictor of the number of vehicles at the rest areas, in which, as the number of vehicle volumes on major road increases the parking demand at the rest area increases as well.

4.2 Parking Demand at Machap Northbound Rest Area

As shown in previous section, number of vehicle volume on major road is a predictor of the number of vehicles entering rest area. Therefore, parking demand study at Machap Northbound Rest Area was conducted during weekday, weekend, Malaysia Day and Deepavali Day. Each of these days has significant variation in the vehicle volume on major road thus the reason of conducting the study at this period. Parking demand data collection was carried out based on

the time period determined in the section 4.1 which was from 9:00 am until 6:00 pm (9 hours recording period) with the time interval of 15-minute as determined in turnover study. The Machap Northbound Rest Area has 120 parking spaces in total which consist of 96 parking spaces for car and 24 parking spaces for heavy vehicle. The parking area between car and heavy vehicle were separated, therefore, the parking accumulation can be known for each of vehicle types: car and heavy vehicle. The total parking accumulation considering all vehicle types (car and heavy vehicles) were also determined. Parking accumulation is defined as the number of vehicles parked at a given instant of time. Normally this is expressed by accumulation curve. Accumulation curve is the graph obtained by plotting the number of bays occupied with respect to time.

4.2.1 Parking Demand on Weekday

Data collection on weekdays was conducted on normal day, not on public holiday or festival day (3rd September 2014). Figure 9 and Figure 10 shows the observed parking accumulation on the rest area for cars and heavy vehicles respectively in 15 minutes interval.

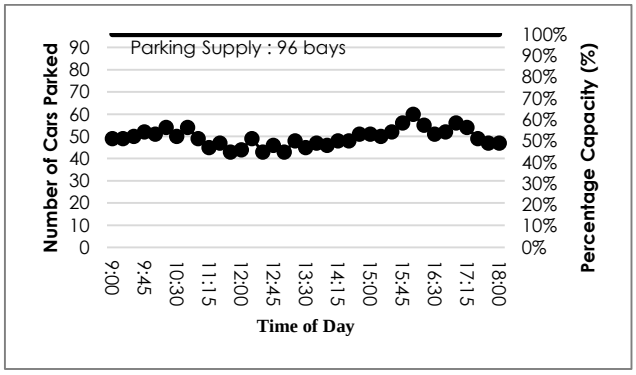


Figure 9 Parking accumulation during weekday for cars

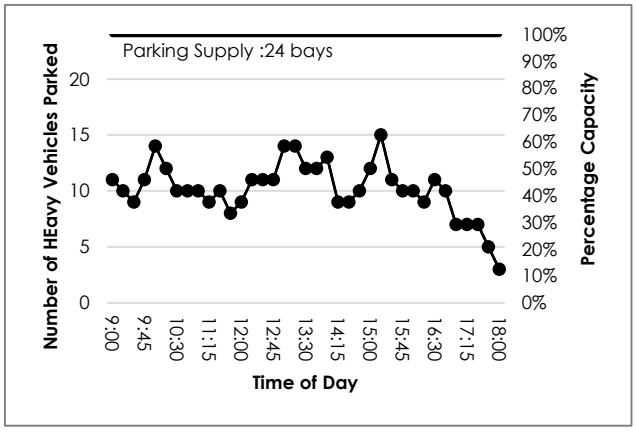


Figure 10 Parking accumulation during weekday for heavy vehicle

As seen in Figure 9, the highest number of cars parked in the designated parking space is 54 cars during morning period with 56% capacity and 60 cars during evening period with 60% capacity. For heavy vehicle, the highest number of heavy vehicles parked in the designated parking space is 14 heavy vehicles during morning period with 58% capacity and 15 heavy vehicles during evening period with 63% capacity as shown in Figure 9 .

Then, the highest 15 minutes parking demand within the observed hour was used to plot the accumulation curve of parking demand during weekday. Figure 11 shows peak hourly parking demand on weekday for Machap Northbound Rest Area.

