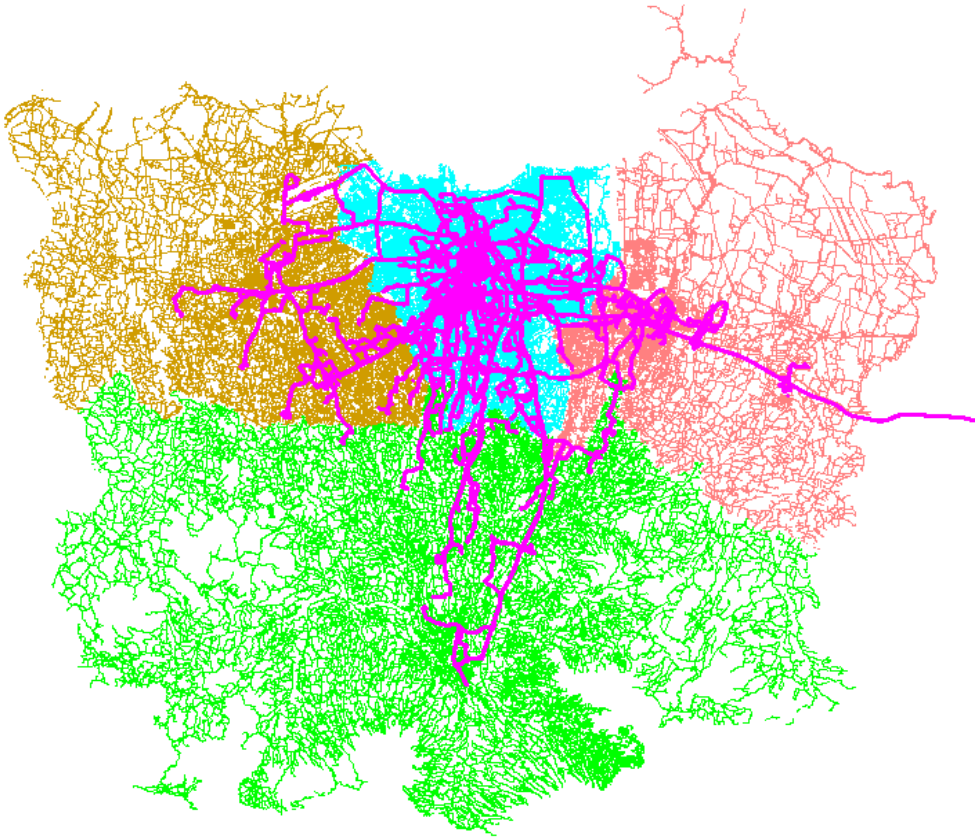

Investigating Commute Mode and Route Choice Variability in Jakarta using multi-day GPS Data

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Abstract

Traffic congestion has become a part of commuters' life in Jakarta for several years. Even though 3-in-1 traffic regulation has been implemented since 1992 in order to reduce the number of car driver travelling in busy corridors during morning and evening peak hours, and Bus Rapid Transit (BRT) has been operated since 2004, which is aimed to attract car drivers to use public transport, the traffic congestion problem in Jakarta has not been solved. The condition is even predicted to worse if the transport facilities in Jakarta are not improved. In order to find effective measures for reducing car use and improving public transport attractiveness in Jakarta, better understanding of commute mode and route choice behavior would be advantageous.

This paper reports the first results of data analysis regarding dynamic behavior of commuters' mode and route choice in Jakarta. The data were collected using GPS devices including questionnaire sheets during a one-week period. 93 commuters participated in the survey. Even though commute trips are routine trips and therefore often assumed to be static, the results show the presence of dynamic behavior in choosing both modes and routes for commuting. The dynamic behavior is as a way to avoid traffic congested roads and 3-in-1 corridors, and to maintain trip-chaining activities/stops. Car drivers and motorcyclists change frequently their routes, especially during work-to-home trips. Motorcyclists were more dynamic in choosing their routes than car drivers. A unique pattern of mode and route choice behavior was found which can be used for developing mode and route choice model in Jakarta.

