Evaluating Parking Characteristics of Park-and-Ride Facility at Gombak LRT Terminal Station

Abdul Azeez Kadar Hamsa*, Nur Aina Syafiqah Akmal & Zurin Hafika Zolkpeli

Department of Urban and Regional Planning, Kulliyyah of Architecture and Environment Design
International Islamic University Malaysia, Kuala Lumpur, Malaysia, 50728

Corresponding author: abdazeezkh@gmail.com

ABSTRACT

Malaysia has been experiencing a rapid increase in the number of private vehicles each year. This has increased in the use of private vehicles for various trip purposes especially work trips. Park-and-ride (PnR) is one of the travel demand management measures that would help to reduce traffic congestion and sustain urban mobility. The success of a park-and-ride facility, however, depends on many factors besides parking characteristics at the public transit stations. This paper evaluates the parking characteristics at one of the rail-based PnR stations of an LRT line. The parking characteristics at the selected rail station were evaluated by applying both a parking utilization survey and a pre-designed questionnaire survey. The parking utilization survey was administered by targeting all the parking spaces at each level of the parking building and a questionnaire survey by targeting a pre-determined sample of parking users. A total of 295 questionnaires were proportionately distributed to the parking users at each level of the PnR facility. The analysis reveals maximum utilization of the parking facility especially during morning and late afternoon hours representing a high proportion of work trip commuters. This finding was well supported when compared with the results from the questionnaire data analysis. There were no clear differences in the parking characteristics between the findings of this study and that of other studies. However, the parking behavior and the pattern of the parkers differ conspicuously from that of other studies. A few recommendations were drawn to overcome the unavailability of parking spaces.

Keywords: Park and ride; parking characteristic; parking demand; parking users; parking utilization survey; parking questionnaire survey

INTRODUCTION

Parking is an important traffic element in a town or a city to allow vehicles to park at a designated location for accomplishing social, cultural, economic, business, and recreational activities. It includes a park-and-ride (PnR) facility at the public transit stations and terminals. The provision of parking at the PnR facility, however, allows parking users to park their vehicles at the facility and transfer to public transit or other high occupancy vehicles (HOVs) to reach their destinations at a city centre for accomplishing social, economic, cultural and recreational activities. PnR facility is a transportation demand management strategy to address the growing problems of traffic congestions, air pollution, and urban mobility.

According to the 12th Malaysian Economic Monitor by World Bank, it is estimated that the people in Greater Kuala Lumpur spent over 250 million hours per year involved in traffic congestion resulting in a substantial loss of 2.2% of Gross Domestic Product (GDP) (Star online). PnR would help decrease the number of private vehicles entering the urban centres leading to many social, physical and environmental benefits. The success of PnR, however, depends on factors like parking supply, parking fee, parking security, and parking location. It is crucial to know about the parking demand at the PnR facility to ensure that the parking supply and other related facilities can meet the parking demand which in turn increases the use of public transit.

This paper is an attempt to analyze the parking characteristics and perceptions of the parking users on the

provision of parking spaces at a PnR facility at Gombak LRT terminal station. A clear understanding of the parking characteristics and the views of the parking users are important and crucial to know not only the pattern of parking usage by the parking users but also to ascertain how the facility serves the parking users especially in meeting the parking demand. This will, eventually, help to sustain maximum parking demand at the facility and in turn, would help to increase the use of public transit. The structure of this paper is divided into few sections. Section 1 deals with introducing the main purpose of this paper followed by discussing key literature related to the focus of this paper in section 2. The description of the selected park-and-ride facility is given in section 3. Section 4 highlights the main objectives and methodology that guides to performance of various analyses and findings which are explained in section 5. Finally, recommendations and conclusions are drawn in section 6.

LITERATURE REVIEW

Park-and-ride is a transport demand management strategy to manage the growing problem of traffic congestion at the city centre (1-2). It has been used in many western countries since the 1930s (3-4). PnR facilities were operational in North America in the 1930s (1, 5-6). A bus-based PnR was started in the UK in the 1960s (7, 6), Scotland in the 1990s (8, 6). In Asia, the PnR scheme was started in Singapore in 1975 (9, 6) and Malaysia in 2001 (10, 6). Additionally, many West-European cities and regions are involved in the design, implementation, and exploitation of PnR schemes (11-13). The Paris region has 550 facilities with over 100,000 parking spaces (14, 13), Munich region has more than 26,000 users of park-and-ride sites daily (15, 13), the Netherlands has 446 facilities with 70,600 parking spaces (16, 13) and Antwerp region in Belgium has tens of PnR sites along with development of a new PnR facility with 1500 parking spaces (17-18, 13). This facility allows access to the use of public transportation services for a wider population. It is how public transit use can be increased which in turn negates the ill-impact on the environment by high use of private vehicles (19). "PnR is widely used in many countries and proved to be successful in mitigating congestion, pollution and overcoming difficulties of searching for parking space in the urban centers." (20). It enables commuters to travel to a certain point by motorcar, gathered in one point and transfer to high-occupancy vehicles (HOV) mode such as trains, buses, or trams to complete their journey in reaching their respective destinations (4). The parking facility provided at the transit stations is mainly for motorcars where users park their

vehicles near the station and transfer to public transit to reach their respective destinations (21, 4). The access to public transit, carpool, or vanpool at the fringe of the urban areas to make travel to various destinations at the city centres can also be made by bicycles and parking the bicycles at the provided parking spaces (22). They are parking sites located at the city boundary to divert motorcars from the outskirts areas to a public transit system to reduce traffic congestion and air pollution in urban areas (23).

