Empirical study on Fuel Consumption of Paratransit in Jakarta city

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In developing countries, diversity in term of variety and difference need on transport infrastructure and services among stakeholders and group in a transport system is very high. The real contribution of paratransit becomes significant due to the limitation of government capacity on public transport system and it supports the much-needed mobility especially for the poor. This paper discuss about fuel consumption of several types paratransit such as Angkot, Bajaj and Ojek in Jakarta city. In their daily operation, angkot has fixed route without any fixed schedule, in contrast, bajaj and ojek have no fixed route and schedule, on demand basis. Based on the reveal preference survey distributed to drivers, we examine the several factors which affect on daily fuel consumption of each paratransit type. To do so, we regresses the independent variables of daily trip activities, vehicle characteristics and driver's attributes on daily fuel consumption. The average speed of trips, total kilometer travelled per day, peak and non-peak hour trip, and location of trips were considered to represent paratransit's daily activities. Vehicle characteristic such as vehicle age, engine size capacity also includes in our model. Finally, driver's attributes includes the age, driving experience also incorporated in our regression model. Bajaj shows lowest fuel efficiency follow by angkot and ojek. Driver attitude and experience in driving found significant influence on fuel consumption of Angkot. Trips dairy was influence significant on fuel consumption of Angkot and Bajaj. In developing cities, paratransits have an important role as public transport system and therefore understanding fuel consumption of paratransit is vital in the planning of conservation program.

***Key words**: Paratransit, Fuel Consumption, Jakarta City*

1. INTRODUCTION

In developing countries, diversity in term of variety and difference need on transport infrastructure and services among stakeholders and group in a transport system is very high. Meeting the needs of stakeholders implies a tradeoff of benefits and costs between supply and demand (Feng, 2009). On the same time, the need for mobility is increase due to economic growth and the growth of cities themselves (Booth et,al 2000; Kaltheier 2002). Motorization in developing megacities increase drastically and become worse in the last several decades. This impact has also increase challenge the future existence of such road-based urban public transport system in developing countries (Joewono, 2007). The real problem is not the high use of automobiles, but the poor service quality of public transit (Senbil et al, 2005). In case of Jakarta city, based on an attitudinal survey for government officer and citizen, the perceived performance of urban public transport system rated very low (Nugroho et al , 2010). Then, the real contribution of paratransit becomes significant due to the limitation of government capacity on public transport system (Joewono, 2007). Paratransit is used extensively in almost all cities in Indonesia.

In developing countries, private motorization has dramatically increased last decade due to the capabilities to own and operate private vehicles. With the poor service quality of public transport, for the stakeholders which comes from middle and high income group, driving private vehicle such as motorcycle and car are more attractive. Private vehicle is especially attractive because of its convenience, independence, flexibility, comfort, perceived safety and privacy (Steg, 2005). Car ownership and usage also related to individual`s or household`s social status in developing countries. Then, the combination of private vehicle dependence, poor service of public transport and high demand for paratransit are close related to transport sustainability.

Paratransit supply is best in meeting the transport requirements of the poor in terms fares and flexibility, and in some cases, a symbiosis of paratransit and the poor is assumed (Kaltheier, 2002). Paratransit is also important to respond to mobility demand in suburbs or area devoid of formal public transport (Tarigan, 2010). The service can be easily opened when needed; and on the other hand, this can be closed when number of user decreases (Carvero, 2007). Paratransit also supported the society by creating job for low-skilled workers (1) and low cost operation and maintenance of government` budget (Tarigan, 2010). Instead of positive impact, paratransit also contributes several problems such as congestion, accident, and externalities such as air pollution. The problem of urban air pollution and greenhouse gas emissions is essential problem of fuel consumption.

This study attempts to evaluate the daily fuel consumption of paratransit modes. In this study, we focus on three types of paratransit which are Ojek (Motorcycle Taxi), Bajaj (Auto Ricksaw) and Angkot (Minibus). Due to their specific operational procedures, first, we evaluate the daily trips activities for each paratransit types (Angkot,Bajaj and Ojek) in Jakarta and surrounding cities Bogor, Depok, Tangerang and Bekasi namely Bodetabek. By using revealed preference daily trips data, we evaluate the current activities of several types of paratransit and its influence on the daily fuel consumptio. Then, we examine the influence of trip characteristics, driver attributes,vehicle technology and built environment on the fuel consumption of each paratransit types. As the preliminary result on paratransit study especially on the supply side, this study will analyze the action space and activities of paratransit services.