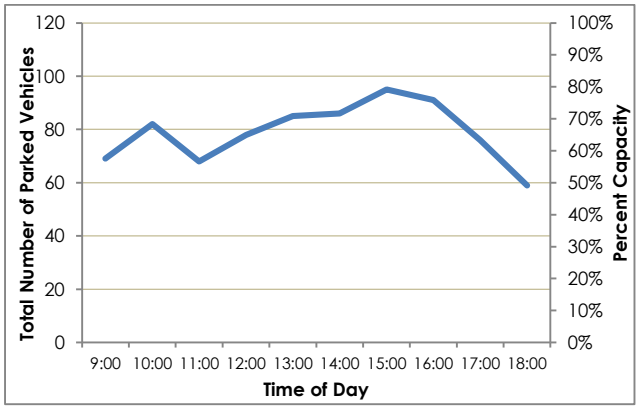


Figure 11 Parking accumulation curve on weekday

Based on the finding in Figure 11, the highest total parking demand for morning period occurs at 10:00 am which is 82 from 120 total parking supplies. On the other hand, the highest parking demand on evening period occurs at 15:00 hour, which is 96 parked vehicles. The result revealed that parking demand of the day (weekday) can be considered as 96 total parked vehicles. The parking demand does not exceed the parking supply provided on the rest area which is 120 parking spaces.

4.2.2 Parking Demand on Weekend

Data collection for weekend was conducted on Saturday (6th September 2014), not on public holiday or festival day to represent normal behaviours of traveller during weekend. Figure 12 and Figure 13 show the parking accumulation on the rest area for cars and heavy vehicles in 15-minute interval.

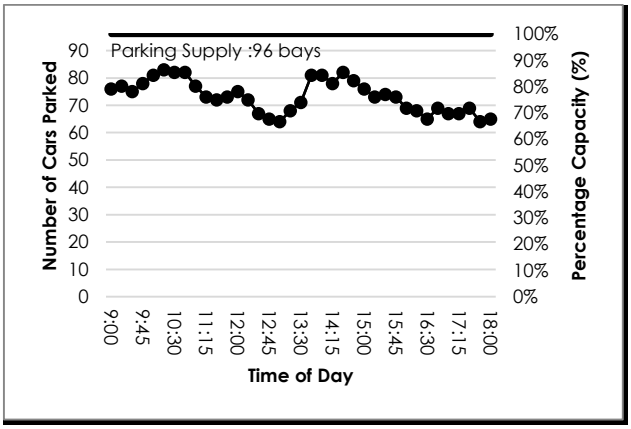


Figure 12 Parking accumulation during weekend for cars

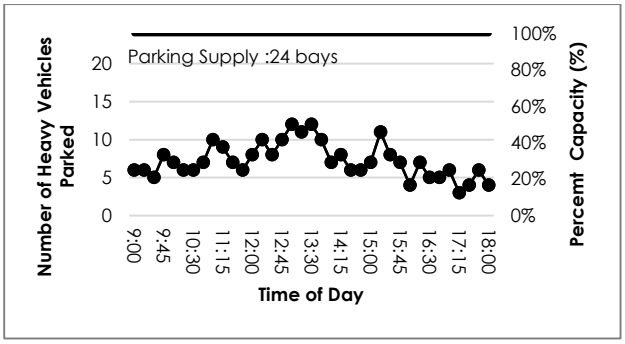


Figure 13 Parking accumulation during weekend for heavy vehicle

From Figure 12, it can be seen that the highest parking accumulation for cars is 83 cars in the morning period with 86% capacity and 82 cars in the evening period with 85% capacity. As seen in Figure 13, the highest parking accumulation for heavy vehicles is 10 heavy vehicles during morning period with 42% capacity and 12 heavy vehicles during evening period with 50% capacity.

Figure 12 reveals a higher parking accumulation for cars in the weekend compared to the weekday (shown in Figure 9). However, it shows an opposite trend for heavy vehicles in which the parking accumulation for heavy vehicles is higher in the weekday compared to weekend as shown in Figure 10 and Figure 13 respectively. This is because heavy vehicles are mostly involved in industrial transportations, thus their preference to travel during the working days (weekdays) instead of weekends.

Then, the highest 15-minute parking demand within the observed hour was used to plot the accumulation curve of parking demand during weekend. Figure 14 shows peak hourly parking demand on weekend for Machap Northbound Rest Area.