The high private vehicle use on the road has increased in traffic volume and consequently increases the demand for road infrastructure and parking facilities. Cities have been suffering from traffic congestion immensely due to an upsurge in private vehicle use on road networks (4). The limited capacity of transport infrastructure has allowed traffic congestion and associated environmental pollution to deteriorate the quality of life and safety of the people in many urban areas (4). To cater to the urbanites' mobility, and sustaining the environmental quality in the urban centers, PnR is a commonly used measure. It receives greater attention in countries that deal with the increased use of private transport. PnR also plays an important part in providing access to public transport services to suburban and urban sprawl populations. It helps to promote the use of public transport (24, 11, 13). PnR is an effective measure in minimizing the use of private cars in the central business district and thus reducing congestion both during morning or evening peak hours (25). It also helps to improve urban accessibility, reduce vehicle-km travelled, and parking pressure in the cities (13). It is necessary to identify reasons for the utilization of a PnR from the users' perceptions to better understand how to conveniently assist the shift in modal share from private to public transit through the use of the facility.

The utilization pattern of PnR facilities mainly in terms of parking accumulation, parking duration, and parking occupancy is almost identical in many countries like Korea, Germany, Canada, UK, and Malaysia (22). The vehicles, normally, started to accumulate early in the morning reaching high accumulation of vehicles during morning hours and it started to decrease in the evening with a low accumulation of vehicles during evening hours (17, 26, 1, 27, 22, 28-29). This parking pattern shows that most of the parking users at the PnR facilities were work trip commuters. Because most parking users were work trip travellers, they were found to park at the PnR facilities for a longer parking duration, averaging more than 8 hours (22, 29). The parking occupancy rate for those who park at the PnR facilities performing work trips was close to 100% (22). It indicates that the PnR facility during weekdays mainly caters to commuters who travel for work purposes and thus allowing them to park for longer hours

and also shows the use of parking reaching the maximum capacity of the parking spaces (*30*). The perceptions of parking use at a PnR scheme at Melbourne, Australia shows that the convenience of the PnR site, parking fee in the CBD area, public transport service satisfaction, and transfer time at the PnR facility were the major factors that influence the commuters to use the facility (*4, 19*).

The main factor affecting parking demand at the PnR facility is the location of the facility that serves the surrounding catchment area of the population (31). Liu et. al. (2009) cited in (29), mentioned that factors like location, parking charges, public transit service quality, fares of public transit, level of road congestion, road tolls, and parking charges at the city centers affect the attractiveness and effectiveness of PnR schemes. According to (32), the five elements for selecting a site for the development of a PnR facility are informal PnR activity, the density of residential areas, intensity, and concentration of employment, the distance between major residential areas and employment centers, and current and future levels of service on pertinent roadways. Based on these elements, areas such as urban corridor, HOV corridor, peripheral, urban fringe, and remote areas are suitable for the development of a PnR facility.

DESCRIPTION OF THE STUDY AREA

Gombak LRT terminal station which is located on the outskirts of Kuala Lumpur along the Kelana Jaya LRT line was the case study area selected for this study. This station is a terminal station along the Kelana Jaya LRT line serving passengers along this rail corridor covering a total distance of 46.4 km. This LRT line runs from Gombak LRT terminal station in the East to Putra heights in the South with a total of 37 stations in between including these two stations. This LRT line serves some of the major commercial areas in the Kuala Lumpur city centre. The PnR facility at the Gombak LRT terminal station is a multi-storey parking facility consisting of six levels (G+5) with a total of 1260 parking spaces including 24 for disabled individuals and 155 for ladies. The number of parking spaces at each level of the facility is the same except at level G and level 5. Level G has 207 parking spaces, level 1-4 210 parking spaces each, and level 5 213 parking spaces. Figure 1 shows the location, building façade, and layout of the PnR facility at Gombak LRT terminal station.
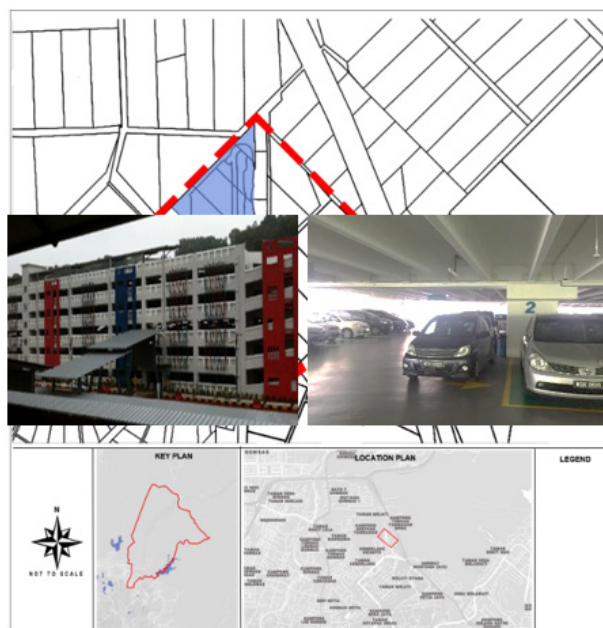

FIGURE 1. Location, building facade and layout of PnR facility at Gombak LRT terminal station

OBJECTIVES AND METHODOLOGY

The objectives are statements that are normally set during the initial stage of a study to guide it in a clear, direct, and specific direction. In this way, it is acclaimed that the objectives can be achieved at the end of the study. In this study, the main objectives are 1) to determine the parking demand of the parking users for a better understanding of parking usage at the PnR facility 2) to analyse the perceptions of the parking users on the parking characteristics for knowing the intricacies of parking service attributes that apply to the parking users.

