TRANSITION IN MODE CHOICE DUE TO MOTORIZATION AND IMPROVEMENT OF PUBLIC TRANSPORTATION SYSTEM IN JAKARTA

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ABSTRACT

The Jakarta metropolitan area of Indonesia with 24 million population is the capital region of one of the emerging countries. Along with economic development, the number of motorized trips, especially, use of motorcycles has been rapidly increasing, and urban transportation problems, such as traffic congestion, are worsening even while the city has introduced a bus rapid transit (BRT) system. A survey revealed the preferences of residents along the BRT corridors, and indicated a transition in mode choice before and after the introduction of the BRT system and the characteristics of these preferences were identified. In addition, through development of a simple multi-nominal logit model, it is revealed that the history of the transition to BRT may affect the future transition to a mass rapid transit (MRT) system.

Keywords: Jakarta, Mode Choice, Trip diary survey, Motorcycle, Developing countries

1. INTRODUCTION

The city of Jakarta is the capital of the Republic of Indonesia and the largest city in the country. Jakarta city and the surrounding 8 municipalities comprise Jakarta metropolitan area with approximately 24 million population according to the 2005 intermediate population census. The gross regional domestic product (GRDP) of Jabodetabek reached Rp.617 trillion (Indonesian rupiahs) (approx. 65 billion US dollars) in 2005, which is approximately 22

percent of the total Indonesian gross domestic product (GDP); thus, it is economically the most important area of the country. Although there are large gaps between districts, the GRDP per capita of a district in Jakarta has reached the level of developed countries. Along with economic development, the number of motorized trips, especially, use of motorcycles has been rapidly increasing. For instance, the number of registered motorcycles increased almost three times in this decade. This aggravated urban transportation problems, such as traffic congestion, and they are worsening in the Jakarta metropolitan area. It is feared that this will hinder economic development by suffocating the flow of people and goods. Distribution capabilities have suffered because of longer travel times, and environmental decline caused by air pollution, due partly to vehicle exhaust, has become a social issue.

In this regard, Jakarta city is planning to provide new transport modes such as BRT (bus rapid transit), MRT (mass rapid transit), and monorail. In fact, operation of the first BRT line commenced in January, 2004, and the government of DKI Jakarta gradually expanded the BRT network, and eight routes were in operation as of January 2010. Furthermore, an additional two routes are planned to be operating by the end of 2010. The first roughly 14 km of MRT line from the central business district (CBD) to the southern part of the city is expected to start operation by 2016 utilizing Japan's official development assistance (ODA) loan. With the steady progress of BRT and MRT lines, the Jakarta city government is discussing to adopt a road pricing policy to restrict the car traffic volume in the CBD because simple improvement of public transport may not be enough to induce the car users to shift to public transport.

It is anticipated that there are many large cities in rapidly growing developing countries facing similar transportation problems. As mentioned in the Jakarta metropolitan transportation master plan (JICA and BAPPENAS, 2004), how to shift private mode to public mode of transport is considered as a common concern for those cities. While a conventional approach for them was improvement of public bus service as well as development of MRT systems, BRT is currently a more typical option as a transient mode to MRT due to the smaller size of investment for the local authorities. In this regard, how previous use of a transportation mode affects future modal choice can be a significant factor to project future travel behaviour in modal choice especially in rapid changing environments. For instance, previous BRT users may be easy to transfer to MRT but previous car and motorcycle users may stick to private modes of transport.

As such, this paper presents the transition in mode choice in Jakarta metropolitan area as well as the effect of transportation mode choice history on future mode choice by utilizing a home interview survey on past, current and future transportation mode choices.

2. CURRENT TRANSPORTATION IN JAKARTA

2.1 Motorization

In light of substantial changes in Jakarta's transport system during the second half of this decade, one significant change is the increase in the number of motorized private transport modes, especially motorcycles. Although the increase in gross regional domestic products per capita in the last 5 years was roughly 20%, the number of registered motorcycles in Jakarta was almost doubled and that of cars was increased more than 25% in this five years.

