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Research paper

Park and ride study at light rapid transit (LRT) stations in Puchong, Malaysia

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Abstract

This paper explored the factors influencing commuter's preferences of using park and ride (PnR), by investigating their travel mode choice behaviour, and assessing the effectiveness of PnR facilities. Binary logistic regression (BLR) was used to develop travel mode choice model which provides insight into commuter's considerations contributing to the utilisation of PnR facility. Several scenarios were modelled to investigate the effect of policy changes on commuter's travel mode shift, which could be essential in formulating effective strategy to promote the use of PnR. The results revealed working trip, short travel time (< 15 mins) and medium long travel distance (1–3 km), were the main considerations of commuter using PnR. The significant influencing factors were determined as travel distance from origin to departing station and from arriving distance to destination, trip purpose, frequency of using light rapid transit (LRT), education level and occupation. 3 scenarios were modelled which revealed that provision of parking subsidy, medium travel distance (around 10 km) and medium travel time (around 20 mins) encouraged commuter to use PnR while travelling in group discourage the use of PnR.

Keywords: *Light Rapid Transit (LRT); Mode Shift Model; Park-and-Ride; Regression Model.*

1. Introduction

An efficient and reliable public transportation system often has multiplier effects on economy growth. With an objective of stimulating sustainable economic growth and alleviate traffic congestion, the Malaysian Government has made major infrastructure investments in recent years to encourage greater utilisation of public transport, in the context of improving liveability and productivity of the country. However, the issues of car-oriented lifestyle and high private car ownership has significantly affected the utilisation of public transport. In recent decades, the modal share of public transport in Klang Valley has declined from 37% in 1990 to 19% in 2012 while modal share of the private vehicle has increased from 63% in 1990 to 81% in 2012 [1]. Meanwhile, the motorisation rate in Malaysia has increased tremendously in recent years. In 2015, it has recorded 26 million units of registered vehicles in Malaysia compared to 19 million in 2009 [2]. The increased reliance on private vehicles has given greater pressure on the capability of road infrastructure, thereafter incurred more traffic congestion in and around the city. In addition, the associated environmental impacts such as gas emission and noise pollution have immensely deteriorated the liveability of the city. Therefore, a well-integrated public transportation system is necessary to influence commuter's perceptions and their car-oriented behaviour into shifting from using private vehicle to using public transport.

Thus, park and ride (PnR) scheme is introduced to seamlessly integrate the use of private vehicle with public transport services to make public transport a more feasible alternative for commuting rather than driving. The provision of designated parking facility at public transport station provides alternative for commuters to park their vehicle and to continue their remaining journey by using public transport. By shifting their travel mode from using private vehicle to using public transport, it reduces the number of vehicles on road and subsequently mitigates traffic congestion in urban area.

PnR scheme was often evaluated by the utilisation pattern of parking facility and increase in public transport ridership. Many studies have suggested commuter's consideration was one of the most important determinants in choosing PnR as their travel mode. However, there were limited researches providing an in-depth understanding towards the impact of commuter considerations on the use of PnR. These considerations could be interrelated with each other directly or indirectly and thereon affect the PnR demand in practice. It is crucial for policymakers to recognise commuter's need to develop sustainable transport policy. Therefore, it necessitates reliable transportation forecasting to understand the influencing factors on commuter to utilise PnR facility.

In [3], it was revealed that factors influencing travel mode choice can be classified into three categories which are characteristic of travellers, characteristic of trips and characteristic of transport facility. With regards to characteristic of travellers, many researchers associate socioeconomic background such as income level, age, gender, occupation and car ownership with their travel mode choice. In [4], they investigated traveller's preferences on PnR facilities in Nanjing, China by using logit models. Their findings suggested the income class is associated with car ownership while the middle-income class has greater car ownership compared to other income classes and is the primary trip maker in the city, which corroborated with the research by [5]. Their investigation on PnR performance adopted revealed preferences survey on PnR users and non-PnR users. They highlighted that the non-PnR users were generally comprised of higher income group. However, the individual travel demand or desire of mobility were not con-

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sidered in the studies. In the case where commuter requires to make multiple trips in one day, it requires all destinations be well-connected and accessible by public transport, the associated costs shall be similar or lesser of alternative travel mode, else driving will be considered. Besides, many researches do not consider the nature of trips. For trips with uncertain length of stay and timing, higher mobility is often demanded, commuter considerations could be associated with the waiting time, transit time and operating hour of public transport services and PnR facility.