Data, data collection, and data analysis are the major components of methodology in this study. A parking inventory survey was conducted to collect data on the type, number, and dimensions of parking spaces, traffic circulation within parking areas, and the locations of the entry and exit of the vehicles to the parking area. To attain data on parking characteristics, a parking utilization survey was conducted at the PnR facility. The PnR facility at the Gombak LRT terminal station is a multi-level parking facility consisting of six levels, ground plus five levels (G + 5). The parking data by noting the registration number of parked vehicles were collected at all the six levels of

the facility by parking utilization survey. These data were collected at every one-hour interval for a total duration of 12 hours starting from 8 am and ending at 8 pm on a weekday. Figure 2 shows the circulation path of the enumerators for collecting parking data at the ground level. Figure 3 shows a sample of the parking data collection approach at each of the five levels of the parking building.
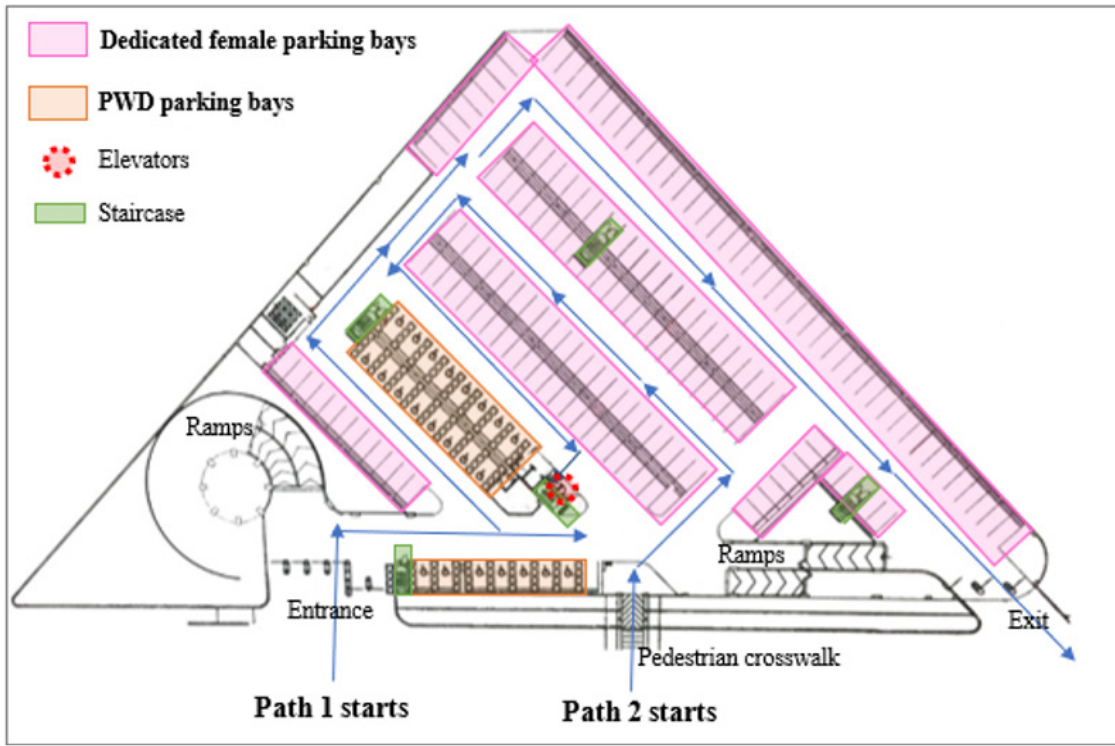

FIGURE 2. Circulation path for collecting parking data at the ground level

The data on parking demand was subsequently analysed and related to the views of the parking users. It is imperative to ascertain what parking users' views on the parking infrastructure at the PnR facility for a better understanding of the existing parking demand. The views of the parking users on the parking facilities at the selected PnR facility were gathered by administering a pre-designed and pre-validated questionnaire survey. The total number of parking spaces at the PnR facility was 1,260 parking spaces. A breakdown of the parking spaces at each level of the parking facility is given in Table 1.

A total of 295 samples from the total population size was the final sample size with a margin of error of 5%. Then, these 295 samples were proportionately distributed to the parking users who park at each level of the PnR facility according to the actual number of parking spaces at each level. Thus, a total of 41 samples were distributed at the Ground level and 51 samples each at each of the other five levels. The parking users at each level of the facility were selected by the convenience sampling method. However, only 188 questionnaires were received accounting for a response rate of 63.7%.
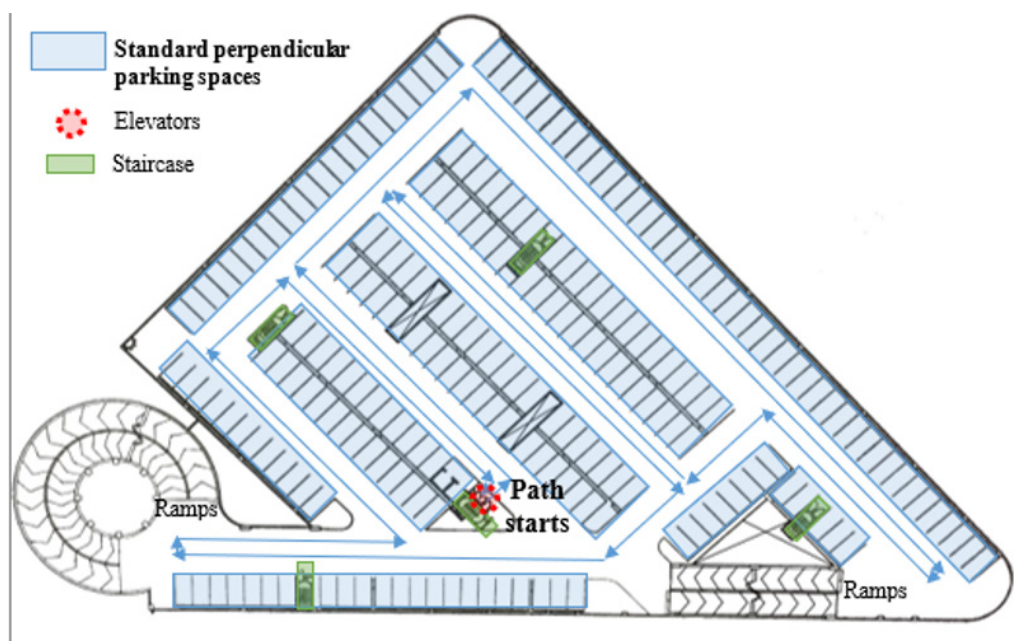
FIGURE 3. Circulation path for collecting parking data at each of five levels

The parking data were analysed to calculate parking accumulation, parking volume, parking duration, parking turnover, and parking occupancy. These parking characteristics were determined at each level of the PnR facility to understand the variations in the parking demand. These variations would eventually help to determine the parking patterns of the users at each level of the parking building.