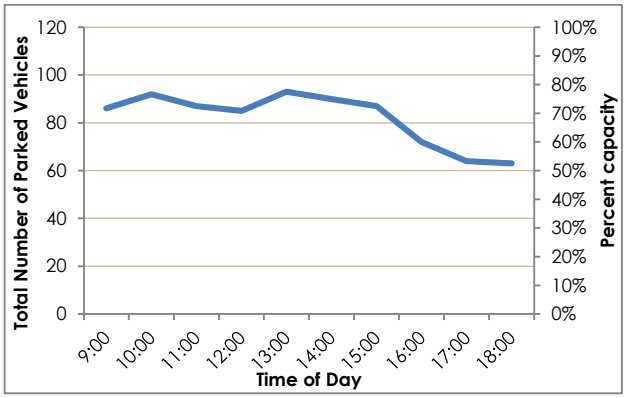


Figure 14 Parking accumulation curve on weekend

Results in Figure 14 shows that the highest total parking demand for morning period occurred at 10:00 am which is 92 total parked vehicles. The highest parking demand at evening period occurred at 13:00 pm which is 93 parked vehicles. The parking demand for the particular day (weekend) can be considered as 93 parked vehicles. The number of parked vehicles does not exceed the total parking supplies provided on the facilities.

4.2.3 Parking Demand on Malaysia Day

During the study period, the researcher encountered a public holiday on Malaysia Day (16 September 2014) which falls on school term break. It was observed that there is a higher tendency of people travelling during this period. Therefore, data collection was continued on Malaysia Day and a day after it. However, only the highest parking demand between these two days was plotted. Figure 15 and Figure 16 show the parking accumulation on the rest area for cars and heavy vehicles in 15-minute interval on this day.

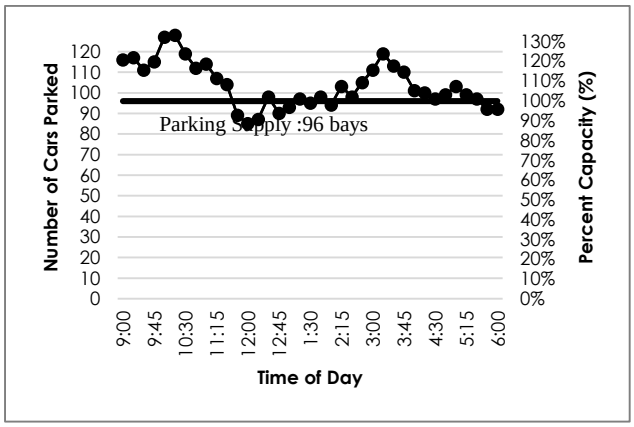


Figure 15 Parking accumulation during Malaysian Day for cars

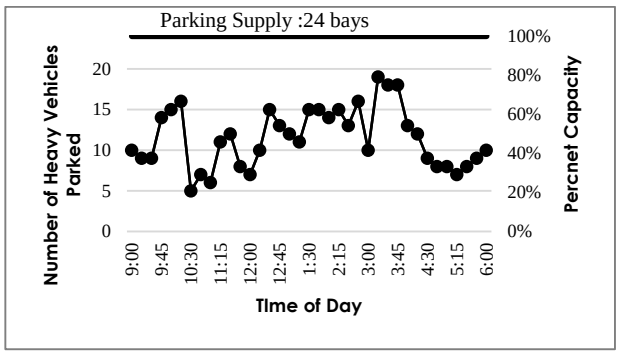


Figure 16 Parking accumulation during Malaysian Day for heavy vehicle

From Figure 15, it can be seen that the highest parking accumulation for cars is 128 cars in the morning period with 133% capacity and 119 cars in the evening period with 124% capacity. For heavy vehicle parking accumulation as shown in Figure 16, the highest parking accumulation for heavy vehicles is 16 heavy vehicles in the morning period with 67% capacity and 19 heavy vehicles in the evening period with 79% capacity. The parking demand in this day exceeded the capacity of the parking space provided in the rest area. It revealed that public holiday do has an impact on the people's choice to travel thus affecting the parking demand at the rest area.

Figure 17 shows the peak hourly parking demand on Malaysia Day for Machap Northbound Rest Area. The peak hourly parking demand was based on the highest 15-minute parking demand within the observed hour.

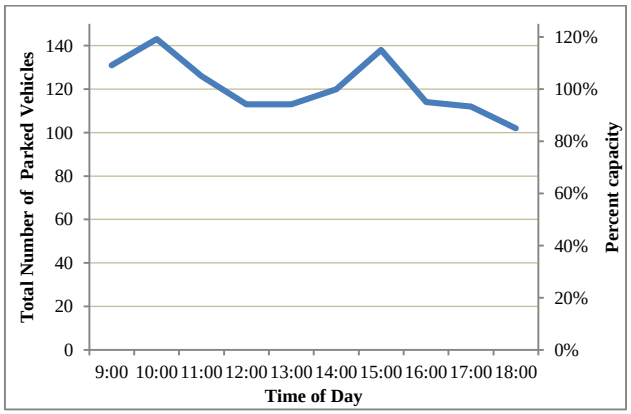


Figure 17 Parking accumulation curve on Malaysia Day

As shown in Figure 17, the highest parking demand for morning period occurs at 10:00 am (143 parked vehicles). Then, the highest parking demand for evening period occurs at 3:00 pm which is 138 parked vehicles. Note that the parking supply on the area is 120 parking space. On the Malaysia Day, the demand fluctuates over 15% to 19% from the capacity of the parking space provided in the rest area during this day.