2. LITERATURE REVIEW AND METHODOLOGY

In recent years, studies regarding paratransit in developing countries have become popular. Most studies mainly concerned with paratransit itself such as service characteristics and position in transportation hierarchy (Cervero, 2000); Market structures, regulations and impacts of paratransit on transportation system (Cervero and Golob, 2007). Paratransit's feeder potential and performance in urban transportation have gradually been examined (Satiennam et al., 2006, Tangphaisankun, Akkarapol., 2009). Public perception was recognized as an important tool in evaluating paratransit operation and its future (Joewono and Kubota, 2007). The last two topics provide the several agendas about the importance and usefull function of paratransit in the future.

In Indonesia, various types of paratransit are used to provide services such as mikrolet/angkot (minibus, 10-16 seats), Bajaj (Motorist tricycle, 2 seats), Ojek (Motorcycle taxi, 1 seat), Becak (Human Ricksaw, 2 seats) and others. In Jakarta city, the use of motorized vehicle (bus,minibus,mikrolet,taxi and bajaj are dominant, while non motorized vehicle are prohibited, at least in certain areas of the cities. Mikrolet passengers get on and get off the vehicle at any point along the route. The drivers tend to drive fast when the vehicle is full, but slow-down and make frequent stop whenever space for passenger still available. Sometimes they made a long stop to wait and find the passengers. This situation leads the idle condition of vehicle while waiting some passengers (Arintono S, 2003). On the other hand, Bajaj operated as similar as taxi vehicles while they aren`t not equipped with meter reading and that is why we need to made advance negotiation process when riding a Bajaj. Sometimes they also made a long stop at the certain place such as bus terminal, station or other potential places to get the passengers. Bajaj only operated in inner city of Jakarta and prohibited at some major roads. Ojek, was very flexible in term of operational conditions since it is looks similar with normal private motorcycle. In fact, it was difficult to identify the normal private motorcycle and ojek while driving in the road. And so, ojek could be found in everyplace in Jakarta and surrounding cities. It also could cross and drive at all roads which also allow for motorcycle. However, sometimes ojek may stop and wait for passenger in the junctions, bus stop, train station, shopping mall, residential areas etc.

Transportation sectors are one of the most important sources of greenhouse gas emissions (mostly CO_2) and one of the biggest contributors to the poor quality of urban air environment. The problem of greenhouse gas emissions is essential problem of fuel consumption. In the city level, urban density is found to affect fuel consumption, mostly through variation in vehicle stock and in the distance travelled, rather than through fuel consumption per kilometer (vehicle technology) (N Karathodorou, 2010). Traffic intensity has increased in urban areas such as Jakarta city and driving pattern over a specific route varies to great extent. Traffic congestion and variation of driving pattern has resulted in excess fuel consumption. The fuel consumption of a specific trip is not only affected by the distance driven but also by the driving patterns of vehicle, i.e. speed, acceleration and grea changing, over the road sections involved (Ericsson et al, 2006). The travelled distance and stop time are considered to estimate fuel consumption. In the study by Y Saboohi and H Farzaneh (2009) emphasized three factors affect on fuel consumption, which are:

a. Driver behavior
   Driver is usually forced to accelerate, decelerate, brake and change gear more often in heavy traffic. Such a process has significant impact on fuel consumption. The fuel consumption is in part determined by degree of acceleration resistance which occurs when the speed of vehicle is raised. As mentioned in above, due to their specific operation, mikrolet, ojek and bajaj will often to force the change of driving cycle to the passengers get-in and get-off process.
b. Interrelationship between fuel consumption and speed and gear ratio
c. Impact of engine load on fuel consumption
   Actual performance of a vehicle on the road indicates that major portion of a journey is associated with part-load engine operation. Part-load covers about 20-80 percent of engine load when the engine speed is increased gradually. Excess fuel consumption is also observed in an intense traffic flow where the engine runs idle for longer time. It could be applied for all types of paratransit.

Among various design features, vehicle mass is a key variable having the potential to considerably the fuel consumption rate (R Tolouei, 2009).

There are a wide range of discussions on the transportation issues in developing cities, but fuel consumption study on Paratransits are less discussed compared to others. Thus, in this study, daily trips activities and fuel consumptions is discussed. Paratransit (Ojek and Bajaj) driver`s typically select routes that minimize their travel time or generalized cost which also reduce fuel consumption. Concretely speaking, this study first attempts to clarify the influence of driver attributes, vehicle technology and trip characteristics on their daily fuel consumption.