The data representing the views of the parking users on parking availability, parking charges, parking accessibility, and other parking attributes were analysed to know how they differ from that of the data from the parking utilization survey. The socio-economic and travel characteristics of the parking users were also analysed to relate these attributes with the perceptions of parking users on key parking elements.

TABLE 1. Parking spaces by the level of the parking facility

Level	Level G	Level 1	Level 2	Level 3	Level 4	Level 5
Parking space	207	210	210	210	210	213

ANALYSIS AND FINDINGS

This section deals with the analysis of data to derive important and meaningful findings. The analysis of the data is divided into two distinct subsections, one on the analysis of the data and associated findings on parking characteristics and the other on the perceptions of the parking users on the parking availability, parking charges, parking accessibility, and other parking elements. These are explained in the following subsections:

PARKING CHARACTERISTICS

The findings on the parking characteristics are important to comprehend the extent of parking demand that is generated by parking users at the selected PnR facility. It is commonly known that parking supply must be adequate to meet the parking demand to ensure the maximum use of the PnR facility. Parking accumulation, parking volume, parking duration, parking turnover, and parking occupancy are the parking characteristics that are determined in this paper.

PARKING ACCUMULATION

The parking accumulation would help to understand the variations in the parking demand at the parking facility at each preselected hour of the total survey duration. It provides an avenue to know about the usage of the parking facility indicating the maximum and minimum parking demand during the survey duration. Figure 4 depicts parking accumulation at each level of the PnR facility during the survey duration. The findings show that the parking pattern was almost the same at each level of the parking facility but induces a high parking demand especially in the morning and late afternoon hours. The parking demand during these hours was much higher, and it almost reached its capacity than during later hours of the day. It is a typical and usual parking pattern at a parking facility where the majority of the parking users were

travelling for work purposes (30). The parking accumulation pattern at the Gombak LRT terminal station park-and-ride facility is similar to that of the park-and-ride facility at Sheung Shui, Hong Kong where it has a drastic increase in the number of vehicles during morning hours and started to peak from 0900 to 1600 hour, and subsequently drops after 1700 hour (1).
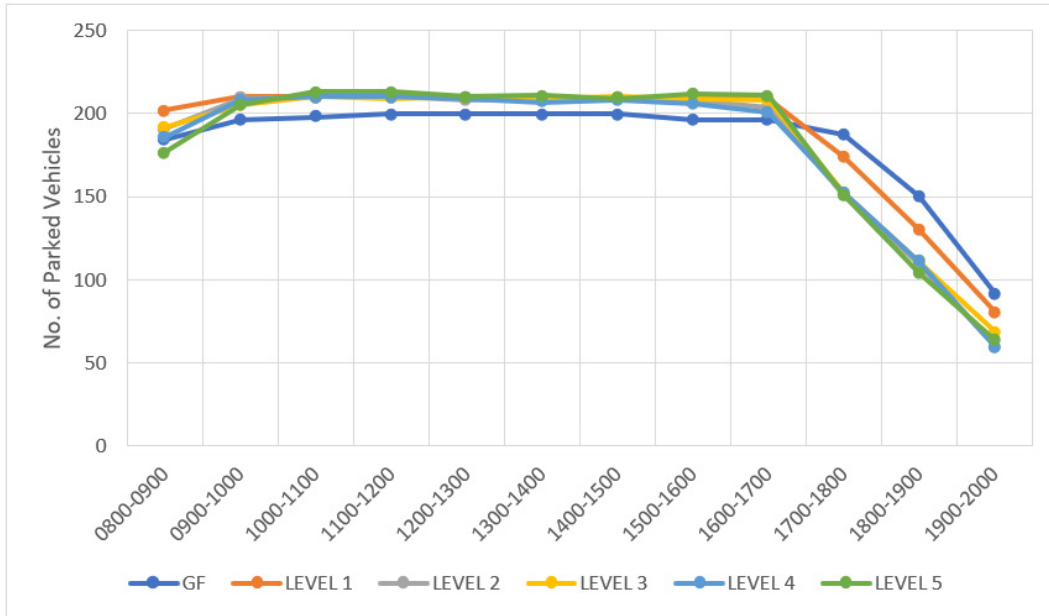

FIGURE 4. Parking accumulation pattern at the park-and-ride facility

The occupancy of the parking facility indicates the actual demand from the parking users to the available parking supply. High parking occupancy indicates high demand whereas low parking occupancy indicates low demand. Generally, parking occupancy varies according to the time in which it attracts the parking users to park at the facility. Like parking accumulation, it follows the working pattern of the commuters.