Keywords

Jakarta – GPS – commutes – mode choice – route choice – variability

1. Introduction

Traffic congestion has become a part of commuters' life in Jakarta Metropolitan Area (JMA) for several years. Even though 3-in-1 traffic regulation has been implemented since 1992 in order to reduce the number of car driver travelling in busy corridors during morning and evening peak hours, and Bus Rapid Transit (BRT) has been operated since 2004, which is aimed to attract car drivers to use public transport, the traffic congestion problem in Jakarta has not been solved. The condition is even predicted to worse if the transport facilities in Jakarta are not improved. In fact, traffic congestion in Jakarta is not caused merely by the lack of transport facilities, but it is a very complex problem consisting of various social, economic and cultural aspects. However, the basic question to solve the problem is: how to reduce car use and improve public transport attractiveness in Jakarta. Therefore, in order to find effective measures for reducing car use and improving public transport attractiveness in Jakarta, better understanding of commute mode and route choice behavior would be advantageous.

This paper reports the first results of data analysis regarding dynamic behavior of commuters' mode and route choice in Jakarta. The data were collected using GPS devices including a paper-and-pencil questionnaire during a one-week period. 93 commuters participated in the survey. The remainder of this paper is organized as follows: section 2 presents the data collection methods and then followed by section 3 presenting the empirical results of data analysis. Finally, section 4 provides a summary of the research findings and outlook on possible extensions of the research.

2. Data Collection

GPS-based survey

Two types of person-based GPS devices were used for the survey: Mobitest produced by MGE DATA and Holux M-1000C produced by HOLUX Technology Inc (see Figure 1). The devices are capable for collecting second-by-second GPS position and time and provide an accurate itinerary of the traveler, including short, intermediate, and infrequent stops. The recorded data are downloaded offline using their application software after the survey period. The survey period of one week was chosen to be able to capture day-to-day variability of commute pattern (dynamic behavior of commutes). Participants of the survey were chosen

randomly from 15 selected offices located in the CBD area of Jakarta. The selected offices are located both inside and outside 3-in-1 areas, in which only high-occupancy vehicles (at least three passengers) are allowed to travel during peak periods (i.e. morning operation from 06:30 to 10:00 and evening operation from 16:00 to 19:00). The selection of office locations were intended to capture the impact of 3-in-1 traffic management policy toward mode and route choice pattern. The survey was conducted from July to September 2010.

Figure 1 MobiTest and Holux GPS Logger

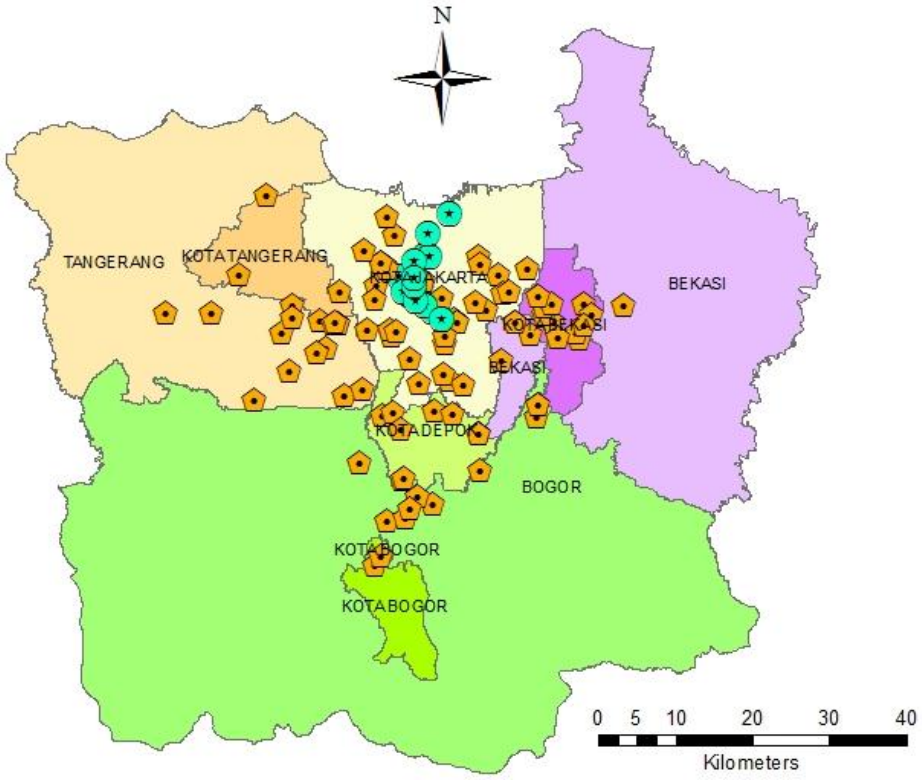
Each participant carried a GPS device every day during a week period. 4 days commuting activities in average can be clearly identified from the recorded GPS-data of all participants. Missing data for some days within the survey period were found from some participants because they forgot to carry the devices or the battery had not been recharged at the time, in which the participant was travelling.

