A joint choice decision model of intra-household interaction-based motorcycle mode and departure time in Yogyakarta, Indonesia

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Abstract. The motorcycle-based joint trip between family members in a household becomes a common phenomenon in responding to unreliable public transport. This study aims to model the joint choice decision between intra-household interaction-based joint trip using motorcycle and departure time. With the data collected from 416 workers using the motorcycles in Yogyakarta, Indonesia, a cross-nested logit model was developed to explore the individual and household characteristics, work- and travel-related characteristics influencing household-based joint trip and departure time. The model result reveals that motorcyclists are more likely to change their departure time rather than an intra-household-based joint trip. Motorcyclists departing on a peak hour have a lower elasticity due to the alteration of travel time and travel cost than motorcyclists leaving on an off-peak hour. In a case of the off-peak departure time, motorcyclists leaving home to work by driving alone are more elastic for a change of travel cost than motorcyclists departing to work with their family member.

1. Introduction

1.1. Background
Motorcycles become a primary mode of urban transportation in Southeast Asia, such as Indonesia, Thailand, Vietnam, and Malaysia. Mixed land use and narrow streets in Indonesia have caused motorcycles as a reliable travel mode to connect the point of origin to the point destination [1]. The number of motorcycles in Indonesia increases every year by reaching 105.15 million units in 2017, and it has significantly increased by 52.75% in the last five years. In 2016, motorcycles were accounted for 81.33% of all registered motorized vehicles [2]. Motorcycles are also indicated as one of the major contributors to a road accident, and it increases in accident fatality rates [3]. The Indonesian Ministry of Transportation recorded that 108,883 motorcycles were involved in traffic accidents in 2014 [4]. Meanwhile, forty-five percent of road accidents in Malaysia involved motorcycles, with 60% of them resulted in fatalities [5].

Understanding motorcycle ownership and usage in Asian countries have been carried out on many studies aiming to reduce motorcycle growth and to control its usage [6-9]. Several previous studies are also carried out concerning motorcycle fatalities [5,10,11]. However, there is a lack of studies on motorcyclists’ behavior considering the departure time choice decision and the effect of intra-household interaction. It is crucial because intra-household interaction influences the mode choice...
decision of family members [12]. In a case of the motorcycle-based joint tour between the family members in a household has become a way out due to the unreliable public transport service [13], analyzing the departure time choice and the intra-household interaction-based travel mode choice could be an approach to explore deeply the motorcyclists’ behavior for a home-based work trip.

This study aims to model the joint choice of departure time and intra-household interaction-based ridesharing for the motorcyclist in Yogyakarta Urban Area and to understand the various factors influencing both of those choices. Some previous researches have shown that travelers choose travel mode and departure time simultaneously [14,15]. By understanding the interactions between the two dimensions, demand-side policies can be proposed aiming both to reduce the households’ dependency on motorcycles and to increase the propensity of mode shifting from motorcycle to public transport. Understanding the departure time choice could also be a solution to decrease traffic congestion on peak hours or to spread traffic congestion outside peak hours, which remains one of the most common transport problems in urban areas. Based on random utility maximization theory, a cross-nested logit model within the theoretical framework of generalized extra value (GEV) class [16] was used to capture the relationship between alternatives for both dimensions of departure time and ridesharing mode.

The remainder of this paper is organized as follows. The next sub section gives a brief description of the study area. The second section reviews the main contributions to the choice of departure time and the effect of intra-household interaction on a joint trip. The third section describes the data collection. The fourth section defines a detailed formulation of the proposed models in this study. Furthermore, the fifth section presents detailed model estimation results and discussions. The last section provides the main conclusions and recommendations for further study.