The parking occupancy at the selected PnR facility was higher during early and middle hours of the day, where it reaches close to 100% of the capacity than during late hours. Thus, it indicates that the parking demand during the early and middle hours was much higher than during late hours of the day. The average parking occupancy was near to 90% of the parking supply at each level of the facility during the entire survey period. Figure 5 illustrates this trend.
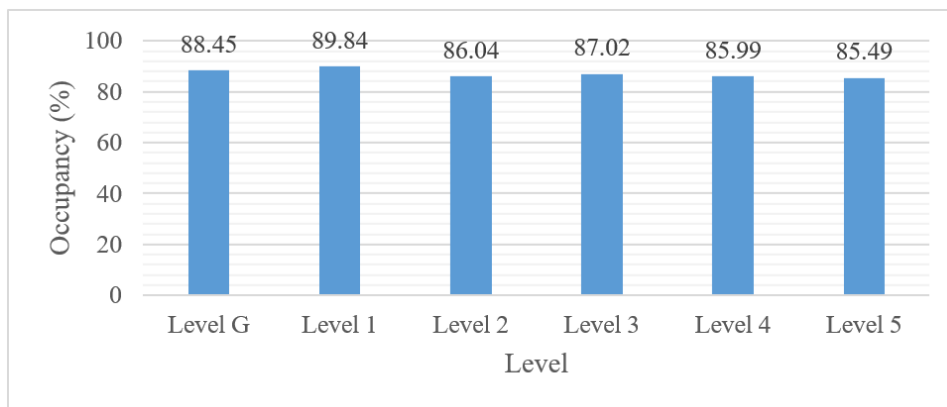

FIGURE 5. Parking occupancy at the park-and-ride facility

PARKING DURATION AND TURNOVER

Parking duration and parking turnover are directly related to each other. High parking turnover indicates shorter parking duration and on the other hand, low parking turnover indicates longer parking duration. The parking duration at the Gombak terminal LRT PnR facility indicates that this facility is a long-duration facility that is in line with parking accumulation and parking volume. The parking users have parked their vehicles at an average duration of more than 9

hours during the 12-hour parking survey. It again indicates that the parking users are the commuters who parked their vehicles to travel for work purposes.

Figure 6 shows the parking duration at each level of the PnR facility. Because of the longer parking duration, the parking turnover was, indeed, low. The average parking turnover was slightly more than one indicating each parking space, on average, was occupied by one vehicle during the entire parking survey. Figure 7 illustrates this trend. The findings also show that there is no clear difference in the parking turnover between each level of the parking facility. It is obviously due to most of the vehicles were parked and unparked at each level of the parking facility at almost the same time during the morning and evening hours.
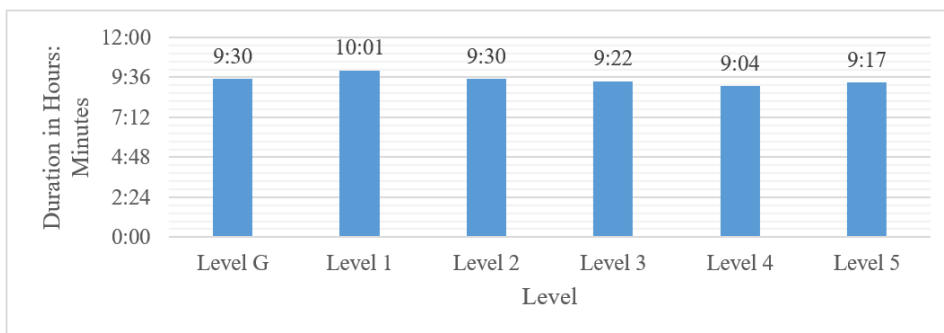
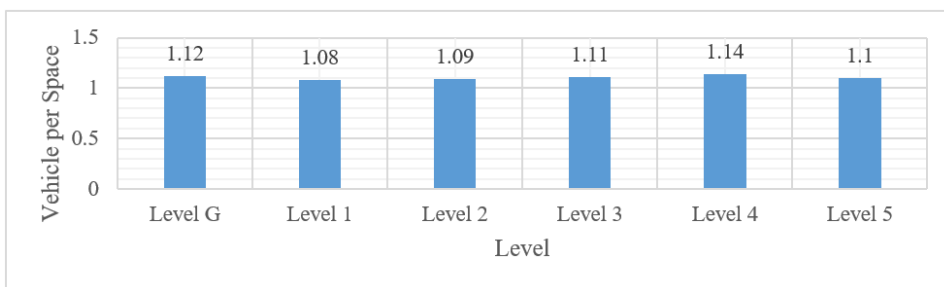FIGURE 6. Parking duration at each level of the park-and-ride facility

FIGURE 7. Parking turnover at each level of the park-and-ride facility

Figure 8 shows the relationship between parking duration and parking turnover at the PnR facility. This figure indicates that there is no distinct relationship between these two parking elements. The parking pattern at each level of the facility is almost identical which indicates the importance of this PnR facility in attracting a high number of parking users.

The vehicles were seen parked almost at the same time at each level of the facility. It indicates, again, that this PnR facility was used by the workers who after parking was then travelled to the workplaces by LRT where most of the offices begin at the same time in the morning.
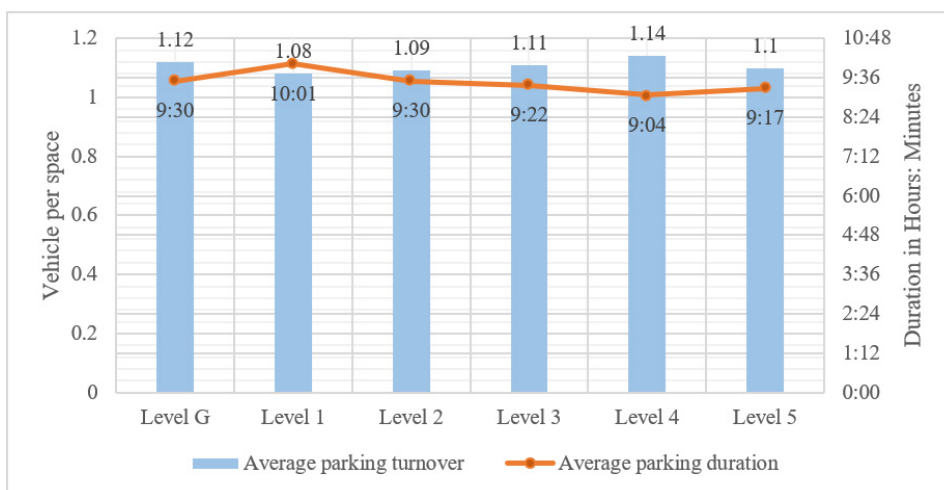
FIGURE 8. Average parking turnover and parking duration

PARKING QUESTIONNAIRE SURVEY

This section explains the results of the questionnaire survey administered to the targeted parking users at the PnR facility. This section covers socio-economic profiles, travel characteristics, and perceptions of the parking users on the parking availability, parking charges, parking accessibility, and other parking elements. Each of these aspects is highlighted in the following subsections.