4.2.4 Parking Demand on Deepavali Day

Then, the study on parking demand was conducted on Deepavali day (22nd October 2014) and a day after Deepavali. However, only the highest parking demand between these two days was plotted. Figure 18 and Figure 19 show the parking accumulation on the rest area for cars and heavy vehicles in 15-minute interval.

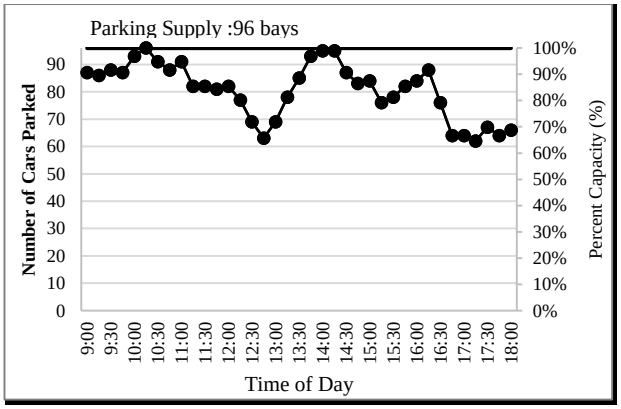


Figure 18 Parking accumulation during Deepavali Day for cars

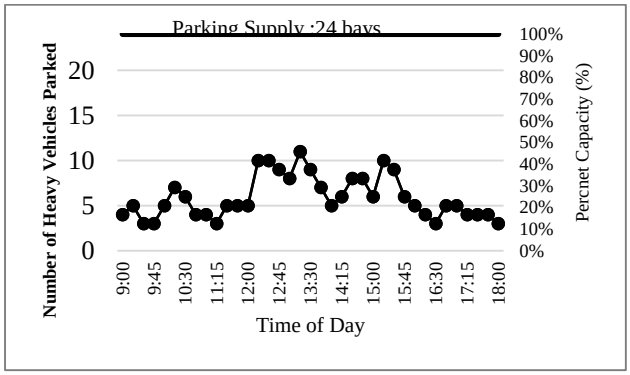


Figure 19 Parking accumulation during Deepavali Day for heavy vehicle

From Figure 18, it can be seen that the highest parking accumulation for cars is 96 cars in the morning period with 100% capacity and 95 cars in the evening period with 99% capacity. For heavy vehicle parking accumulation as shown in Figure 19, the highest parking accumulation for heavy vehicles is 7 heavy vehicles during morning period with 29% capacity and 11 heavy vehicles during evening period with 46% capacity.

Figure 20 shows peak hourly parking demand on festive season which is Deepavali for Machap Northbound Rest Area.

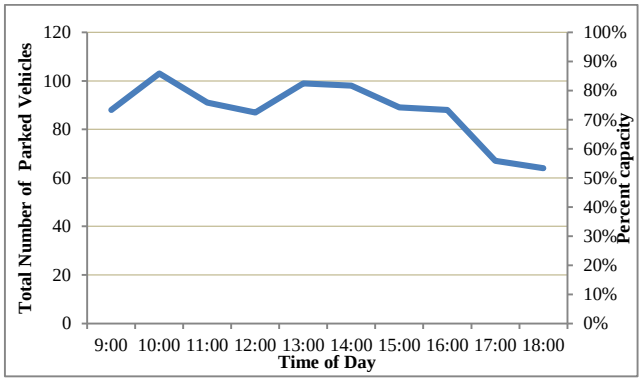


Figure 20 Parking accumulation curve on Deepavali

As shown in Figure 20, the highest parking demand for morning period occurs at 10:00 am which is 103 parked vehicles. The highest parking demand on evening period is 99 parked vehicles, occurs at 13:00 hour. Based on the finding, the parking supply is adequate to handle the demand during of festive season (Deepavali).