I.2. Study Area: Yogyakarta Special Region

This section provides a brief description of the Yogyakarta Special Region (YSR) as an area of study. YSR is one of two special provinces in Indonesia with a population of 3.7 million in 2016 [17]. YSR consists of five regions: Yogyakarta as a capital city, Sleman, Bantul, Gunung Kidul, and Kulon Progo. As a capital city, a high number of motorized vehicles enter to Yogyakarta from its vicinity areas resulting in severe traffic congestion. The rise in the urban population linked to economic growth and motorization has led to an expansion of Yogyakarta city. Being adjacent to the city of Yogyakarta, Sleman and Bantul Regency have high urban growth attributing to residential projects. In 2016, YSR Agency for Land and Land Use introduced a Yogyakarta Urban Area (YUA) consisting the City of Yogyakarta, a part of Sleman and Bantul Regency [18]. YUA has an area of 19,651 hectares and includes 71 sub-districts in Yogyakarta, 15 sub-districts and 11 sub-districts in Sleman and Bantul, respectively.

Besides being a tourist destination, YSR is a city of education in Indonesia with more than 19 universities and colleges by the student population of about 351,293 in 2016. It nearly accounts for 9.5% of the YSR total population [17]. Almost all of the university students who come from the outside of YSR brought the motorcycle from their hometown, causing the number of the operated motorcycle is more than the registered motorcycle. There are 1,115,145 registered motorcycles in YSR in 2016 [19]. There is also a high number of elementary schools and high schools in YSR. Many students in elementary school and junior high school are escorted using motorcycle by their family members when they depart to/return from school. For senior high school students, most of them use a motorcycle because their age has met the minimum age threshold to have a driving license.

On the road, motorcycles are the dominant transport mode by around two-third of traffic. It also appears that more than one people occupy a motorcycle. Meanwhile, comparing the number of population and the number of registered motorcycles in YSR, the ratio value reaches 0.89 meaning that every people residing in Yogyakarta have a motorcycle mode. People living in YSR highly depend on a motorcycle in fulfilling their daily activities. They prefer to use a motorcycle compared to walking although on a trip less than 200 meters away. The high motorcycle dependence has also caused the disinterest on public transport use although the government has significantly improved the
quality of public transport and the service coverage area. Survey result on public transport use (i.e., Trans-Jogja Bus) in 2017 reveals that the average load factor from 17 licensed bus routes reaches 17.35% only which consisted of 27.43% load factor on the 6 existing routes, and 11.84% load factor on the 11 new routes [20]. In YSR, purchasing a motorcycle is easy and cheap through a simple credit process. With a down payment of 500 thousand IDR (USD 34.45), people can own a new motorcycle with a price of around 20 million IDR (USD 1,378). In addition, since there is no policy of the motorized vehicle age limitation, the availability of the used motorcycles with a very affordable price makes it much easier for people to own a motorcycle. Perhaps, when people decide to buy a used motorcycle by a credit system for the four-year duration, the monthly expenses to pay the motorcycle installment, tax, and operating costs, are insignificant different with the money that must be spent to buy a monthly ticket for using public transport.

2. Literature review
Studies on departure time have been extensively researched over the past decades in both dynamic user equilibrium analysis and econometric modeling. However, only a few studies incorporating the impact of intra-household interaction on the decision-making process of departure time. Yang et al [21] used the nested logit (NL) and cross-nested logit (CNL) model structures to estimate the joint choice of residential location, travel mode, and departure time for 8,900 households in Beijing. They pointed out that some factors such as house price, travel time, travel cost, working time flexibility, age, income, and car ownership was found as the influential variables on those three choice dimensions. They found that the departure time is the lowest substitutability and the residential location is the highest substitutability. It means that the travelers are more likely to change their departure time and travel mode rather than their residential location. In addition, travelers are willing to alter their departure time first rather than their travel mode if there is a change in travel time or other influential variables.

Ding and Mishra [15] applied the CNL model to the joint choice departure time and travel mode for urban commuting trips using a revealed preference data collected in the Maryland-Washington DC Region. Four travel modes: (1) drive alone, (2) transit, (3) shared ride, and (4) walk and bike, and two departures time: (1) peak and (2) off-peak were used in the choice decision model. The result found that males were more likely to drive alone and to use public transport, walk and bicycle relative to females, while young adults were less likely to drive alone. People who work in the CBD area tend to use public transport, walk and bicycle rather than drive alone. Also, individuals with flexible working time are more likely to depart to work on the off-peak period by using public transport, walk and bicycle, and drive alone.

