

## **INTERCITY MODE CHOICE MODELLING: CONSIDERING THE INTRACITY TRANSPORT SYSTEMS WITH APPLICATION TO THE JAKARTA-BANDUNG CORRIDOR**

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### **ABSTRACT**

The choice among modes of intercity transport depends on conditions of not only intercity transport modes but also intracity transport in both the departure city and the arrival city. Intracity transport conditions might be advantageous for one intercity mode and disadvantageous for others. Intercity and intracity transport conditions are complex and need to be approached systemically. This study proposes an approach based on the passengers' preferences. The logit model was adapted to evaluate the transport modes' choices in competition. This model is called the "Adapted Mixed Multinomial Logit Model" (AMML). It was applied on the Jakarta-Bandung corridor in both directions. It contributes to a complete approach for intercity transport mode choice by considering the influence of the intracity transport conditions in both the departure and arrival cities. The results proved that the choice of intercity transport mode depends not only on its own quality of service but also, importantly, on that of the intracity transport systems.

*Keywords:* Adapted Mixed Multinomial Logit Model; Intercity Transport; Intracity Transport; Modal Choice; Modal Competition

### **1. INTRODUCTION**

The city/urban and regional transport systems can be considered as a macro system because they are defined by the interactions among micro transportation networks (Tamin, 2000). Intercity transport, as part of the micro transportation network, could offer many modes of transport to choose from. In a complex system, before choosing one intercity mode over the others, it is necessary to consider intracity transport conditions in the urban area (Behrends, 2012). In this paper, intercity transport mode choice considerations were not only on intercity modes performance but also on intracity transport performances. Mode performance can be identified as a combination of cost, travel time, and information conditions for users (Aydin & Dzhaleva-Chonkova, 2013; Wu et al., 2013). Such conditions can be expressed as a passenger's (dis)utility: for example a weighted sum of safety, connectivity, expected waiting time, and expected in-vehicle travel time (Chandra et al., 2013; Prasertsubpakij & Nitivattananon, 2012).

Any intercity transport mode which is not directly connected by door to door service needs a

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feeder transit service, particularly for public transport. Many feeder services operate in a way that is responsive to the demands of passengers near the residential areas (Koffman, 2004; Potts et al., 2010), and their performance depends on such factors as drivers' experience, stop frequencies, shuttle type, and demand at every stop. The interaction between two cities needs intermodal and multi-modal transport (Reis et al., 2013). A passenger's wrong decision about the different modes of transport to take for the total travel could result in a high cost or extra delay. The main motivation for our research is to propose tools to define the most profitable improvements for a particular transport mode in order to survive and possibly progress in modal competition.

In the present study, the competitive characteristics were explored for the three modes (train, private car and minibus) on the Jakarta-Bandung corridor. The modal share of transport between the two cities is 17% for train, 50% for car, and 33% for bus (Van der Ven, 2010), and the expected demand for 2017 is nearly 65 million passengers per year. The three modes were formalized and compared to find the modes' strengths and weaknesses as a function of their utility functions (Ben-Akiva & Lerman, 1985) and their probabilities of being chosen. In a second part, the principle of conditional probability is used to consider the relation between the three segments of travel, intracity A-intercity-intracity B, and their respective mode choices (Barus, 2015).

## 2. THEORY AND METHOD

Passenger's modes choice would be the one which could give them the maximum advantages. The logit model is one of the most realistic models for mode choice as a function of multi-criteria considerations. Logit model is based on a utility function  $f$  as defined for each mode. The function  $f$  represents the influence of particular characteristics of the service for each transport mode  $i$  (Ben-Akiva & Lerman, 1985):

$$U_i = f_i(V_1, V_2, V_3, \dots, V_p) \quad (1)$$

$V_1$  to  $V_p$  are variables related to the characteristics of the service of the transport mode;  $p$  represents the number of significant variables or service characteristics. The values of  $V_1$  to  $V_p$  are extracted from the set of passengers' preferences as expressed in questionnaires.

The utility function can be expressed as:

$$U_i = \beta_1 V_1 + \beta_2 V_2 + \beta_3 V_3 + \dots + \beta_p V_p + \varepsilon \quad (2)$$

The coefficients  $\beta_j$ ,  $j = [1, p]$  are calculated using maximum likelihood estimation, taking into account all passengers' preferences. They can be positive or negative.  $\varepsilon$  is an error term that accounts for unobserved factors. The  $\beta$  coefficients are associated to each transport mode's characteristics. The value  $U$  can be computed using a given set of variables  $V_j$ ,  $j = [1, p]$  expressed by passengers.