With regards to characteristic of trips, the total travel time of using PnR should be less than the total travel time of using private vehicle [6]. In [7], it adopted discrete choice models to examine the willingness of commuter of using PnR facilities. Their studies have clearly concluded that the total travel time and costs were the most influential factors on commuter's considerations of using PnR. In [8], it concluded the associated costs of PnR against other travel modes, have substantial influences on attracting new users and retaining existing user. The associated costs comprised of travel cost, fares, waiting cost and other measurable cost attributes of transport.

With regards to characteristics of transport facility, in [9], the mode change behaviour of PnR users was studied through empirical models developed with multinomial logistic regression. They identified that lower parking fares was the driving factor for commuters to choosing driving instead of using PnR. They further concluded that lower traveling time by using public transport resulted in greater proportion of commuter of choosing PnR mode over driving. In [10], their investigation on traveller's preferences of PnR mode choice revealed that reliability of public transport services was the most decisive factor of using PnR among other factors such as time, cost and parking aspects. In [11], PnR choice model was developed to simulate various policy measures through multiple simulations. It revealed that car drivers were generally concerned on parking location, the safety aspects and integration with other transit services.

This paper aims to explore the key considerations influencing commuter preferences on using PnR, and to investigate the effectiveness of PnR scheme and its effect on commuter travel mode shift.

2. Method

Three PnR facilities located adjacent to Light Rail Transit (LRT) stations in Puchong, namely IOI Puchong Jaya (IOI), Pusat Bandar Puchong (PBP), and Taman Perindustrian Puchong (TPP) station, were selected for investigation. These stations shared common characteristic in term of adjacent land use and accessibility to major expressways. Questionnaire was distributed randomly to boarding and alighting LRT commuters at respective stations and PnR facilities on weekends and weekdays during daytime. For the purpose of study, respondent who aged less than 18 years old or working at LRT station, were excluded as invalid response. 117 questionnaires were completed and 110 valid responses were collected.

Questionnaires survey was designed to understand commuter preferences on using PnR as travel mode. It comprised of two major components which were revealed preference (RP) questions and stated preference (SP) questions. The RP questions revealed information on respondent's socioeconomic characteristics, trip characteristics and parking behaviour while SP questions contained information relating to commuter's perceptions on using of PnR. For socioeconomic characteristics, it included information on respondent's education level, gender, employment status, average monthly income, subsidisation on parking and ticket fare, and private vehicle ownership. While for trip characteristics, it included information on respondent's trip purpose, travel group size, carpooling behaviour, number of trips made in a day, frequency of using LRT, travel mode, travel time, travel cost and travel distance from the origin to destination and etc. Lastly, for parking behaviour, it revealed information on respondent's parking duration, parking location, time to search parking, parking cost, and frequency of parking in a week.

Table 1: Shows the Key Findings on PNR Users in Questionnaires Survey

Characteristics of PnR user		Percentage (%)
Trip Purpose	Working	58.70
	Leisure	17.39
	Schooling	13.04
	Random	10.87
Travel Distance to LRT Station	<1km	6.52
	>3km	93.48
Travel Mode from LRT station to destination	Walking	84.78
	Bus/ Vehicle Drop-off	15.22
Travelling Time in LRT	< 5 mins	10.87
	> 15 mins	89.13
Frequency of using PnR	4-7 days a week	58.70
	1-3 days a week	13.04
	< 1 day a week	28.26
Average parking duration	< 5 hour	8
	> 5 hour	38