3. DATA

(1) Study Locations

The area of Jakarta is around 664 km^2 with flat topography, closed to the Java Sea and has an average elevation 7 meters above sea level. Climate can be classified into wet season from November to March and dry season from May to September. A few weeks in April and October are transition period, respectively. Jakarta has been experiencing serious public transport problems which are mainly contributed lack of capacity and increasing the private automobiles. Rapid urbanization and motorization in greater Jabodetabek areas is further worsening current situations.

(2) Attitudinal Data

A questionnaire survey was conducted in Jakarta metropolitan area, Indonesia and its surrounding city called as Jabodetabek with respect to the driver of each paratransit types. The questionnaire item includes:

1) Driver attributes such as age, gender, academic background, holding a driving license or no, driving as full-time job or other, and working experience as paratransit driver.
2) Vehicle related aspects such as vehicle age, engine size displacement (cc) and fuel type
3) Driving behavior such as: experience with traffic accident while drive as paratransit driver, maintenance frequency of vehicle, maintenance cost of vehicle.
4) Daily Trips characteristics, such as: Origin places, departure time, no of passengers, address of departure point, destination place, travel time, total money received by driver and travel distance. In our questionnaire survey form, we allocate maximum 15 trips per day for each type of paratransit

Questionnaire was distributed randomly in Jakarta city and surrounding cities in January-March 2010. In total, 205 Angkot driver`s, 195 Bajaj driver`s and 208 Ojek driver`s were interviewed. All drivers for all three type of paratransit are men. The average oldest driver age was Bajaj 39.13 years and the youngest is Ojek driver, 34.08 years. Ojek driver also shows the lowest experiences (4.71 years) compare to other drivers. This data shows that ojek driver relatively new compare to other well-established paratransit drivers. It is also supported by the average of vehicle age of ojek which is lowest compare to others. Ojek drivers also travelled lowest than the other drivers, it is about 22.3 km per day. The longest was done by mikrolet driver, 91.27 kilometer per day. The total average trip for each type of paratransit driver was almost similar 9 trips per day. The shortest travel time per day was Ojek driver around 140.83 minutes. In contrast, the lowest waiting time per day was Mikrolet/Angkot driver around 159.65 minutes. Due to the eldest vehicle, we could see clearly that bajaj has lowest fuel efficiency per kilometer travelled compare to other types of paratransit. Detail information on driver`s attributes, vehicle characteristics and trips characteristics are shown in Table 1.

Table 1 General characteristic of Paratransits

Characteristics	Mikrolet	Ojek	Bajaj
Driver` Age	38.5 (7.27)	34.08 (9.22)	39.13 (10.45)
W. Experience	8.96 (4.59)	4.71 (3.63)	10.03 (6.96)
Vehicle Age	10.15 (5.02)	6.09 (3.59)	32.43 (6.17)
Engine Size	1641.55 (1050.99)	116.62 (97.05)	150.13 (1.79)
N-Trips/day	9.05 (2.55)	8.53 (3.33)	8.89 (2.50)
Total Kilometer Travelled/day	91.27 (32.43)	22.30 (29.57)	35.80 (23.98)
Total Travel Time per day (minute)	512.24 (172.102)	140.83 (75.66)	212 (121)
Total Waiting Time per day (minute)	159.65 (126.77)	246.03 (376.55)	346 (175)
Average Speed (km/hour)	11.64 (5.93)	9.36 (11.53)	10.07 (7.77)
Average trip distance (km)	10.2 (3.39)	2.48 (2.81)	3.85 (2.20)
Maintenance Frequency per year	11.54 (6.07)	6.64 (5.05)	91.77 (99.63)
Fuel Consumption per day (liter)	15.18 (7.99)	1.85 (1.62)	9.53 (4.65)

Note: About the mean value (inside the bracket: standard deviations).

Interesting phenomena was found for average speed which shows the lowest for Ojek. It seems on the opposite of the current opinion that instead of flexibility, ojek was also faster than others. Looking at figure 1, most of driver has 9 trips per day. As mention in above, Ojek and Bajaj has no fixed route neither schedules. Looking at the share of trips in a day (figure 2), Ojek has single peak in the afternoon (around 11:00-12:00) while bajaj has peak in the morning in between 8:00-10.00. It supposed to be closed related with the distribution of origin of bajaj trips which are from traditional market (figure 3) and final destination was home (figure 4). It is also support our previous studies which mention that bajaj was convenience for shopping trips which allow excess baggage.