SOCIO-ECONOMIC PROFILES OF THE PARKING USERS

The socio-economic profiles of the parking users will help to understand the social and economic profile of the parkers who park at the PnR facility. The socio-economic characteristics of the parking users that are covered in this study include gender, age, marital status, monthly income, car ownership, and employment. The "gender" of the parking users shows that the male parking users were slightly higher than their female counterparts. The male parking users were 51% and female 49%. More than 80% of the parking users were in the age group of 18-40 years old with a mean age of 31 years. On the marital status, about 53% of the parking users were "single" and 46% were "married". The monthly income of the parking users indicates about 60% of the parking users were earning a monthly income between RM 1000 and RM 5000 with an average monthly income of RM 4000. It indicates that most of the parking users who parked at the PnR facility were low and middle-income parkers. The findings on car ownership show that 65% of the parking users were having at least one car and 28% were having two cars and above. In Malaysia, the level of car ownership is high even among the low and middle-income groups. Most of the parking users (58%) were working in the private sectors followed by 19% in the public sectors.

TRAVEL CHARACTERISTICS OF THE PARKING USERS

The travel origin of the parking users will help to identify the point of generation and distance travelled by parking users to the PnR facility. The findings show that most of the parking users (45%) were travelling within a short distance (2 km radius) to park at the PnR facility. Figure 9 shows the point of travel origin of the parking users at the PnR facility. About 85% of the parking users were travelling for "work" after parking their vehicles at the PnR facility. Almost 85% of the respondents who parked at the PnR facility were "driving alone". The parking charges incurred by the respondents who parked at the PnR facility were between RM 50 and RM 500 per month.

PERCEPTIONS OF THE PARKING USERS ON PARKING SUPPLY

The perceptions of the parking users on parking infrastructure at the selected PnR facility are crucial to understand how they react to the provision of parking spaces to determine parking demand. Their views are useful and it is important to know the difficulties that they face whenever they park at the parking facility. Additionally, it will also help to relate with the findings from parking usage analysis. Because the main trip purpose of the parking users was "work", most of them (91%) were seen parking at the facility early in the morning and leaving from the facility late in the evening (80%). Thus, it indicates that most of the parking users were parked at the facility for a longer duration. It supports the findings from parking usage analysis that indicates, on average, the parking users were parked for more than 9 hours at the PnR facility. About 90% of the users were "very frequent" and "frequent" parking users at the facility. As expected, the parking users stated that they found it difficult to park at ground level and the first level as compared to other levels of the parking facility. The findings on the easiness to find a parking space at various levels of the PnR facility show that none of the parking users stated that it was easier to find a parking space at the ground level, 40% stated it was easier to find in the first level and more than 90% stated easier to find a parking space at the fifth level.

Thus, it shows that the higher the level of the parking facility, the easier it to find parking spaces. It indicates that the parking spaces at the lower levels were occupied first before the parking spaces at the higher levels were occupied. It shows the attractiveness of the parking spaces at lower levels due to ease of accessibility to the parking spaces and more convenience to transfer to the LRT station.