Inventory survey was conducted to assess the operational performance and effectiveness of PnR facility. The numbers of car, motorcycle and bike were recorded hourly in record form from 11.00 a.m. to 8.00 p.m. for both weekday and weekend. The inventory survey on parking facility and information extracted from questionnaire survey such as information containing respondent's parking duration, parking purpose, parking frequency, parking cost, time to search parking, was used to assess the performance of the parking facility. The information was interpreted and evaluated to determine user parking behaviour, parking occupancy, average parking duration etc. Moreover, the parking management system was assessed through on-site observations and interviews with representatives from parking operator to understand and evaluate their parking management strategy and operation.

Binary Logistic Regression (BLR) was selected to establish a PnR mode choice model to determine the probability of an individual of choosing PnR as travel mode. In the analysis, the response variable (dependent variable) was the probability of choosing PnR as travel mode while the predictors (independent variables) were the influencing attributes relating to socioeconomic, trips and parking characteristic.

3. Results and discussion

3.1. Model estimation and implications

In regression analysis, the coefficients of variables were estimated in statistical software and the logged odd of final model was shown in Equation (1);

$$Y' = -6.45 - 0.0640\ TimeOD - 0.257\ TimeAD + 0.0\ ModeAD_1 - 4.66\ ModeAD_3 - 2.50\ ModeAD_4 + 0.0\ CostDA_2 - 8.73\ CostDA_3 - 2.78\ CostDA_4 - 2.45\ CostDA_5 + 1.11\ CostDA_6 - 8.32\ CostDA_7 - 3.18\ CostDA_8 + 0.0\ DistOD_1 + 7.83\ DistOD_2 + 10.89\ DistOD_3 + 0.0\ DistAD_1 + 5.80\ DistAD_2 - 0.48\ DistAD_3 + 0.0\ Park_0 + 5.14\ Park_1 + 0.0\ Trip_1 - 2.26\ Trip_2 - 6.78\ Trip_3 - 6.00\ Trip_4 + 0.0\ Group_0 - 3.19\ Group_1 + 0.0\ LRT_1 + 5.98\ LRT_2 + 4.90\ LRT_3 + 0.0\ Edu_1 + 8.98\ Edu_2 + 7.23\ Edu_3 + 0.0\ Occ_2 + 1.10\ Occu_3 - 5.70\ Occ_4 + 9.42\ Occ_5 \quad (1)$$

Whereas the logit transformation of the logged odd of model was presented in Equation (2). This equation was used to calculate the probability of using PnR as travel mode. Alternatively, the probability of not using PnR as travel mode was given by Equation (3). The logged odd, Y' represent a value calculated from the equation comprising parameters which influence the value differently by having different coefficient in the equation. The logit transfor-

mation of logged odd expressed the value in term of probability to study the relationship of the parameter to the study objectives.

$$P(1) = \frac{exp(Y')}{1 + exp(Y')} \quad (2)$$

$$P(0) = 1 - \frac{exp(Y')}{1 + exp(Y')} \quad (3)$$

Table 1 shows the coding for each variable used in the regression model as presented in Equation (1).