4.2.5 Discussion on Parking Demand Observations

The objective of the survey was to count the number of vehicles parked at the time of peak parking demand and various other times during the day. Observations can be made multiple times within an hour or once in an hour depending on the variations of parking demand. The highest observation for parking demand within the hour within the time interval represents the highest demand for specific hour in data survey observations [15]. Figure 11, Figure 14, Figure 17 and Figure 20 show the hourly parking demand based on the highest parking demands in 15-minute interval on the specific hours for weekday, weekend, Malaysia Day and Deepavali respectively.

The finding also revealed that more people travel on the simultaneous school holiday and public holiday which is on Malaysia Day (section 4.2.3) followed by festive season thus the higher parking demand observed in the rest area during that period. The parking demand has exceeded the capacity of the parking space provided in the area during the Malaysia day. On the other days, the rest area still can accommodate the parking demand from vehicle. However, on the Deepavali Day and weekend, the parking demand varies from 80% to 95% which is almost reach parking capacity.

4.3 Relationship between Parking Demand and Vehicular Volume on Major Road

From the parking accumulation curve obtained in the previous sections, it shows a various trend of parking demand on those days: weekday, weekend, Malaysia Day on school term break and festive season (Deepavali Day). To determine the relationship between the parking demand at Machap Northbound Rest Area and vehicular volume on major road, the total vehicle volume on major road was recorded using video capturing in the same duration that the highest parking demand was observed. Table 4 shows the highest 15-minute interval parking demand within the observation period and the total vehicle volume observed on the major road in the same period of observation.

Table 4 The Highest Parking Demand and Vehicular Volume on Major Road

Observation Day	Time Period	Parking Demand	Vehicular Volume on Major Road
Weekday	15:45-16:00	70	364
Weekend	10:00-10:15	89	484
Deepavali	10:00-10:15	103	523
Malaysia Day	10:00-10:15	144	641

Based on the information obtained in Table 4, a scatter plot and linear regression is then plotted as shown in Figure 21.

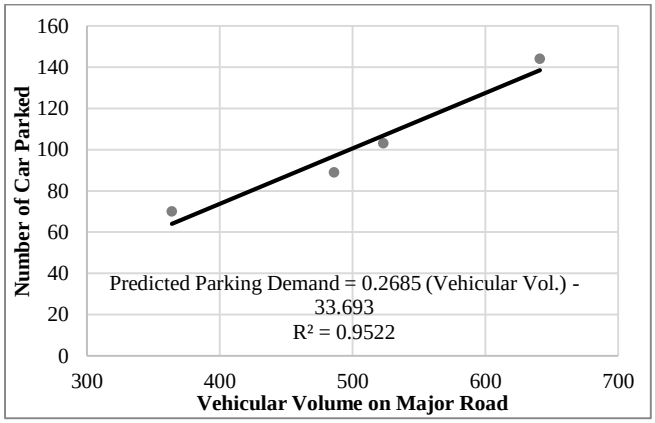


Figure 21 Relationship between parking demand and vehicular volume on major road

Then, separate analysis was conducted to determine the relationship between parking demand and vehicular volume on major road for both morning and evening period. Figure 22 shows the relationship between parking demand and vehicle volume on major road for both morning and evening period.

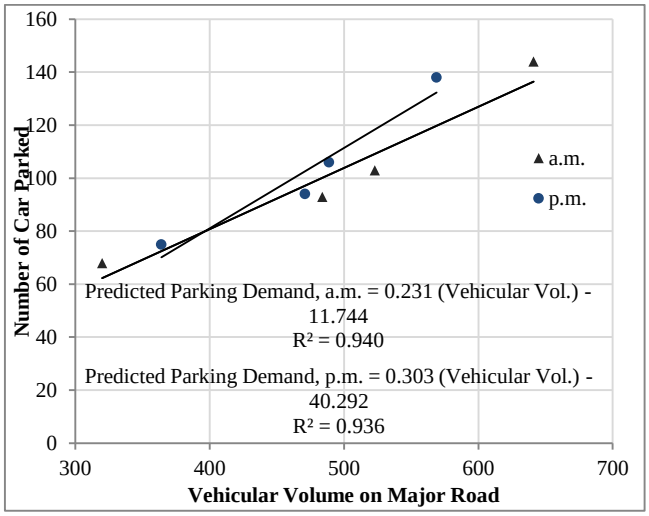


Figure 22 Relationship between parking demand (morning and evening) and vehicular volume on major road