A series of algorithm were developed to identify commute trips from GPS tracking data. The algorithms constituted a combination of three basic GPS processing procedures: identifying trip/activity, trip purpose, and trip destination. The entire set of algorithms consists of three components: data filtering, home and workplace identification, and commute trips detection. The identified commute trips were map-matched with digital road and transit network by using GIS software to identify route and mode chosen by the respondents (see Chung and Shalaby, 2005; Tsui and Shalaby, 2006). Subsequently, the characteristics of commute trips were determined.

Questionnaires

The participants of GPS survey were asked additionally to fill a questionnaire related to socio-demographic information and their commuting behavior, such as travel mode used, office hours, etc.

Figure 2 Home and Work Locations of the Participants



3. Data Analysis

3.1. Respondents' Characteristics

Table 1 shows the descriptive statistics of respondents' characteristics. The respondents were mostly male (69.9 %), ages between 21-30 years (51.6 %), university graduated (89.2 %), married (83.9 %), family head/husband (62.4 %), government employee (64.5 %), staffs (73.1 %), middle income (60.2 %), and have driving license (88.2 %). 53.8 percent of the respondents own one or more cars, while 77.4 percents of the respondents own one or more motorcycles. 60 percent of the respondents own both a car and a motorcycle. Dwelling respondents spread across JMA, which reflects the share of commuters residing at each region in JMA (see Figure 2). 35.5 percent of the respondents use motorcycle as primary mode for commuting, followed by using car (31.2 %), bus (18.3 %), train (12.9 %) and taxi (2.2 %).

Table 1 Socio-demographic characteristics of the respondents

Characteristics		Observation	Characteristics		Observation
Gender	Male	65 (69.9%)	Individual Income	< 5 Mio IDR*)	17 (18.3%)
	Female	28 (30.1%)		5 – 10 Mio IDR	56 (60.2%)
Age	≤ 20	29 (31.2%)		> 10 Mio IDR	20 (21.5%)
	21-30	48 (51.6%)	Motorcycle Ownership	No Motorcycle	21 (22.6%)
	31-40	15 (16.1%)		Have Motorcycle	72 (77.4%)
	41 - 50	1 (1.1%)	Car Ownership	No Car	43 (46.2%)
Education	Junior H. School	1 (1.1%)		Have Car	50 (53.8%)
	Senior H.School	8 (8.6%)	Driving License Own	No Dri- Lic.	11 (11.8%)
	University	83 (89.2%)		Have Driv-Lic.	82 (88.2%)
Marriage Status	Single	14 (15.1%)	Home Location	DKI Jakarta	36 (38.7%)
	Married	78 (83.9%)		Bogor	13 (14.0%)
	Break-up	1 (1.1%)		Depok	11 (11.8%)
HH-member Status	Fam. Head (Husband)	58 (62.4%)		Tangerang	18 (19.4%)
	Wife	21 (22.6%)		Bekasi	15 (16.1%)
	Children	14 (15.1%)	Primary Mode	Car	29 (31.2%)
Type of Occupation	Govt. Employee	60 (64.5%)		Motorcycle	33 (35.5%)
	Private Company	33 (35.5%)		Taxi	2 (2.2%)
Job Position	Staff	68 (73.1%)		Bus	17 (18.3%)
	Supervisor	12 (12.9%)		Train	12 (12.9%)
	Manager	13 (14.0%)			

* 1 USD = 8,750 IDR

3.2. Commute Main Mode Choice

Commute Main Modes

The decision of mode choice for commuting basically depend on vehicle's availability in household, availability and performance of public transport between home and work, traffic conditions, and characteristics of commuters. Around 70 percent of commuters in Jakarta have motorcycles, while around 50 percent of commuters have cars. There are vary types of public transport available in Jakarta, but their performance is poor. Traffic conditions are bad every workday. Under these conditions, a commuter tries to choose mode which give him/her maximum utility. Even though commute trips are routine trips, it is hypothesized that there is a dynamic behavior of commute main mode choice. A commuter might not use only one main mode for every his/her commute trip.