LEGEND

◀ Location of park and ride   ⭕ Distance radius from the facility

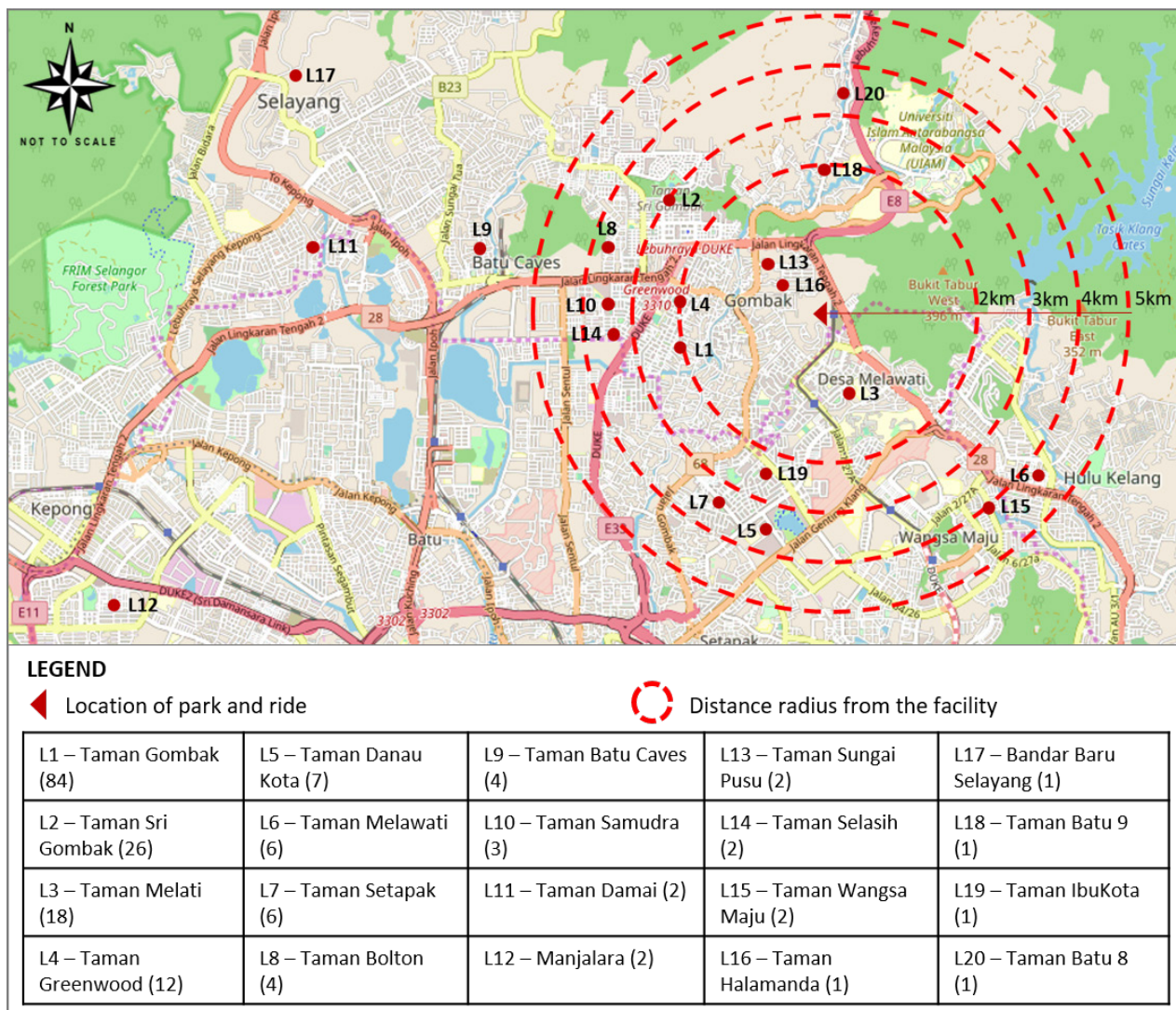|				
L1 – Taman Gombak (84)	L5 – Taman Danau Kota (7)	L9 – Taman Batu Caves (4)	L13 – Taman Sungai Pusu (2)	L17 – Bandar Baru Selayang (1)
L2 – Taman Sri Gombak (26)	L6 – Taman Melawati (6)	L10 – Taman Samudra (3)	L14 – Taman Selasih (2)	L18 – Taman Batu 9 (1)
L3 – Taman Melati (18)	L7 – Taman Setapak (6)	L11 – Taman Damai (2)	L15 – Taman Wangsa Maju (2)	L19 – Taman IbuKota (1)
L4 – Taman Greenwood (12)	L8 – Taman Bolton (4)	L12 – Manjalara (2)	L16 – Taman Halamanda (1)	L20 – Taman Batu 8 (1)

FIGURE 9. Point of origin of the parking users

There is no clear difference in parking behaviour by gender. Both male and female parking users in almost equal proportion were found parking at different levels of the parking facility. An almost equal number of male and female parking users have seen parking for longer hours and "very frequently" and "frequently" at the PnR facility. Comparing the income levels of the parking users, the findings show low-income group (RM 1000-RM 5000) was found parking more frequently (more than 80%) than the higher income groups. It shows that the low-income groups are using LRT services more frequently than high-income groups. There were no short-term parkers (3 hours and less) at the parking facility among the high-income groups. Most of the long-term parkers (more than 50%) were seen parking at ground level, fourth level, and fifth level, whereas short-term parkers (50% and more) were parked at the first, second and third level of the parking facility. It indicates that ground level and the top levels were more attractive for long-term parkers while

intermediate levels for short-term parkers. "Monday" is seen as the most difficult day of the week to find parking spaces to park the vehicle among the parking users. More than twice as many of the parking users stated that "Monday' is the difficult day to park their vehicles. It is contrary to other findings where "Wednesday", being the middle of the week, normally has the highest commute travel than other days of the week.

The parking users' perceptions on the provision of parking spaces and other facilities at the PnR facility were measured by a four-point Likert scale. A four-point Likert scale against a five-point was used to prevent a high number of respondents from answering "neutral" which otherwise would have led to clear ambiguity on the stated variables. Each of the drafted statements on the parking facility was measured by "strongly disagree" "disagree", "agree' and "strongly agree" points of measurement.

The views of the parking users on the parking facilities would help to indicate the conditions and standings of these

facilities that are being used regularly by the users. The parking supply and other related facilities must be adequate and appropriate to induce parking demand which, in turn, would make this facility attractive for greater use. When

the parking demand increases and reaches the capacity of the parking supply at the PnR facility, it allows a larger number of commuters to shift to public transit for their commute to various destinations at the city centres.
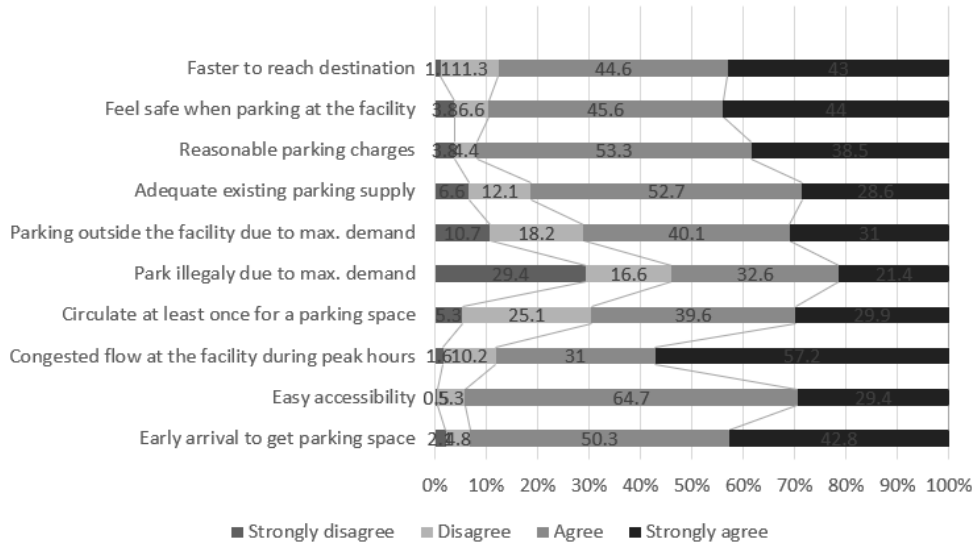