Figure 21 and Figure 22 shows the relationship between parking demand and vehicular volume on major road. According to ITE, for a data set with at least four study sites, linear regression equation and line can be established if the coefficient of determination (R^2) is greater than or equal to 0.60 [15]. The data collection in this study was only conducted at one site that is at Machap Northbound Rest Area. However, four data sets representing different variation of vehicle volume on major road has been gathered to determine the relationship of this parameter with parking demand on the Machap Northbound Rest Area. Based on the findings in Figure 21 and Figure 22, the analysis of relationship between the highest parking demands and vehicular volume on major road with R^2 value closes to 1 show a good correlation. It shows that an increase in the number of vehicles on major road (expressway) caused an increase in the number of parking demand at the rest area.

In normal practice in Malaysia, 'turn-in rate' which is the rate of vehicle volume from major road entering the facilities, normally between 5% and 15%, can be used to predict parking demand on the rest area if no heavy vehicle is considered [17]. This 'turn-in rate' value is used without taking into consideration any other factors such as amenities and size of facilities. However, in reality, the amenities and reserved space of the facility are expected to have some effect on the traveller's choice to stop to the rest area, hence the rate may vary. Therefore, initial assumption on turn-in rate of 8% to 10% could be used if there is no information available [17]. Figure 23 shows the comparison of the current observed parking demand and parking demand based on 5% - 15% turn-in rate on the rest areas.

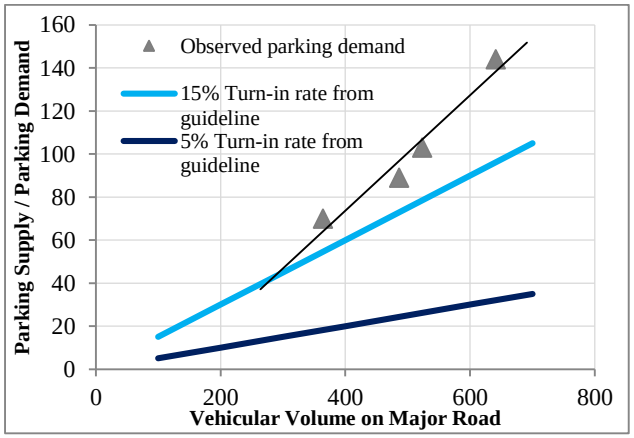


Figure 23 Observed Parking Demand and Standard Parking Demand based on Standard Turn-in Rate (Guidelines for Malaysia Toll Expressway System, 2008)

It can be seen from Figure 23 that the observed parking demand is higher compared to the prediction of parking demand based on maximum 15% turn-in rate especially at a higher vehicle volume on major road. The vehicle volume increases every year hence the higher turn-in rate observed on the site compared to the standard turn-in rate of 5% to 15% obtained from the guideline.

5.0 CONCLUSIONS

This study revealed that parking demand and vehicular volume on major road (expressway) is directly proportional to vehicular volume on major road (expressway). Based on the findings, the vehicular volume on major road has a positive correlation on the parking demand at the Rest Area with value of R^2 equal to 0.95. As a result, this parameter (vehicle volume on major road) can be used as a benchmark by the transport planner and the rest area authority in planning any future development or improvement on the rest area. The finding obtained in this study was based on a constrained duration of study (September to December 2014) at one site, Machap Northbound Rest Area. This study has raised question on how the vehicle volume on major road can be used to predict the parking demand for future planning. Therefore, further investigation will be conducted for a better insight on the effect of the parameter to the parking demand. With the increase in the number of sites under investigation, a model on parking generation can be developed for this type of land use based on number of vehicles on major road. So that it can be used to predict the parking requirements at the rest area in Malaysia.

The demand for parking at the rest areas is dependent on the distance of the travel. In general, for a travel distance of 400 km, the users tend to make a halt at the mid-way of their travel. Therefore, origin and destination studies are required to determine the

arrival rate at the rest and relax facility. Furthermore, the total traffic volume from the origin cities is a major predictor of the arrival rate at the Rest and Service Area (RSA) facilities. The distance between the other rest areas can also be a major predictor of the distribution of arrival at the RSA facilities. More importantly, the facilities at the RSA areas in terms of the composition of the shops (for eating, for using public convenience, for banking etc.) must be considered while conducting the study of trip purpose at the RSA facility. The above considerations were absent in the present study and further studies must include distance from the trip origin, distance from the nearest RSA areas and the originating total traffic volume.

Acknowledgement

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