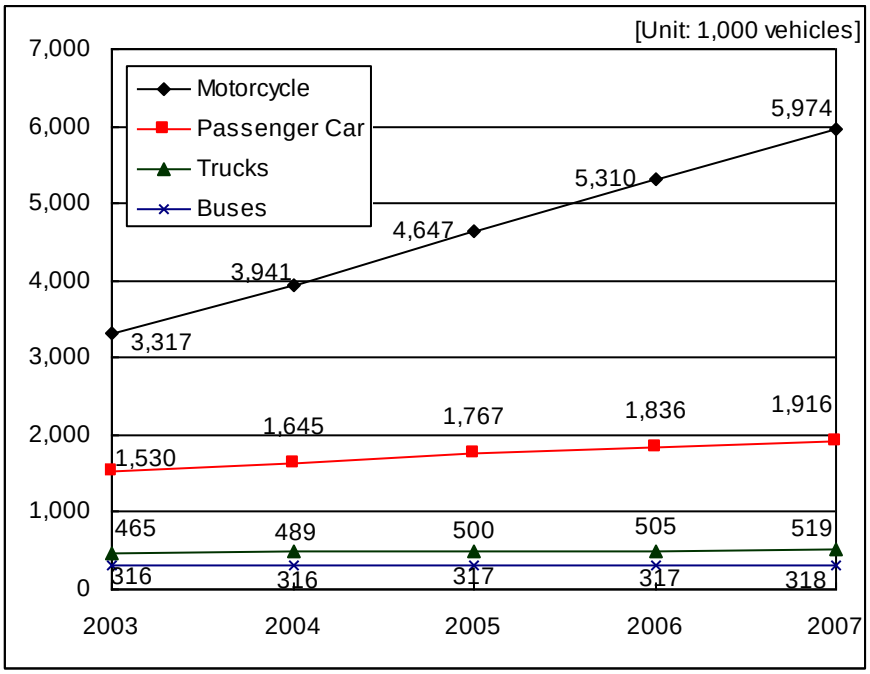
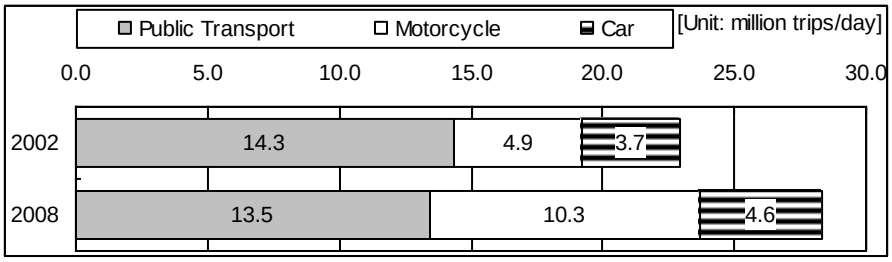


Figure 1 – Vehicle registration numbers in Jakarta city (BPS DKI, 2008)

In line with the surge in registered vehicles, car and motorcycle use increased in six years. This is corroborated by the result of the traffic count survey along the boundary of Jakarta city. The traffic volume of motorcycles has almost tripled in this decade whist the increase in passenger cars is limited or rather decreased accordingly (JICA, 2010). Since road development in Jakarta city is limited due to the land acquisition problem, it is anticipated that this will aggravate the congestion in Jakarta.



Note: Non-motorized transport is excluded. 2002 data is estimated from person trip survey and 2008 data is projected by the survey on revealed preferences and socio economic conditions (JICA, 2010).

Figure 2 – Transition in mode choice in 2002 and 2008

2.2 Improvement of public transportation system

The city of Jakarta is keen to develop a BRT system with a dedicated lane and stations called “Transjakarta”. Transjakarta started their operation in 2004 and 8 routes, with a total length of 97 km, are currently carrying 200,000 daily passengers in Jakarta city. The city government has developed almost 100km of BRT network in four years. An additional two routes are planned to be operating by the end of 2010. Furthermore, detail design of 3 routes has already finished and will start operation after the completion of the preceding 2 routes.