In Jakarta, commuters using public transport may need to interchange from home to access mode, feeder mode, trunk mode, and at last egress mode to workplace. Therefore, this study defined commute main mode as the travel mode, which covers the longest distance used by a commuter during a commute trip. Nine types of commute main modes were identified from the dataset (see Table 2).

Table 2. Commute Main Mode Distribution

No.	Commute Mode	No. of Trips	Mean Travel Time (minutes)	Median Travel Time (minutes)
1	Drive Motorcycle	189 (31.4 %)	63.7	60.5
2	Drive Car	165 (27.5 %)	78.5	74.1
3	Bus	106 (17.6 %)	103.8	92.8
4	Train	76 (12.6 %)	72.6	98.3
5	Car Sharing	34 (5.7 %)	96.6	92.7
6	Taxi	14 (2.3 %)	62.6	68.2
8	MC Sharing	6 (1.0 %)	27.5	26.3
9	Company Bus	6 (1.0 %)	107.8	106.6
7	Informal Transit	5 (0.9 %)	89.8	87.6

Respectively around 30 percent of commute trips observed during survey period used car or motorcycle, while 17.6 % of the trips used bus and 12.6 % of the trips used train. This reflects the dominant of using private vehicles for commuting. It seems that commuters prefer to use cars or motorcycles due to bad performances of public transport. Even more, travelling by

motorcycle is more dynamic in choosing routes and also faster on congested traffic. Additionally, Table 2 shows the comparison of mean and median travel time for each mode.

If we define the most frequently used commute main mode during the survey period as a commuter's primary mode, a total of 571 out of 601 (95.0 %) of commute trips used the primary modes. The remaining 30 trips (5.0 %) used alternative modes. Table 3 shows commute main mode choice matrix. Company bus and informal transit were not used as primary modes, but they were used as alternative modes. Commuters using taxi as primary modes did not utilized alternative modes. Car or motorcycle drive commuters utilized trains as alternative modes, while train users used drive car as alternative modes. Bus users, car or motorcycle ridesharing commuters utilized more alternative modes. Bus user used company bus, train, informal transit and drive car as alternative modes, while motorcycle ridesharing commuters used informal transit, bus and car sharing as alternative modes. Car ridesharing commuters used bus and train as alternative modes.

Table 3 Commute Main Mode Choice Matrix

Primary Main Modes	Alternative Main Modes								
	Drive MC	Drive Car	Bus	Train	Car Sharing	Taxi	MC Sharing	Company Bus	Informal Transit
Drive Motorcycle	189			2					
Drive Car		162		1					
Bus		1	99	3				6	2
Train		2		68					
Car Sharing			5	2	33				
Taxi						14			
MC Sharing			2		1		6		3
Company Bus								-	
Informal Transit									-

Number of Commute Main Modes

In the sample, around 83 percent of the commuters used only one main mode for commuting during the survey period (see Table 4). The remaining 17 percent of the commuters used at

least two main modes for their commutes. This proves that dynamic behavior of commute main mode choice exists.

Table 4 Number of Commute Main Modes Distribution

Number of Commute Main Modes	Number of Commuters	%
1	77	82.7 %
2	14	15.1 %
3	2	2 (2.2 %)

Commute Main Mode Choice Variability

For deeper understanding of commute main mode choice dynamics, this study investigated main mode choice variations during AM-commutes (home-to-work trips), PM-commutes (work-to-home trips), and between these two type of commutes. If there was no variation (only one main mode), then it was coded by "No". Else, if at least 2 main modes were used, then it was coded by "Yes". Table 5 shows that around 12 percent of the commuters used at least 2 main modes during AM-commutes and around 13 percent of the commuters used at least 2 main modes during PM-commutes. Then, around 17 percent of the commuters used at least 2 main modes during the survey period.