Table 1: Variable's Dummy Coding for Regression Modelling

Variables	Options	Code	Denotations in Model
Occupation	College / University Student	2	Occ_2
	Employed	3	Occ_3
	Self-Employed / Unemployed	4	Occ_4
	Retired	5	Occ_5
Education Level	Primary / Secondary School	1	Edu_1
	Bachelor's Degree	2	Edu_2
	Master's / Doctoral Degree	3	Edu_3
Subsidy on Parking	Yes	1	Park_1
	No	0	Park_0
Trip Purpose	Random Trip	1	Trip_1
	Working Trip	2	Trip_2
	Leisure Trip	3	Trip_3
	School Trip	4	Trip_4
Frequency of using LRT in a week	4 - 7 days per week	1	LRT_1
	1 - 3 days per week	2	LRT_2
	< 1 days per week	3	LRT_3
Travel Group Size	1 (Travel alone)	0	Group_0
	> 1 (Travel in gang)	1	Group_1
Travel Time (Origin to Departing Station)			TimeOD
Travel Distance (Origin to Departing Station)	< 1km	1	DistOD_1
	1km - 3km	2	DistOD_2
	> 3km	3	DistOD_3
Travel Cost (Departing Station to Arriving Station)	≤ RM 2	2	CostDA_2
	≤ RM 3	3	CostDA_3
	≤ RM 4	4	CostDA_4
	≤ RM 5	5	CostDA_5
	≤ RM 6	6	CostDA_6
	≤ RM 7	7	CostDA_7
	> RM 7	8	CostDA_8
Travel Mode (Arriving Station to Destination)	Walking	1	ModeAD_1
	Bus	3	ModeAD_3
	Vehicle Pick up	4	ModeAD_4
Travel Time (Arriving Station to Destination)			TimeAD
Travel Distance (Arriving Station to Destination)	< 500m-1km	1	DistAD_1
	1km - 3km	2	DistAD_2
	> 3km	3	DistAD_3

To understand the impacts of variables in influencing the probability of using PnR, the odd ratios of several influencing variables such as subsidy on parking, travel distance and travel time from origin to departing station and from arriving station and travel group size were selected.

The subsidy on parking is positively influencing commuter preferences of choosing PnR over other alternative travel modes. The coefficient and odd ratio for providing parking subsidy are +5.14 and 170.6667, indicating the commuters would be more inclined to choose PnR rather than choosing other travel modes. The high odd ratio implied that providing subsidy on parking could potentially increase the probability of choosing PnR tremendously.

For travel times from origin to departing station and from arriving station to destination with an odd ratio of 0.9380 and 0.7737 respectively, the commuters would be 6.2% and 22.6% less likely to adopt PnR for any increase of travel time in minutes. Therefore, the accessibility to surrounding areas could be improved to reduce the travelling time and distance, thereon to encourage more commuters to participate PnR. Pedestrian bridge linking to surrounding areas from the station could be built to encourage more commuters to participate PnR and choose walking for their journey from arriving station to destination. With regard to travel group size, the coefficient of -3.19 and odd ratio of 0.0413 implied that travelling in group would negatively influence the likelihood of using PnR. Commuters would be 95.9% less likely to choose PnR as travel mode if they are travelling in group. The finding on the influence of commuters travelling in group could have substantial effect on promoting travel mode shift into using public transport only instead of promoting using PnR. Potential policy such as fare pricing which favours commuters travelling in group could be implemented to encourage more commuter change their car-oriented travel mode to using public transport only. For result interpretation, the travel distance of lesser than 1 km from origin to departing station was taken as base variable for comparison of odd ratios. With relative to base variable, two categories of travel distance with the range of 1km to 3km and more than 3 km, the odd ratios are 2518.7677 and 53791.3832 respectively. The high odd ratios would indicate that individuals having travel distance within the ranges of these categories would have high probability of adopting PnR.

3.2. Scenario modelling

The model developed was used to predict the likelihood of an individual of using PnR. Several scenarios were simulated to investigate the impacts of various influencing factors on commuter's preferences of using PnR while travelling. Therefore, through simulation, effective strategies can be proposed to promote the use of PnR. For variables like subsidy on parking and travel group size, the commuter data collected was used as the base data (reference data) for simulation and the proportional change of PnR user due to the change in variables, were compared against base data and reported. Whereas variables like travel distance, travel cost and trip purposes were manipulated and presented in the form of case studies.

3.2.1. Effect of parking subsidy on PNR

Two scenarios were simulated. In scenario 1, parking subsidy is provided while in scenario 2, parking subsidy is not provided. The results were presented in Fig. 1.