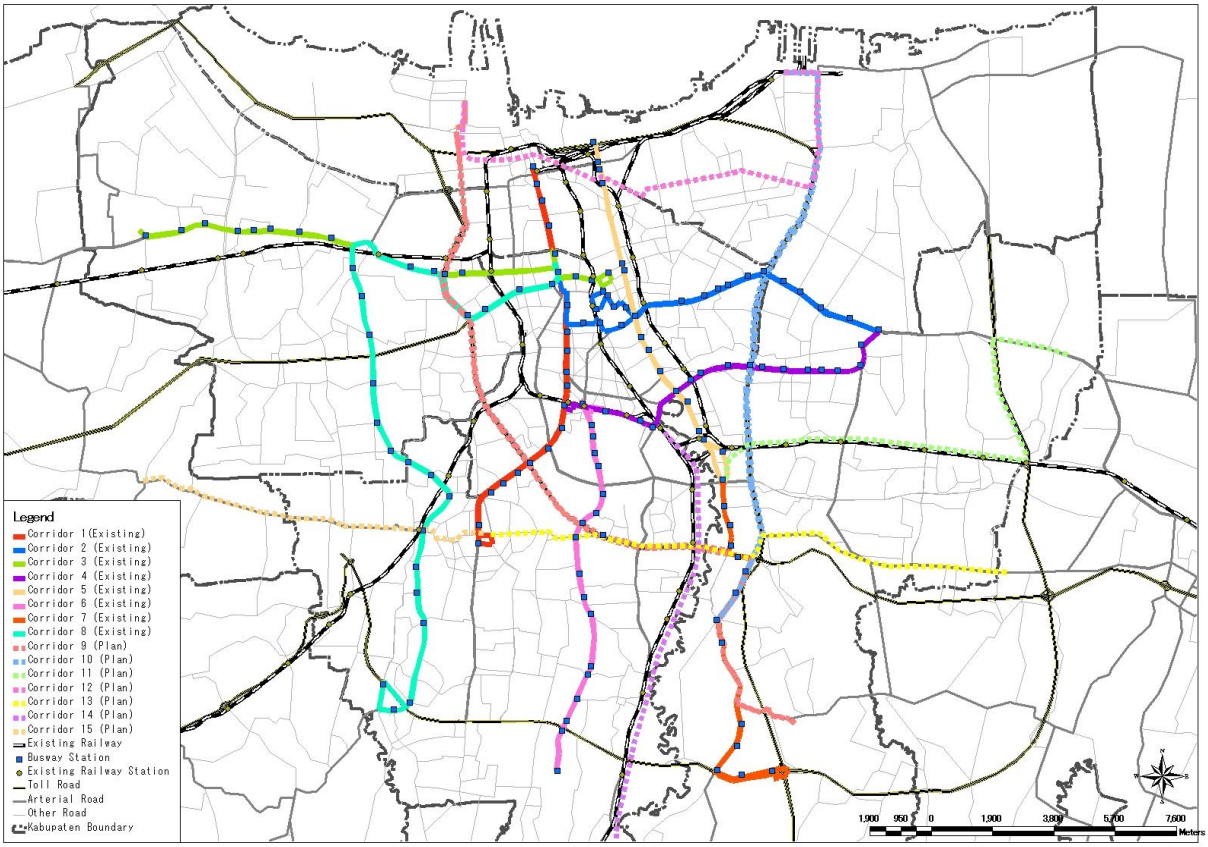


Figure 3 – BRT network in Jakarta

Table I – Annual operational indices of BRT in Jakarta

Year	Unit	2004	2005	2006	2007	2008
Operated Corridor		Corridor I	Corridor I	Corridor I, II, III	Corridor I - VII	Corridor I - VII
Corridor Length	km	12.90	12.90	45.90	97.35	97.35
Annual Passengers	million pax. per year	15.94	20.80	38.83	61.44	74.62
Bus-km	million bus-km per year	4.65	5.48	13.18	24.50	29.86
Passenger per Bus-km	Passenger per bus-km	3.43	3.79	2.94	2.51	2.50
Fare level	Rupiahs (*USD*)	2,500 (*0.27*)	Jan-Sep; 2500 (*0.27*) 3500 Oct-Dec; (*0.37*)	3,500 (*0.37*)	3,500 (*0.37*)	3,500 (*0.37*)

3. DATA SOURCE

3.1 Interview survey on mode choice

The interview survey on past, present and stated preference on mode choice was conducted during 3 weeks in June 2009 and covered 1,404 samples (700 households). The survey was in the course of the study for the planned MRT system. While the survey was conducted at planned MRT corridors taking different level of accessibility and income level into account, respondents along the BRT corridor 1 and corridor 3 with roughly 1 km buffers were extracted for this paper. The sample size for this analysis was 861 respondents (431 households) consisting of 367 commuter respondents and 494 non-commuter respondents.