Table 5 Distribution of Main Mode Choice Variation

Main Mode Choice Variation	Number of commuters		
	AM-commutes	PM-commutes	AMxPM-commutes
No	82 (88.2 %)	81 (87.1 %)	77 (82.8 %)
Yes	11 (11.8 %)	12 (12.9 %)	16 (17.2 %)

Furthermore, commute main mode choice variation is categorized as shown in Table 6. There are 5 categories of main mode choice variation:

- Category 0: no main mode variation (only one main mode was used during the survey period).
- Category 1: there was no main mode variation during both AM-commutes and PM-commutes, but there was main mode variation between AM-commute and PM-commutes.

- Category 2: there was no main mode variation during AM-commutes, but there was main mode variation during PM-commutes.
- Category 3: there was main mode variation during AM-commutes, but there was no main mode variation during PM-commutes.
- Category 4: there were main mode variation during both AM-commutes and PM-commutes.

Table 6. Distribution of Main Mode Choice Variation Categories

Category	Commute Main Mode Choice Variation			No. of Commuters
	AM-commutes	PM-commutes	AMxPM-commutes	
0	No	No	No	77 (82.8 %)
1	No	No	Yes	2 (2.2 %)
2	No	Yes	Yes	3 (3.2 %)
3	Yes	No	Yes	2 (2.2 %)
4	Yes	Yes	Yes	9 (9.6 %)

Based on Table 6, around 83 percent of the commuters used only one main mode during the survey period (category 0). Around 2 percent of the commuters used the same commute main mode during both AM-commutes and PM-commutes, but they used different main mode between AM-commutes and PM-commutes (category 1). Around 3 percent of the commuters used different main mode only during PM-commutes (category 2). Around 2 percent of the commuters used different main mode only during AM-commutes (category 3). Finally, around 10 percent of the commuters used different main mode during both AM-commutes and PM-commute (category 4).

3.3. Commute Route Choice

In a road and transit network, there are a large number of possible alternative routes between home and workplace. Some commuters use only a single route; others choose multiple routes. Some chosen routes might share links, others have no overlap. This study utilized GPS data together with a GIS platform to capture this important spatial pattern of routes chosen by commuters. Our collected GPS dataset covers multimodal route tracking data. But, this chapter summarizes general findings of route choice pattern of car and motorcycle trips only. A total of 601 commute trips were identified from the GPS dataset. 212 commutes were

detected as car trips and 195 commutes were detected as motorcycle trips. Car trips cover 35 O-D pairs (home-workplace), while motorcycle trips cover 33 O-D pairs.

Number of Commute Routes

If the most frequently used route between an O-D pair during the survey period is defined as a commuter's primary route, 105 car trips (49.5 %) were on the primary routes, while the remaining 107 car trips (50.5 %) were on the alternative routes. For motorcycle trips, 84 trips (43.1 %) were on the primary routes and 111 trips (56.9 %) were on the alternative routes. In the sample, around 20 percent of car trips and 6 percent of motorcycle trips used only one commute route during the survey period (see Table 7). The remaining 80 percent of car trips and 94 percent of motorcycle trips used at least two routes (multiple routes) for their commute. This reflects the dynamic behavior of car drivers and motorcyclists in choosing routes. However, motorcyclists are more dynamic than car drivers.

Table 7 Number of Commute Routes Distribution

Number of Routes	Number of Commuters			
	Car Trips		Motorcycle Trips	
1	7	20.0 %	2	6.1 %
2	5	14.3 %	9	27.2 %
3	9	25.7 %	8	24.2 %
4	5	14.3 %	6	18.2 %
5	3	8.5 %	4	12.1 %
6	4	11.4 %	2	6.1 %
7	1	2.9 %	2	6.1 %
8	1	2.9 %	-	-
Total	***35***	***100 %***	***33***	***100 %***

Route Deviation Pattern

Depending on the commuter's familiarity of the road network, deviation can occur anywhere along the route. This study investigated spatial deviation pattern of routes chosen by commuters. The spatial pattern is defined based on where the deviation occurs: near home, near work, or in the middle of the route. This study defines nine types of route deviation