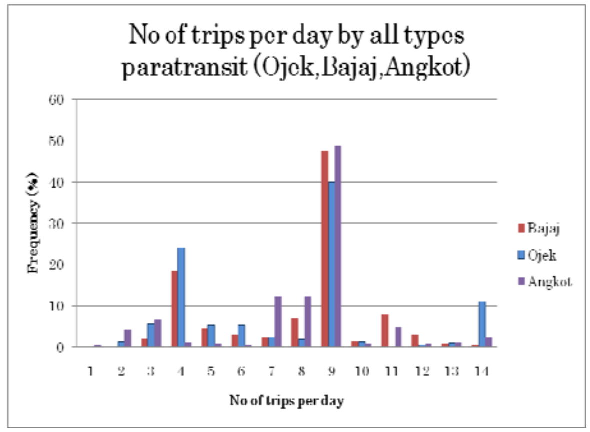

Figure 1. Number of Trips per day

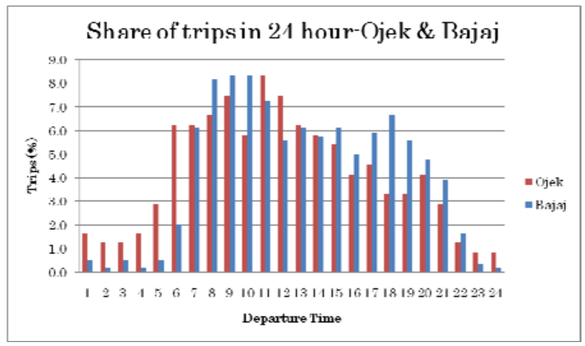

Figure 2. Share of trips per day based on departure time

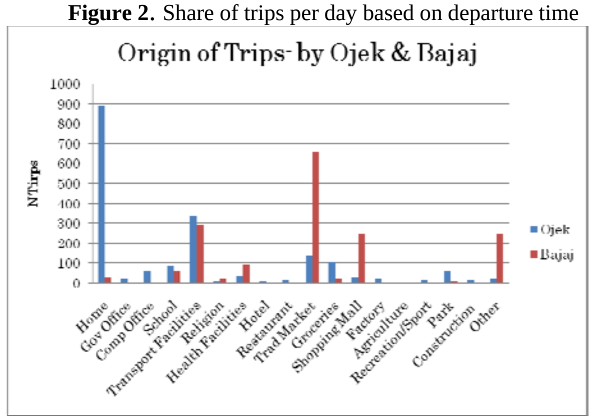

Figure 3. Share of trip origin

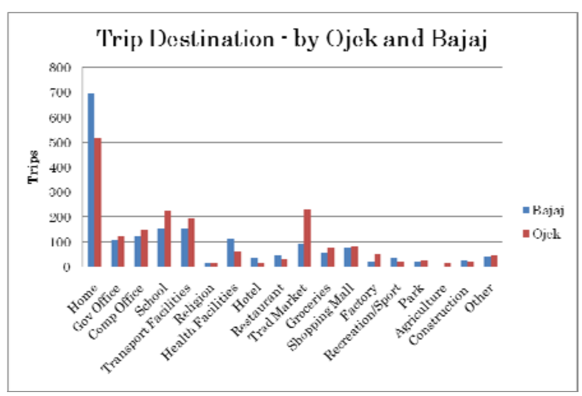

Figure 4 Share of trip destination

4. MODEL ESTIMATION

A statistical modeling approach was used to investigate the effects of driver attitudes, driver behavior, vehicle characteristics and trips characteristics on daily fuel consumption. Dependent variable was fuel consumption per day (liter/day) which is continuous quantities. Other independents variables are also continuous quantities. Driver age (year) and driver experience (year) used to represent the driver attributes. Vehicle age (year) and engine size of vehicle (cc) are selected as technological aspect of vehicles. Due to the homogeneity of engine size, this variables wasn`t consider in Bajaj`s model. To represent the driver behavior, we use data of maintenance frequency per year. Number of trips per day, total travel time per day, total kilometer travelled per day (km), average speed (km/hr) and total waiting time per day are considered to represent daily trip activities of paratransit. Tolouei (2009) use generalized linear models (GLM) to investigate the effect of vehicle mass and vehicle-related variables on fuel consumption. Poortinga (2004) used regression analysis to evaluate the influence of individual attributes on home and transport energy use. In this study, we apply ordinary least squares (OLS) to examine the influence of independent variables on daily fuel consumption of paratransit. Due to data cleaning process 184 samples of Angkot, 148 samples for ojek and 171 samples for Bajaj are used in the model and the estimation results shown in table 2.