In scenario 1, 65.35% of commuters would choose to use PnR, having an increase of 19.81% in proportion compared to 45.54% in base data. Whereas in scenario 2, there was no significant differences in the proportion of PnR user against base data. It could be deduced that preferences of using PnR is influenced by the provision of parking subsidy to commuters. Strategies could be recommended such as providing incentives or subsidy on parking to encourage commuters to park their vehicle at parking facility and use LRT to travel to their destination. Potential strategy on parking charge could be formulated such as providing discounted or free parking charges on specific day to attract new or potential PnR users which gradually cultivate the culture of using PnR and eventually transform their travel behaviour. Cost concern was significant in deciding the adoption of PnR, parking charge could be revised, making PnR a more economical option compared to other alternative modes.

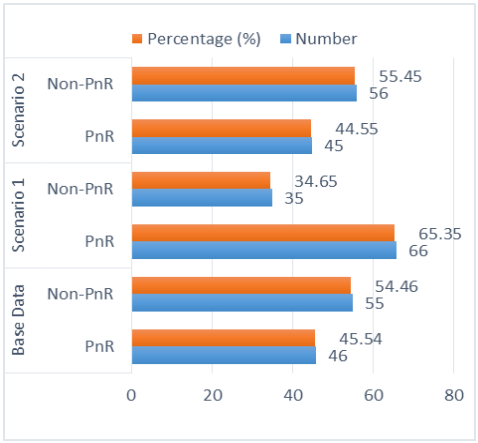


Fig. 1: Proportion of Commuters Due to Parking Subsidy.

3.2.2. Effect of travel group size on PNR

Two scenarios were simulated which commuter travelling in-group in scenario 1 and commuter travelling alone in scenario 2. The results were presented in Fig. 2.

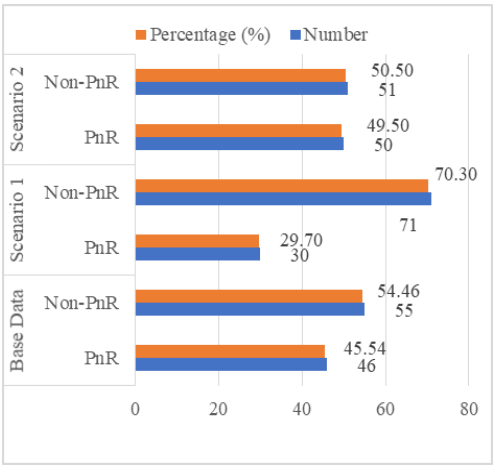


Fig. 2: Proportion of Commuters Due to Travel Group Size.

For scenario 1, the proportion of PnR users (29.70%) reduced significantly by 15.84% compared to 45.54% in base data. Whereas for scenario 2, a slight increase of 3.96% in the proportion of PnR user were observed. From these findings, it could be deduced that travelling in group would have greater effect on increasing non PnR users instead of PnR users. However, these findings revealed great potential of PnR users to shift their travel mode from using public transport only to driving by encouraging them to travel in group. This would affect the utilisation of public transport and make greater contribution on traffic congestion.

3.2.3. Effect of travel time and travel distance on PNR

Three scenarios namely, scenario 1, 2 and 3, representing short, medium and long-distance travel were defined in simulation and only travel distance and travel time from origin to departing station were considered. In scenario 1, travel distance and travel time were defined as 2km and 10mins while for scenario 2 and 3, it was defined as 10km and 20 mins, and 20km and 35mins respectively. The results were presented in Fig. 3.

From the scenarios 2 and 3, it was observed that majority of commuters would consider using PnR for medium (71.29%) and long-distance travel (61.39%). Whereas in scenario 1 for short distance travel, a slight increase (7.93%) in the proportion of PnR user was observed compared to base data. Therefore, it could be deduced that higher proportion commuters would consider using PnR for medium and long travel distance, however some commuters would consider alternative travel modes for long distance travel such as using vehicle drop-off or public transport to travel to departing station. This preference could be addressed to commuters tend to avoid traffic congestion, driving stresses and productivity loss due to long distance travel.