Table II – Samples of the stated preference survey for this paper

Survey Type	No. of Samples
- Commuter Respondents	367
- Non Commuter Respondents	494
Total	861

The home interview survey was carried out using a survey form. The surveyors visited the homes, interviewed the respondents, and recorded responses into the survey form. Since the primary objective of the survey was to understand mode choice with an MRT system and electronic road pricing (ERP) system, the project summary of the MRT system as well as ERP was explained before asking questions of the respondents. The alignment of MRT the line, travel time, estimated travel time, and information on crowding condition of the MRT

system were also briefed by the interviewer. The questionnaire forms consisted of an introduction to MRT and a road pricing system, household survey form, commuter survey form and non-commuter survey form. The commuter survey was utilized for all commuting household members and the non-commuter survey form was utilized for those who do not commute.

3.2 Sample characteristics

Household income level has been a significant factor in travel behaviour especially modal choice in developing countries. While the survey was intended to collect varieties of income level samples, respondents with middle level of household income were dominant. Based on the relations between household income level and car/motorcycle ownership, low, middle and high income households were classified as shown below. Car ownership is also shown below Table IV. This also shows that a variety of samples in terms of vehicle ownership were collected in the Stated Preference Survey.

Table III – Household Income Distribution

Household Income Classification	Monthly Household Income in Million Rupiahs	Monthly Household Income in USD	Number of Household	Share
Low	Less than 1	Less than 106	41	9.5%
	1.0 – 1.4	106 – 158	51	11.8%
Middle	1.5 – 1.9	159 – 212	35	8.1%
	2.0 – 2.9	213 – 318	45	10.4%
	3.0 – 3.9	319 – 426	30	7.0%
	4.0 – 4.9	425 – 531	30	7.0%
	5.0 – 5.9	532 – 687	122	28.3%
High	6.0 – 7.4	638 – 796	32	7.4%
	7.5 – 9.9	797 – 1,062	20	4.6%
	More than 10	More than 1,063	23	5.3%
Unknown			2	0.5%
Total			700	100%

Table IV – Household car and motorcycle ownership

N=431 (100%)		Motorcycle Ownership				
		Not owing	1	2	3 & more	Total
Car Ownership	Not owing	11.8%	29.9%	11.1%	2.3%	55.2%
	1	7.7%	15.8%	3.0%	1.6%	28.1%
	2	6.0%	4.2%	1.4%	0.2%	11.8%
	3 & more	1.4%	2.3%	0.9%	0.2%	4.9%
	Total	26.9%	52.2%	16.5%	4.4%	100.0%

4. TRANSITION IN MODE CHOICE

4.1 Mode choice before BRT system and current mode

Since it is expected that there have been significant changes in mode choice behaviour in this last half decade, transition in mode choice behaviour was analyzed. Transportation mode choice before the implementation of the BRT system and commuting/residential place before the implementation of BRT were also investigated in the interviews. Through these questions, the mode choice data become almost equivalent to panel survey data. Comparison of the mode choice before the BRT system and current choice is shown below. The analysis was focused on respondents whose address was the same before and after the implementation of the BRT system. For commuting purpose analysis, only the respondents whose workplace and school was same were utilized for comparison. For non-commuting trips, a hypothetical destination was set by the interviewer randomly and the mode choice before and after the BRT system was analyzed.

It is noteworthy that the share of private vehicles has remained almost the same in this five year period for commuting trips while BRT system was installed to the surveyed locations and yet a significant increase in the number of motorcycles is observed in the city. Instead, the share of other public transport (mainly buses) decreased and was replaced by the new BRT system. In terms of commuting purpose, the city's intention of modal shift by installation of the new BRT system was not achieved for the surveyed corridors.

For non-commuting trips, the behaviour is unique by income level. The share of low income motorcycle users has increased. This may be explained by dissemination of motorcycle loans for low income groups and the current surge in motorcycle ownership. On the other hand, the share of public transport (BRT and other public transport) has increased for respondents with high and middle household incomes. For the middle income group, the use of public transport increased to equal roughly 4% of all modes. Travel speed of the BRT system in peak hours is not always competitive due to congestion at intersections where dedicated lanes for the BRT system have not been completed. This might affect the mode choice of commuting trips.