FIGURE 10. Level of agreement on parking facilities at the PnR facility

Figure 10 shows the level of agreement expressed by the parking users on the parking facilities at the PnR facility. The findings show that the parking spaces were adequate to meet the demand from the parking users at some time, but at other times, some of the users had expressed that they parked their vehicles at the undesignated locations both inside and outside the PnR facility because of non-availability of parking spaces. More than 70% of the users "agree" and "strongly agree" that they parked outside the PnR facility due to the non-availability of parking spaces. It supports the views of the users stating that the facility is usually congested during morning peak hours due to high parking demand and lack of parking spaces. Almost 90% of the users "agree" and "strongly agree" that the PnR facility is congested when parking at the facility during morning peak hours. It indicates that the PnR facility has reached its capacity and thus unable to accommodate an increasing number of vehicles at the facility. The parking users had expressed that improvement on some of the existing parking facilities should be made to further facilitate parking at the PnR facility. The responses on the improvements to the parking facilities are shown in Figure 11.

RECOMMENDATIONS AND CONCLUSIONS

Park-and-ride facility is one of the transportation demand management strategies to address the growing problem of

increasing private vehicles on the city roads. To increase the patronage on public transit and decrease the use of private transport in the city areas, it is vital to attract private vehicle users at the periphery of the city areas to park at PnR facility and shift to public transit. To realize this shift on a wider scale, it is important to accommodate the needs of the parking users at the PnR facility. It can be seen from the findings that the selected park-and-ride facility is a long-term parking facility catering mainly for work trips. With the average parking occupancy exceeding 85%, it reflects that this facility is highly utilized, and it is almost reached the maximum capacity. It is well supported with the findings from the views of the parking users who had expressed that they need to park at undesignated locations both inside and outside the PnR facility.

The findings from the views of the parking users revealed that poorly maintained automated system for entry, narrow accessways to the entrance to the parking facility, poor lighting system are some of the issues that are required to be addressed.

To address these issues, few recommendations were drawn which include; regular maintenance of automated gate system to allow smooth and quick entry to the parking spaces, widening the access at the entrance to the parking facility to accommodate more vehicles at less time, thus decreasing the congestion, and improving and maintaining the lighting system to increase the level of safety and security to the parking users. Additionally, it is also recommended to increase the number of parking spaces at

each level of the building to allow for high parking demand and hence decrease the level of discomfort to the parking users when parking and unparking at the facility. Another recommendation that is being suggested is to introduce a "smart parking system" so that the parking users will be duly informed about the availability of empty parking spaces at various levels of the building. This will help the parking users to save time in searching for parking spaces without having to circulate the different levels of the building.
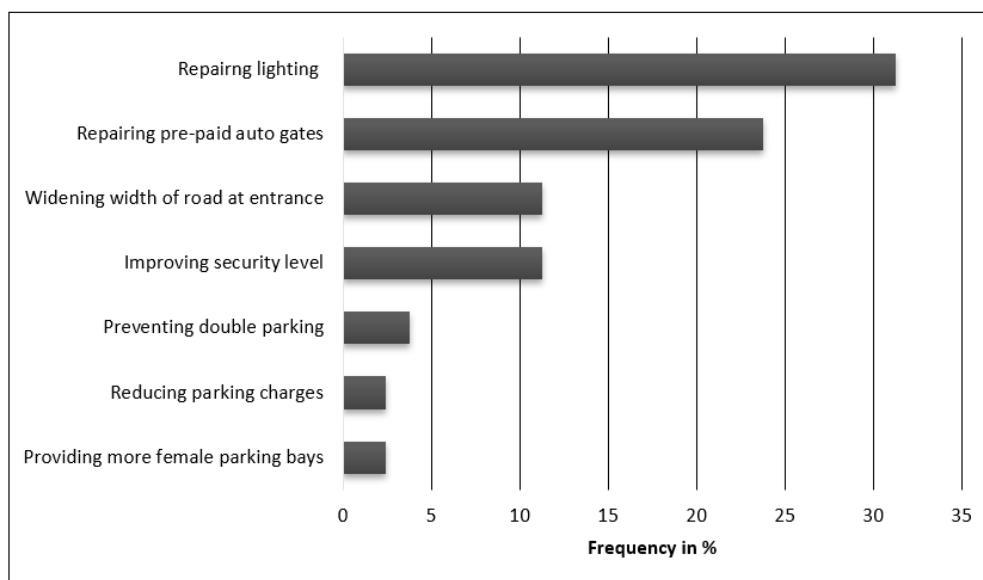

FIGURE 11. Responses on the improvement of parking facility at the PnR facility

In conclusion, it is pertinent to make the PnR facilities attractive mainly in terms of parking location, parking charges, parking supply, parking accessibility, so that it will eventually induce higher use of these facilities. When the number of parking users at the PnR facility increases, the patronage on the use of public transit either road-based or rail-based will also increase and thus limiting the number of private vehicles entering the city centres.

This, in turn, will have a positive impact on the reduction in traffic congestion, pollution, and improving urban mobility.

DECLARATION OF COMPETING INTEREST

None

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