Reviewing previous studies of motorcycle usage, it found that individual features such as socioeconomic and demographics have a strong relationship with the motorcyclists’ commuting behavior. By involving 503 students in six universities in Danang, Vietnam and applying a conditional logit regression model, Nguyen-Phouc et al [22] found that factor of travel time, travel distance, age, gender, income, bicycle and motorcycle ownership, driving license, location of school and living status have a strong correlation to mode choice decision. Surprisingly, travel cost does not influence mode choice. They also found that improving public transport service could potentially shift the motorcyclists to public transport users. Tran et al [23] revealed that household characteristics have a significant effect on the mode choice of motorcycle. They found that although 79% of 2605 respondents in Hanoi, Vietnam choose to walk from home to urban mass railway transit station for the trip distance less than 1 kilometer, 17% of them remain using motorcycles. Irawan et al [24] displayed that more than 70% of train users in Yogyakarta choose to use motorcycle from the train station to their destination place.

3. Data collection
Involving 416 respondents residing in YSR, an interview survey was conducted from March 6 to April 10, 2017. The selected respondent are people working in the City of Yogyakarta and riding a
motorcycle during a trip to work. There are five parts in questionnaire form, as follows: (1) Individual characteristics: gender, age, and income, (2) Household characteristics: home location, number of motorized vehicle ownership, and number of family members, (3) travel-related features: travel time, travel cost, and number of time-constrained activities in a day, (4) work-related attribute: strict/flexible time to start working, and (5) trip chain.

Table 1 presents the descriptive statistics of the respondent. The sample consists of nearly 56% of men, and it is dominated by people aged 25-34 years old and people with income 1.5-3 million IDR by 38.46% and 42.55% respectively. The average number of family members in the household is 2.09, while the average number of motorized vehicle ownership is 2.29. Due to this, the ratio between the number of family members and the number of motorized vehicles in a household is 91.27% meaning that a family member in a household has one motorized vehicle. The sample also shows that only 18.03% respondents are living within the City of Yogyakarta (urban area), and 20.67% of them are residing on the outside of Yogyakarta Urban Area (rural area). The rest (61.30%) is residing in the suburban area (i.e., Yogyakarta Urban Area, but excluding the City of Yogyakarta). Taking into account the travel-and work-related characteristics, the average travel time from home to the workplace is 21 minutes, and the average trip cost is 5,348 IDR. Thirty-seven percent of respondents have two time-constrained activities, and 29% of them have more than or equal to three time-constrained activities in a day. Meanwhile, the proportion of respondents with work starting time flexibility is 27.64%.

| Variables                                      | Mean | St. Dev. | N   | %   |
|------------------------------------------------|------|----------|-----|-----|
| **Individual Characteristics**                |      |          |     |     |
| Gender                                         | Male | -        | 232 | 55.77 |
|                                                | Female | -       | 184 | 44.23 |
| Age                                            | 20-24 years old | - | - | 80 | 19.23 |
|                                                | 25-34 years old | - | - | 160 | 38.46 |
|                                                | 35-44 years old | - | - | 81 | 19.47 |
|                                                | 45-54 years old | - | - | 80 | 19.23 |
|                                                | 55-64 years old | - | - | 15 | 3.61 |
| Income                                         | < 1.5 million IDR | - | - | 106 | 25.48 |
|                                                | 1.5-3 million IDR | - | - | 177 | 42.55 |
|                                                | 3-6 million IDR | - | - | 115 | 27.64 |
|                                                | > 6 million IDR | - | - | 18 | 4.33 |
| **Household characteristics**                  |      |          |     |     |
| Number of a family member in a household       | 2.09 | 1.32     | -   | -   |
| Number of motorized vehicle ownership          | 2.29 | 1.42     | -   | -   |
| Home location                                  | Urban | -       | 75  | 18.03 |
|                                                | Suburban | - | - | 255 | 61.30 |
|                                                | Rural | -       | 86  | 20.67 |
| **Work-related characteristics**               |      |          |     |     |
| Type of work starting                          | Strict | -     | 301 | 72.36 |
| time                                           | Flexible | -   | 115 | 27.64 |
| **Travel-related characteristics**             |      |          |     |     |
| Travel cost (IDR per trip)                     | 5,348 | 3,272   | -   | -   |
| Travel time (minutes per trip)                 | 20    | 11      | -   | -   |
| Number of time-constrained activities in a day | 1 trip | -     | 144 | 34.62 |
|                                                | 2 trips | -   | 153 | 36.78 |
|                                                | ≥ 3 trips | - | - | 119 | 28.61 |

Table 1. Descriptive statistics of respondents.