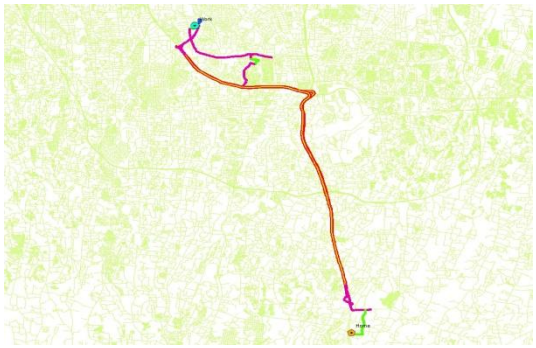
patterns (see Table 8). Our observation shows that none of commuters have only near work route deviation or only mid-route deviation. Most commuters (car driver 34.3 % and motorcyclist 39.4 %) deviates their routes near both home and work, and also in the middle of the route. This reflects dynamic behavior of the commuters in choosing routes to avoid traffic congested roads along the route, to avoid 3-in-1 corridors near workplaces, or to maintain trip-chaining activities/stops. Visual examples of each category are shown in Figure 3.

Table 8 Distribution of Route Deviation Pattern

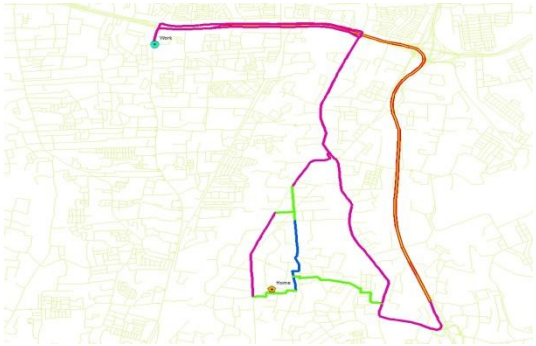
Type	Route Deviation Pattern	Number of Commuters			
		Car Trips		Motorcycle Trips	
0	No Deviation (only one route)	7	20.0 %	2	6.1 %
1	Near Home Deviation	-	-	-	-
2	Mid-route Deviation	-	-	-	-
3	Near Work Deviation	6	17.1 %	2	6.1 %
4	Near Home & Mid-route Deviation	1	2.9 %	4	12.1 %
5	Near Work & Mid-route Deviation	2	5.7 %	6	18.2 %
6	Near Home & Work Deviation	7	20.0 %	3	6.1 %
7	Near Home, Mid-route, Work Dev.	12	34.3 %	14	39.4 %
8	Completely Different Deviation	-	-	2	9.1 %

Figure 3 Visual Examples of Route Deviation Pattern

Deviation type 0: One route, no deviation

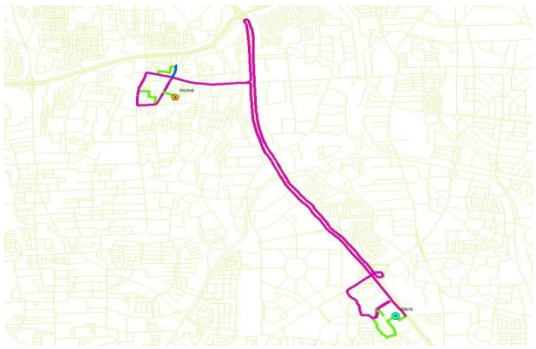


Deviation type 3: Near work

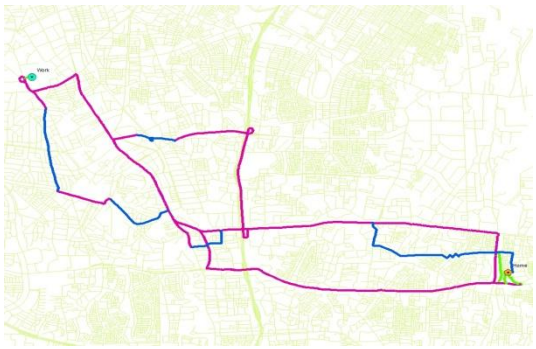


Deviation type 4: Near home and mid-route

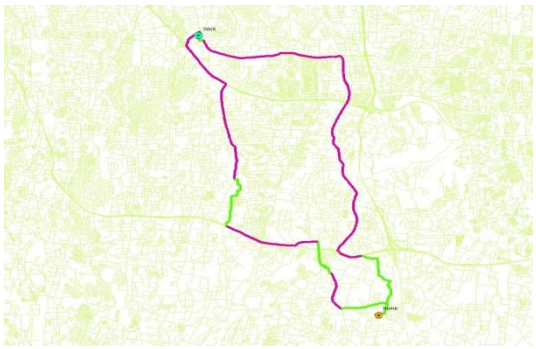
Deviation type 5: Near work and mid-route