Against the assumption of the surge in motorcycle use, the share of motorcycles was not increased or rather decreased as a whole except for low income non-commuting trips. Since the survey was targeted at BRT corridors where public transportation service level has improved, it is assumed that the surge in motorcycle use may be observed in the areas beyond BRT corridors. The increase in trip rate due to motorcycle use may also explain the growing number of motorcycles in traffic count surveys.

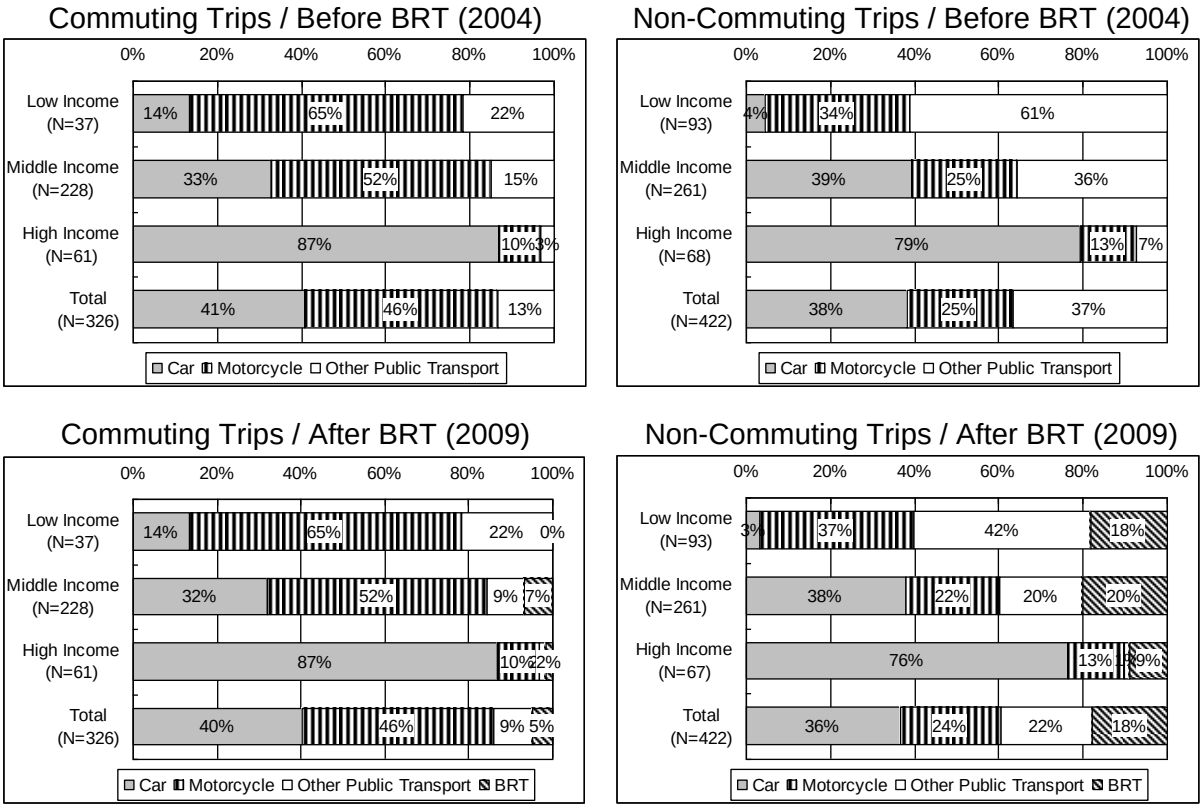


Figure 4 – Mode choice before and after BRT implementation

4.2 Reasons for mode choice

The reasons for choosing the current mode of transport were also investigated during the interviews. The choice set for the questions was prepared considering similar survey results and opinions of local residents. The question was multiple choice style and the top 7 reasons by transportation mode are shown below. The results well described characteristics of the traffic condition in the Jakarta metropolitan area. Car users prefer flexibility and comfort rather than time and price. In the Jakarta metropolitan area, travel time of cars and buses are quite difficult to project due to sever congestion. Since the motorcycle is a virtually "congestion-free" mode of transport by running through the narrow space between cars, it is quite evident that the majority of motorcycle users prefer a faster mode. They also evaluate its convenience as high.