Considering the motorcyclists’ trip chain, there are eight home-based trip chains to the workplace as shown in Figure 1 consisting of four single tours and four joint tours (ridesharing). The distribution of each home-based trip chain is displayed in Figure 2. It can be seen that 56% of motorcyclists’ in
YSR (235 respondents) visit other places for escorting family members, eating, visiting friends, and shopping before departs to the workplace. From 56% of them, 179 respondents conduct a motorcycle-based ridesharing behavior. Concerning the trip chain of escorting family members first before leaving to the workplace, 64% of them (107 respondents) directly depart to the workplace after accompanying their family members, while 10% (18 respondents) and 26% (43 respondents) of them have to visit other places and going home, respectively, before departing to the workplace. Meanwhile, eleven respondents escort their family members after conducting other activities such as shopping, visiting friends, and eating. Referring to Figure 1 and Figure 2, there are 43% of motorcyclists (179 respondents) who jointly travel with their family member by using motorcycle consisting of 107 respondents with type C trip chain, 44 respondents with type E trip chain, 11 respondents with type G trip chain, and 17 respondents with type H trip chain.

Figure 1. Types of motorcyclists’ home-based tour in YSR.

Furthermore, Figure 3 shows the distribution of motorcyclists’ departure time and total trip distance from home to the workplace. It reveals that the majority of motorcyclists depart from their home from 06.30 to 07.30 by 57.69%. Meanwhile, the percentage of motorcyclists’ total trip distance from home to the workplace tends to be evenly distributed, with dominated by a trip distance ranging from three to four kilometers by 14%.

4. Proposed model

As previously explained, this study emphasizes the joint choice behavior of intra-household interaction-based joint trip using motorcycle mode and departure time for home-based work trips. There are two types of the joint trip using motorcycle mode choice: ridesharing and drive alone, while departure time choice subset consists of two alternatives: peak and off-peak. Due to this, the joint model of motorcycle-based joint trip and departure time creates four alternatives for each decision
It should be noted that in this study, peak hour is classified for motorcyclists departing from 06.30 to 7.30.

Figure 2. The distribution of motorcyclists’ home-based tour in YSR.

Figure 3. The distribution of motorcyclists’ (a) departure time, and (b) total trip distance from home to the workplace.

Referring to the Generalized Extreme Value theorem [25-27], the choice probability of a cross-nested logit model alternative \( i \) \((P_i)\) being chosen is defined in terms of conditional probabilities \((P_{im})\) and marginal probabilities \((P_m)\) is shown as follows.

\[
P_i = \sum_m P_{im}P_m = \sum_m \left[ \frac{\tau_{im} e^{V_i}}{\sum_{j \in A_m} \tau_{jm} e^{V_j}} \right] \left[ \sum_{m} \left[ \frac{\tau_{jm} e^{V_j}}{\sum_{j \in A_m} \tau_{jm} e^{V_j}} \right] \right]^{-1}
\]

(1)

Where: \( j \in A_m \) is the set of all alternatives that belong to nest \( m \), \( m \) and \( l \) are indices used to sum over all nests, \( \tau_{im} \) are unknown parameters that characterize the portion of alternative \( i \) assigned to a nest in
which $\tau_{im}$ are non-negative and must sum to one for every alternative. The parameters in Equation 1 are estimated based on the maximum likelihood method [28].