Improvement on accessibility through provision of pedestrian bridge could enhance the connectivity to surrounding areas by reducing the respective travel time and travel distance, creating a pedestrian friendly environment to attract more commuters to adopt PnR. In addition, the use of electronic bike (E-bike) could be encouraged to shorten the transition time. The significant saving on time could potentially attract more PnR user as the modelled scenario suggested.

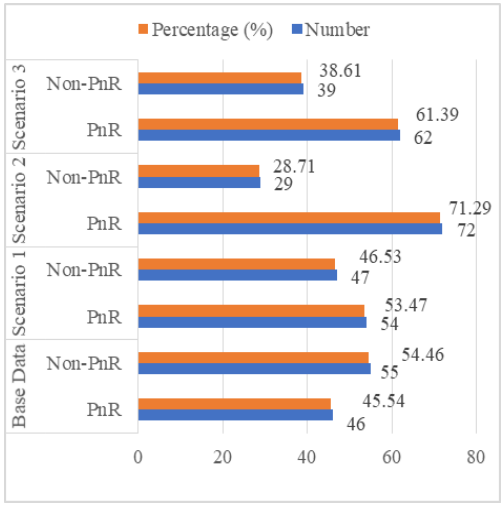


Fig. 3: Proportion of Commuters Due to Travel Time and Travel Distance.

4. Conclusion

With regard to operational performance and effectiveness of PnR scheme, the inventory survey at parking facilities revealed that all parking facilities were relatively underutilised on both weekdays and weekends. Only PBP LRT station was over utilized on weekday due to limited parking bays and high parking demand. Findings suggested majority of trips were working trips, having the highest parking frequency and average parking duration compared to leisure, schooling and random trips. Automated parking charging mechanism could be implemented to regulate unintended use of parking facility by parkers through implementing differential parking charges.

Commuter preferences of choosing PnR as travel mode was investigated with questionnaire survey. Results revealed that commuter would consider using PnR in the condition of working trip purpose, short travel time (< 15 min) and short travel distance (3 km) for journey from origin to departing station and from arriving to destination. In statistical analysis, educational level, frequency of using LRT, trip purpose, travel distance from origin to departing station and from arriving station to destination, and occupation were the significant influencing variables of an individual of choosing PnR over other alternative modes.

A PnR mode choice model was established through binary logistic regression to predict the likelihood of an individual of choosing PnR as travel mode. To stimulate policy changes, three scenarios were modelled. In case subsidy on parking was provided, more commuters would consider using PnR whereas there is no significant difference on proportion change while subsidy on parking is not provided. In the case of commuters travelling in group, more commuters would consider using other travel mode instead of using PnR. With regards to the effect of travel time and travel distance, more commuters would opt for using PnR for medium (1 – 3 km) and long-distance (> 3km) trip from origin to departing station. The finding suggested that some commuters would choose alternative travel mode instead of PnR for long distance travel which could be associated to commuter concerns on traffic congestion, driving stresses, and productivity loss relating to driving.

To further complement the utilisation of PnR facility, few recommendations was suggested. Providing incentive on parking to commuters could potentially encourage them to adopt PnR scheme. Secondly, improvements on accessibility reduces the respective travel time and travel distance, therefore could attract more commuters to adopt PnR. The use of electronic bike (e-bike) could be encouraged to shorten the travel time as well.

This research has established a framework from which subsequent studies could be conducted to achieve more diverse research and to refine the methodologies towards more comprehensive results. For future research purposes, several influencing factors such as subsidy on ticket fare, alternative travel mode and its trip attributes, parking charges etc., which are not included in this paper, could be investigated to determine the respective impact on using PnR in future study. Alternatively, the previous and current travel behaviour of commuters could be compared in term of travel duration, travel distance and travel cost to identify the influencing factors on their travel mode shift.

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