Looking at table 2, the R^2 for Angkot` was the highest among others. Driver age was positive and significant only for angkot` model. In contrast, driver experience was negative significant for Angkot and Ojek. This sign and its significant level is expected in the model. Increasing driver experience will led the driver to have a good manner in driving which give a significant effect on fuel consumption. These results also gives the other possibilities to apply eco-driving policy for normal vehicle (angkot) and it is expected to be significant to reduce fuel consumption. Maintenance frequency also significant but the sign was positive which mean increasing maintenance frequency will also increase the fuel consumption. On the other hand, maintenance frequency was negative sign for ojek, which mean increasing maintenance frequency will reduce fuel consumption of ojek, but this is not statistically significant.

Looking at the estimation results for daily trips-related variables, we found no of trips per day were significant for Ojek`s and Angkot' model. The sign was positive which also proper for logical reason. Total travel time per day were significant for both Ojek` and Bajaj`. The sign was positive for Bajaj`s model which also suitable for logical reason. In contrast, the sign was negative for ojek, this might due to the typical ojek` trip which are short in time and distance. The average kilometer travelled per trip was found positive and significant only for angkot` model. Increasing vehicle kilometer travelled per day will automatically increase the fuel consumption per day. Similar situation was found for total waiting time per day which gives significant on fuel consumption of Angkot and Ojek.

Table 2 Estimation Results

Variables	Angkot		Ojek		Bajaj	
	B	*t*	*B*	*t*	*B*	*t*
Constant	-5.42	-1.48	-0.28	-0.12	5.797	2.904
Driver Age	0.139	2.276	0.010	0.489	0.002	0.058
Drive Experience	-0.25	-2.32	-0.08	-1.68	0.146	0.387
Vehicle Age	-0.04	-0.42	-0.04	-0.79	-0.39	-0.94
Engine Size	0.001	1.675	0.009	0.417	-	-
Maintenance frequency	0.613	7.565	-0.03	-0.94	0.112	0.448
No of Trip	0.573	1.974	0.385	4.111	-0.03	-0.14
Total travel time (Hr)	-0.10	-0.46	-0.69	-2.41	1.181	2.445
Average kilometer per trips	0.459	2.729	0.365	1.018	0.146	0.414
Average speed	-0.02	-0.21	-0.11	-1.39	0.024	0.519
Waiting time (hr)	0.504	2.142	0.11	1.958	-0.01	-0.06
R^2	0.472		0.241		0.290	
Log likelihood	-570.989		-246.275		-474.087	
No of samples	184		148		171	

5. CONCLUSIONS

Paratransit in developing cities supports the much-needed mobility especially for the poor. These types of modes filling the gap between the requirement of mobility which increase drastically and the lack of capacity on public transport system provide by government.

In this study we examine the daily trips activities of three types of paratransit i.e Angkot/Mikrolet, Ojek/Motorcycle taxi and Bajaj/Autoricksaw and their effect on fuel consumption. We found almost similar number of trip per day for all types of paratransit. The driver of angkot drive longer in distance and travel time per day compare to other two drivers. But they were very effective in working time, means the waiting time for passenger was lowest compare to other drivers. We found the unique evaluation based on the average speed, which ojek show the lowest among others. This situation was opposite to the current perception and opinion of the user which expect riding ojek/motorcycle taxi will faster than other, especially due to the current traffic congestion in Jakarta city. Ojek was expected could break through the traffic jam and deliver the passenger faster than others, but data shows the average speed was lowest compare to Bajaj and Angkot. We also found unique distribution of trips among ojek and bajaj which seems complement each other. The resident will use ojek from their home but they will return by Bajaj, especially for housewife which made trips for shopping in traditional markets. This might due to the current situation that ojek was easily found nearby the residential areas and bajaj was suitable and comfort to accompany the excess luggage after shopping.

Driver experience was significant in determining fuel consumption of angkot. This led the opportunity to perform policy action such as eco-driving campaign for angkot driver to reduce the fuel consumption per day. The average speed per day which represent the current traffic condition were on the expected sign especially for Angkot and Ojek but not statistically significant. From the view point of trip intensity and fuel consumption, it was also confirmed by Angkot and Bajaj`s model, which show positive and significant for total kilometer travelled per day (Angkot) and total travel time per day (Bajaj). The activity to stop and idling vehicle while waiting the passenger also contribute significantly on fuel consumption for Angkot and Ojek. The model for Bajaj still need to improve since the contribution of constant was highest and also significant.

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