Furthermore, Wen and Koppelmen [26] formulated direct elasticities ($DE$) for cross-nested logit model as follows.

$$DE = \left[ (1 - P_i) + \sum_m \frac{1 - \mu_m}{\mu_m} P_m \left( 1 - \frac{P_m}{P_i} \right) \right] \beta_k X_{ik}$$

(2)

5. Result and discussion

The estimated parameters of cross-nested logit model are shown in Table 2, while the values of direct elasticity are displayed in Table 3. Direct elasticity is the variation in a decision maker’s choice probability due to a change in one of the variables affecting that alternative. All the coefficients presented in Table 2 and Table 3 were estimated using Biogeme [29].

The model result shows that motorcyclists with flexible work starting time tend to depart during the off-peak period and to escort their family members before or on the way to the workplace. Taking into account the household characteristics, the number of a family member in a household shapes behavior of ridesharing. A more family member in a household increases the behavior of ridesharing by using motorcycles. Meanwhile, motorcyclists residing in the suburban and rural area are more likely to drive alone and to depart during the peak period.

**Table 2.** Estimation result of the cross-nested logit model.

| Attributes/ data fit measures                  | Cross-nested logit parameter | t-statistic |
|-----------------------------------------------|------------------------------|------------|
| Constant driving alone – peak period          | 0.330                        | 1.19       |
| Constant ridesharing – off peak period        | 0.198                        | 1.84c      |
| Constant ridesharing - peak period            | -0.069                      | -0.38      |
| Age                                           | 0.632                        | 4.75a      |
| Gender                                        | 0.813                        | 3.10a      |
| Income                                        | 0.746                        | 3.04a      |
| Home location                                 | 0.460                        | 2.43b      |
| Occupation                                    | 0.765                        | 3.04a      |
| Number of family members in a household       | 0.521                        | 7.19a      |
| Number of time-constrained activities         | -0.796                      | -3.56a     |
| Number of motorized vehicle ownership         | 0.898                        | 6.17a      |
| Travel cost                                   | -0.894                      | -7.47a     |
| Travel time                                   | -0.823                      | -2.30b     |
| $\mu$ peak                                    | 0.455                        | 5.37a      |
| $\mu$ off peak                                | 0.636                        | 2.44a      |
| $\mu$ driving alone                           | 0.359                        | 10.87a     |
| $\mu$ ridesharing                             | 0.546                        | 6.14a      |

*Final LL = -567.334, Rho square = 0.315, AIC = 1176.667, BIC = 1261.311*

Note: *Significance at the 1% level, *Significance at the 5% level, *Significance at the 10% level

Looking into the model fit in Table 2, the final log-likelihood value at the estimates as -567.334 with the rho square is 0.315. The Akaike and Bayesian information criterion (AIC and BIC) are 1176.667 and 1261.311 respectively. From Table 2, it also can be seen that, as expected, the coefficients for travel time (-0.823), travel cost (-0.894), and the number of the time-constrained activities (-0.796) have negative signs, and are statistically significant at levels of confidence well above the 95% limit. Flexible work starting time and living in an urban area contribute to the increase of utility function for workers using motorcycle mode by the coefficients of 0.765 and 0.460, respectively. Comparing among independent variables, variable of travel cost has a high coefficient value and the most significant variable influencing in both departure time and ridesharing behavior. Meanwhile, even though the variable of travel time also has a high coefficient value, its significant
value at the confidence level does not reach above 99% limit. The value of constant is significant for driving alone only (0.198) that signify at 10% level, meaning that share driving by motorcycle and depart on the off-peak period produce the highest utility. However, it should be pointed out that the constant value for the behavior of driving alone on peak-period was fixed as one aiming to normalize the parameters.

From the value of dissimilarity parameters in the cross-nested logit, it shows that the dissimilarity parameter on ridesharing behavior (0.546) is smaller than departure time decision on the off-peak period (0.636), meaning the alternatives in the nest of ride-sharing behavior have high substitutability. If the utility variables alter, the motorcyclists will change their departure time first in a condition when they depart on the off-peak hour. Meanwhile, since the dissimilarity parameter on ridesharing behavior (0.546) is higher than departure time decision on peak hour (0.455), for motorcyclists departing on peak hour tend to change their joint tour into single tour first before changing their departure time. Furthermore, driving alone has the lowest dissimilarity parameter by 0.359 representing that when the utility variable change, they tend to shift their departure time in both peak and off-peak hour situation.