BRT was developed by the city government to improve the service level of public transport including punctuality, comfort and an affordable fare level by providing dedicated lanes, introduction of new shelters and buses. These characteristics represent the reasons that some interviewees preferred the BRT system while other public transport users seek lower price and convenience.

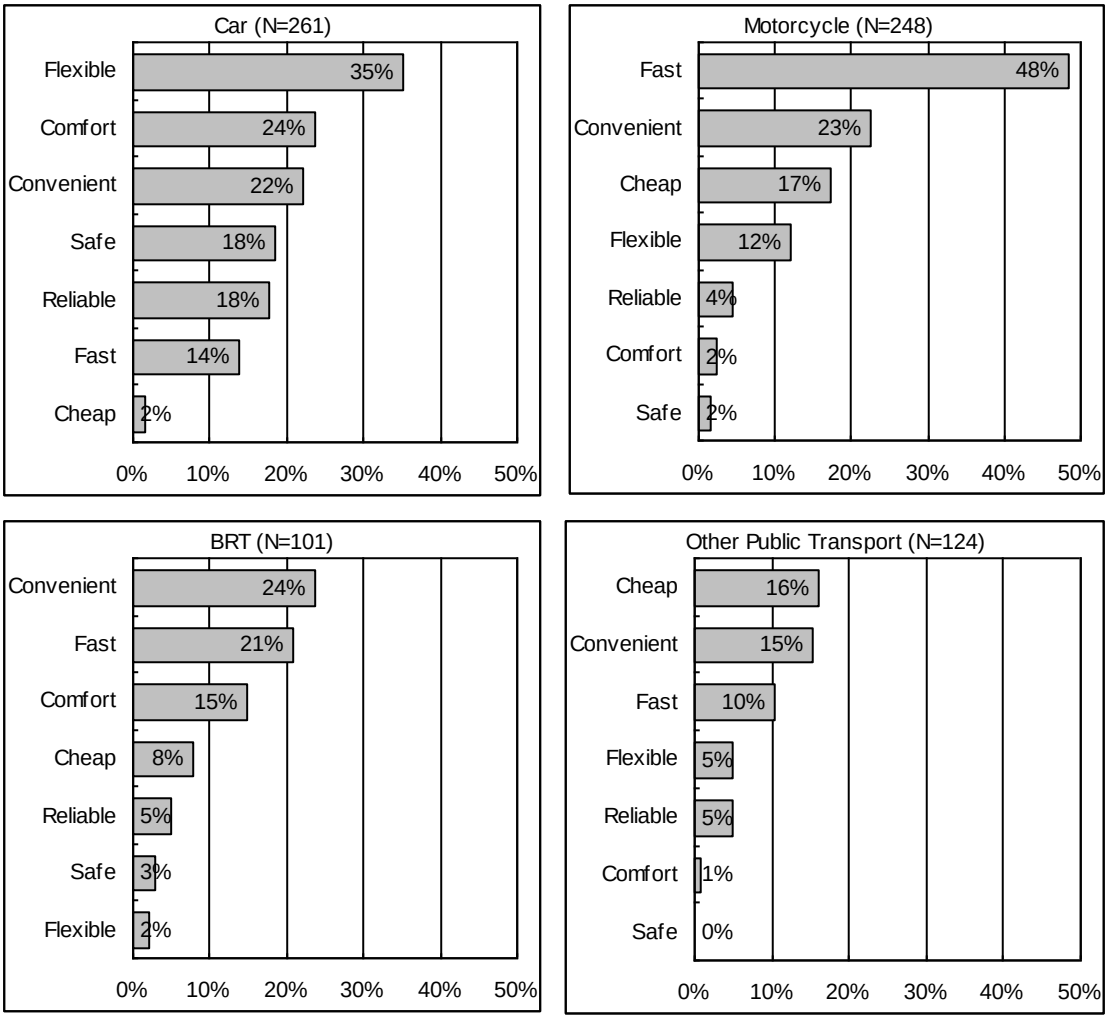


Figure 5 – Reasons for current mode choice

4.3 Classification of transition in mode choice

The observed transition in mode choice is summarized as; private mode (car and motorcycle) to BRT (Prv-Brt), public transport to motorcycle (Pub-Mc), and public transport to BRT (Pub-Brt). While the majority of respondents have not changed their mode of transportation, roughly 5.2% of commuter respondents and 18.5% of non-commuter respondents have changed their mode in this five year period.