Deviation type 6: Near home and work



Deviation type 7: Near home, work and mid-route



Deviation type 8: Complete different

Route Choice Variability

To understand more about route choice dynamics, this study analyzed further the variation of route choice deviation during AM-commutes, PM-commutes, and between these two types of commutes. If a commuter had route deviations (used multiple routes), then he/she was coded with “Yes”, else with “No” if no route deviation (used only one route). Table 9 shows that more than 50 percent of the commuters (both car drivers and motorcyclists) used multiple routes. Route deviations were higher during PM-commutes. Motorcyclist deviate the route

less than car driver in AM-commutes, but more in PM-commute. Overall, motorcyclists share more route deviations than car drivers.

Table 9 Distribution of Route Choice Deviation

Mode	Route Choice Deviation	Number of Commuters (%)		
		AM-commutes	PM-commutes	AMxPM-commutes
Car	No	34.5	25.9	10.3
	Yes	65.5	74.1	89.7
Motorcycle	No	45.5	22.6	3.0
	Yes	54.5	77.4	97.0

Furthermore, route choice deviation can be categorized as shown in Table 10. There are 5 categories of route choice deviation:

- Category 0: no route deviation (only one route was used during the survey period).
- Category 1: there was no route deviation during both AM-commutes and PM-commutes, but there was route deviation between AM-commute and PM-commutes.
- Category 2: there was no route deviation during AM-commutes, but there was route deviation during PM-commutes.
- Category 3: there was route deviation during AM-commutes, but there was no route deviation during PM-commutes.
- Category 4: there were route deviations during both AM-commutes and PM-commutes.

Table 10 shows the distribution of route choice deviation category. Most commuters (car drivers 58.6 % and motorcyclists 45.5 %) used multiple routes during both AM-commutes and PM-commute (category 4). More commuters (car drivers 17.2 % and motorcyclists 30.3 %) used multiple routes during PM-commutes than AM-commutes (category 2).

Table 10 Distribution of Route Choice Deviation Categories

Mode	Category	AM-commutes	PM-commutes	AMxPM-commutes	Number of Commuters (%)
Car	0	No	No	No	10.3
	1	No	No	Yes	6.9
	2	No	Yes	Yes	17.2
	3	Yes	No	Yes	6.9
	4	Yes	Yes	Yes	58.6
Motorcycle	0	No	No	No	3.0
	1	No	No	Yes	12.1
	2	No	Yes	Yes	30.3
	3	Yes	No	Yes	9.1
	4	Yes	Yes	Yes	45.5

4. Conclusion

This study investigated dynamic behavior of commuters' mode and route choices using GPS data together with a GIS platform. The GPS dataset were collected from 93 commuters in Jakarta during the period of a one-week using person-based GPS devices. Dynamic behavior was investigated by analyzing mode and route choice variations during AM-commutes, PM-commutes and between these two types of commutes.

Even though commute trips are routine trips and therefore often assumed to be static, our observations prove the presence of dynamic behavior in choosing both modes and routes for commuting. 17 percent of the commuters used at least 2 different commute main modes and around 10 percent of the commuters used different main mode during both AM-commutes and PM-commute. 80 percent of the car drivers as well as 94 percent of the motorcyclists used multiple routes. Motorcyclists were more dynamic in choosing their routes. Route deviations are higher during PM-commutes than AM-commutes. Most commuters (car drivers 58.6 % and motorcyclists 45.5 %) used multiple routes during both AM-commutes and PM-commute. The dynamic behavior of the commuters in choosing modes and routes in Jakarta are as a way to avoid traffic congested roads along the route, to avoid 3-in-1 corridors near workplaces, and to maintain trip-chaining activities/stops.

From the results of this study can be concluded that dynamic behavior of mode and route choice must be considered into mode and route choice modeling in order to achieve more relevant and accurate estimation's results, especially for areas with bad traffic condition such as Jakarta.

One limitation of the study is that the results based on a small sample size within a restricted area and during short time period. So, they cannot be extrapolated directly to larger samples and other urban areas. Further validation studies could be undertaken in other areas and with larger samples to test transferability of the findings. Nevertheless, the study has provided valuable insight into the actual dynamic behavior of commuters observed over a one-week period and permit the understanding of dynamic behavior of actual commuters' mode and route choice in real transport network.

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