### Table 3. Direct elasticities.

| Departure Time | Driving alone | Ridesharing |
|----------------|---------------|-------------|
|                | Travel Cost | Travel Time | Travel Cost | Travel Time |
| Peak           | -0.041      | -0.012      | -0.024      | -0.008      |
| Off peak       | -0.023      | -0.008      | -0.024      | -0.008      |

Concerning direct elasticities computing results as shown in Table 3, the average value of direct elasticities for travel time (0.010) are triple less than travel cost (0.029) meaning that motorcyclist has a higher sensitivity to travel cost than travel time. According to the results, a 1% increase in the travel cost for motorcyclists who are driving alone and departing on the off-peak hour to become available results in 0.041% decrease in the probability of driving alone and leaving home on the off-peak hour. Except on above condition, it can be seen that the values of elasticity in both travel time (0.008 and 0.011) and travel cost (0.024 and 0.027) for motorcycle-based ridesharing on peak period is slightly lower than driving alone (0.008 and 0.012 for travel time, and 0.023 and 0.041 for travel cost). Meanwhile, for the off-peak period, motorcyclists departing to work by escorting their family member are less elastic for a change of travel cost (0.027) than motorcyclists departing to work by driving alone (0.041). In addition, motorcyclists who depart on off-peak period are more sensitive to change in both travel time (0.012 and 0.011) and travel cost (0.041 and 0.027) than motorcyclists who depart on peak period (0.008 for travel time, and 0.023 and 0.024 for travel cost).

Taking into account the low elasticity values on both travel time and travel cost, it indicates that motorcyclists tend to be inelastic with respect to travel time and travel cost. Even though in this study does not consider the decision process of public transport choice, however, this situation is felt threatening the existing public transport (i.e. Trans-Jogja Bus) and the proposed rail-based public transport [30] in YSR. The transportation planners and policymakers must capture this situation to keep the existing demand and to increase the future demand for public transport in YSR.

### 6. Conclusion

Accommodating the effect of intra-household interaction on the decision-making process of departure time is a fundamental importance in understanding motorcyclists’ travel behavior in YSR. By interviewing 416 workers as motorcyclists, this study has discussed the combined choice of intra-household interaction-based joint tour and departure time.

A cross-nested logit model was used to investigate the effect of individual characteristics (gender, income, age), household characteristics (number of family member, number of vehicle ownership, home location), work-related characteristic (flexible/strict work starting time), and travel-related characteristics (travel time, travel cost, number of time-constrained activities) on the decision process of motorcycle-based joint tour and departure time.
The result shows that a more family member in a household increases the tendency of a joint tour. Motorcyclists residing in an urban area with work starting time flexibility are more likely to depart on the off-peak hour by escorting their family member first. Comparing among alternative, a joint trip conducted on off-peak hour has the highest utility than other options. Travel cost becomes the most significant variable shaping the combined choice of intra-household interaction-based ridesharing and departure time. Motorcyclists also have a higher sensitivity to travel cost than travel time. Meanwhile, comparing between the choice of joint trip and departure time, if there is a change of influential variables such as travel time, travel cost, etc., individuals prefer to alter their departure time rather than a joint trip. In a condition when they have to depart to work on off-peak time duration, they are more sensitive regarding a change of travel time and travel cost than if they leave to work on peak time duration.

A future study could incorporate public transport mode into the existing joint model. Demand-side policies could be proposed aiming to influence the motorcyclists not only to change their departure time but also to shift them as public transport users. In addition, the emergence of motorcycle-based ride-sourcing must be anticipated by the policymakers whether it acts as a substitution, complement, or nothing for both motorcycle and public transport mode [31]. It would be also interesting to include electric motorcycle [1] in order to explore how the existing motorcyclist behaves and reacts due to the emergence of a motorcycle-based new alternative mode and further analyze the potential market share of this mode by reflecting on the failure of hybrid cars in replacing the gasoline-powered cars in Indonesia [32]. It would of interest to explore whether alternative travel mode provides additional insights regarding the decision process of departure time choice and intra-household interaction-based ridesharing behavior.

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