Table V – Transition in mode choice (commuter trips)

N=326 (100%)		Mode choice after BRT			
		Car	Motorcycle	Other Public Transport	BRT
Before BRT	Car	131 (40.2%)	-	-	2 (0.6%)
	Motorcycle	-	148 (45.4%)	-	1 (0.3%)
	Other Public Transport	-	1 (0.3%)	30 (9.2%)	13 (4.0%)

Table VI – Transition in mode choice (non-commuter trips)

N=422 (100%)		Mode choice after BRT			
		Car	Motorcycle	Other Public Transport	BRT
Before BRT	Car	154 (36.5%)	-	-	7 (1.7%)
	Motorcycle	-	98 (23.2%)	-	8 (1.9%)
	Other Public Transport	-	3 (0.7%)	92 (21.8%)	60 (14.2%)

4.4 Characteristics of transition type

The characteristics of this transition were analyzed by cross tabulation analysis. In terms of income level, a higher percentage of low and middle household income respondents changed their transportation mode. It is also noteworthy that respondents with higher household income have a slight tendency to change their mode in spite of installation of the new BRT system. While GRDP per capita of some districts in Jakarta have reached the level of developed countries, there are huge gaps among districts as well as social classes. Since personal security in transportation is one of the most important issues in transportation especially for the higher income households (JICA and BAPPENAS, 2004), it is expected that they will not shift to public mode of transport without improvement in security issues.

The cross tabulation analysis with walking access time to BRT stations showed a higher rate of transition to BRT for respondents within 15 minutes access to a BRT station. In terms of travel distance of the trips, 5 to 15 km range showed a higher rate of transition. This implies that modal shift to a new public transport system is expected for those groups.

Table VII – Transition in Mode Choice and Household Income Level (Commuting and Non-Commuting Trips)

Income Group	Sample size	Car-Car	Mc-Mc	Pub-Pub	Prv-Brt	Pub-Brt	Pub-Mc
Low Income	130	6%	43%	36%	2%	12%	2%
Middle Income	489	35%	36%	15%	3%	11%	0%
High Income	129	81%	12%	2%	2%	4%	0%

Table VIII– Transition in Mode Choice and Access to BRT Stations (Commuting and Non-Commuting Trips)

Walking Time to BRT Station	Sample size	Car-Car	Mc-Mc	Pub-Pub	Prv-Brt	Pub-Brt	Pub-Mc
0 -14 minutes	318	31%	35%	16%	3%	14%	1%
15 + minutes	432	43%	31%	16%	3%	6%	0%

Table IX – Transition in Mode Choice and Travel Distance (Commuting and Non-Commuting Trips)

Travel Distance	Sample size	Car-Car	Mc-Mc	Pub-Pub	Prv-Brt	Pub-Brt	Pub-Mc
0-4km	292	27%	41%	26%	1%	5%	0%
5-9km	204	34%	31%	15%	2%	16%	1%
10-14km	165	52%	22%	8%	6%	11%	1%
15+km	89	57%	29%	4%	2%	7%	0%

5. STATED PREFERENCE ON MRT USE

In addition to the preference revealed on mode choice before and after implementation of the BRT system, stated preferences on the MRT system was also investigated in the interviews. In the course of the interviews, the planned MRT system in Jakarta metropolitan area was explicated including expected travel time, congestion level, planned stations, headway and so forth. The new MRT system is mostly planned along existing BRT corridors, the current BRT system is assumed to be removed if the parallel MRT system is completed. Since the planned electronic road pricing (ERP) system may give significant impact on travel behaviour, the ERP system details such as location, pricing methodology and pricing level was also explained. Based on the proper understanding of the new policy, stated preferences on mode choice in several pricing conditions were investigated in the interviews. The pricing conditions were set by combination of MRT fare level and ERP charge level.

Utilizing the aforementioned survey on MRT use, a modal choice model for motorized transportation was developed for the purpose of understanding the effect of the current experience of BRT use on future MRT choice. A conventional multi-nominal logit model, which can represent the unique characteristics of each choice, was employed. The formula of the multi-nominal logit model is shown below.

$$P_{in} = \frac{\exp(V_i)}{\sum_j \exp(V_j)}$$

P_{in} : probability to choose choice *i* of choice set *n*

V_i : a systematic component of utility for choice *i*

A utility of a choice is explained by liner function of socio-economic attributes.

$$V_i = \beta_1 Z_{1i} + \beta_2 Z_{2i} + \cdots + \beta_k Z_{ki}$$

Z_{1i} : an explaining variable of choice *i* (socio-economic attributes are usually applied)

β_1 : a parameter for an explaining variable 1

The choice set is car, motorcycle, public transportation other than MRT (mainly bus transport) and the MRT system. The estimated parameters of the multi nominal choice model for commuting trips are shown below. While variety of variables such as access to MRT stations, the number of transfers, waiting time, toll for toll roads are examined, the following variables are identified as significant. Travel time is initially incorporated as a common variable for all choices, it was not significant enough to be a detraction for car and public transport mode. The current choice of BRT for commuting purposes meaning the experience of transition to BRT is incorporated as a variable.

The estimated parameters of the multi-nominal choice model for commuters are shown below. The McFadden's adjusted r-squared was 0.231 and this model has adequate likelihood for the analysis. The dummy variable for the BRT experience indicated a positive affect to future MRT use. This implies that current BRT users have a tendency to shift to the MRT system compared with other mode's users, who haven't shifted to the BRT system. This implies that installation of the variables of previous change in transportation mode may increase the reliability of the model. Since local and even central governments in developing countries usually do not have enough budget for an MRT system, installation of a BRT system is considered as a reasonable option to promote ridership of public transport.

Table X – Estimated parameters of multi nominal choice model for commuters

Variable	Car	MC	PT	MRT	t-value
Constant for Car	-3.139				-15.84
Constant for MC		-1.447			-7.83
Constant for PT			-1.551		-10.19
High Income Dummy	0.5330				4.45
Car Ownership Dummy	3.339				19.74
ERP Charge for Car	-0.07427				-10.29
MC Ownership Dummy		1.276			9.51
Travel Time of MC		-0.01566			-5.93
ERP Charge for MC		-0.1021			-5.83
PT Fare			-0.1700		-4.54
MRT Fare				-0.2339	-12.34
Dummy for Current BRT Use				0.7209	2.92
McFadden's r- squared	0.233		Hit Ratio	55.4%	
McFadden's adjusted r- squared	0.231				

Note: MC; Motorcycle: PT; Public transport: MRT; Mass rapid transit system
Fare and ERP charge is in thousand rupiah and travel time is in minutes.
Car and motorcycle ownership is household level.

6. CONCLUSION

The same as other metropolitan areas in developing countries, development of transportation and other infrastructure in the Jakarta metropolitan area cannot catch up with the speed of her growing population and economy while the city government is also tackling the problem by providing the new BRT system. In addition, the surge in motorcycle ownership made it difficult for the city to shift public mode of transport. This paper focused on the transition in mode choice and provides a descriptive analysis as well as development of mode choice model utilizing a stated preference survey on an MRT system and identified characteristics of choice transition as influenced by the introduction of the new BRT system and gave insight on future perspectives on mode choice behaviour.

It is noteworthy that the passengers who shifted to the BRT system were previous users of other public modes of transport while the transition from private motorized transport is limited. In terms of reasons for mode choice, the results showed that car users chose it due to flexibility and comfort while motorcycle users find reasons in travel time and convenience. Thus, it is said that BRT have attracted previous users of other public transportation by its convenience and shorter travel time.

The transition in mode choice was classified by 3 types based on the cross tabulation analysis and the characteristics of transition type were analyzed. The results implied that transition to the new BRT system is evident for low and middle income residents close to MRT stations and that travel roughly in a 5-14 km range.

Finally, based on the stated preference survey data, a simple multi-nominal logit model was developed. With the model analysis, it was found that previous choice of BRT system may have a positive impact on future MRT use. Since development of transport infrastructure and speed of motorization is more rapid in developing countries, it might be reasonable to incorporate variables on current or previous mode choice history.

Overall, it is expected that this experience in the Jakarta metropolitan area will give insight on transition of mode choice behaviour in other cities in developing countries.

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