If  $U_i$  is a statistical representative value of all  $U$  values for mode  $i$ , then according with the basic Multinomial Logit model (Ben-Akiva & Lerman, 1985), the probability of mode  $i$ 's being chosen is given by:

$$P_i = \frac{e^{U_i}}{e^{U_i} + e^{U_{j_n}}} \quad (3)$$

The summation includes the contribution of all modes except  $i$ ,  $U_{j_n}/j \in [1, p]/j \neq i$ ,  $n = [1, k]$ , and  $e$  is exponential.

Previous research has used this model (Paha et al., 2013), and it has been applied to a first

evaluation of the significant variables related to mode choices considering only the intercity link for the corridor Jakarta-Bandung (Barus, 2015). In this study, we explored more advance not only the considerations of the intercity link but also those of the related intracity links. As a consequence, it became necessary to propose another model. The complete system is shown in Figure 1.

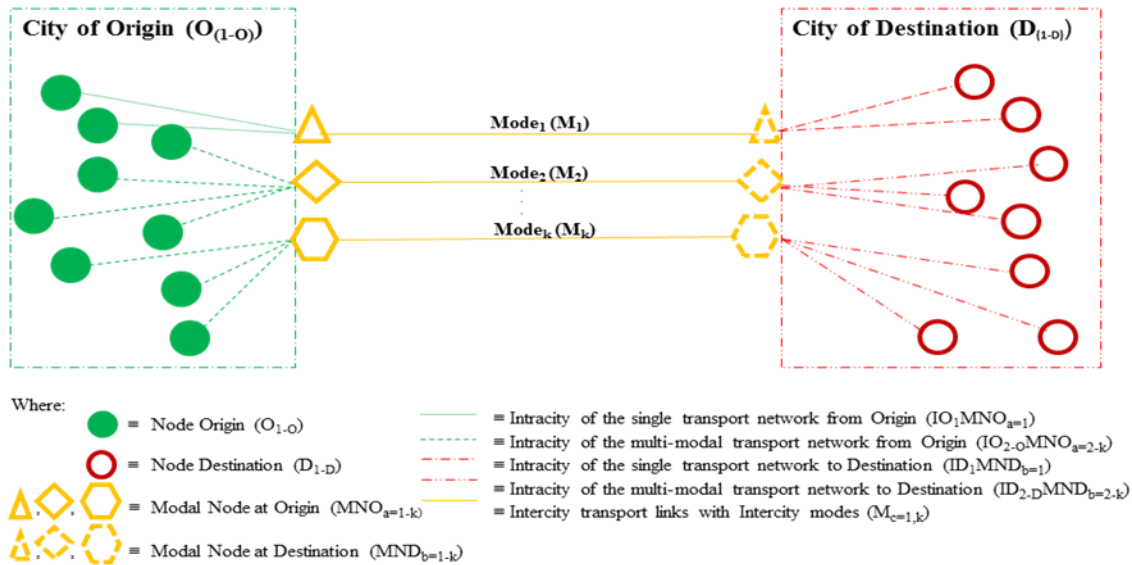


Figure 1 Intercity and Intracity Transport System for total travel

Total travel between two cities consists of three steps (Figure 2): step 1 is intracity transport at City A; step 2 is intercity transport from modal node 1 to modal node 2; and step 3 is intracity transport at City B. Depending on passengers’ preferences, the hierarchy of the decision-making process is not the same with all three steps. The decision process begins with the choice of the itinerary from the point of origin to the modal node as the first step; the choice of the itinerary from the modal node in the second city to the final destination as the second step; and, finally, the choice of the intercity mode of transport as a function of the two previous choices (Figure 3).

Historically, previous studies, such as McFadden and Train (2000), have developed the Mixed Multinomial Logit Model with application in econometrics. The term Mixed signifies that the final choice depends on several different functions. However in this study, the Adapted Mixed Multinomial Logit Model (later called AMML) considers three multinomial functions related to passenger preferences and could be extended more than three. In this study, the transport conditions at the point of origin and those at the destination are taken into account, and then the final probability condition of choosing one particular mode on the intercity link will follow the conditional probabilities with three events to get the final result (Walpole & Myers, 2012). The first event is choosing the modal node at the point of origin; the second is choosing intracity transport alternatives from modal node at the destination; and the third is choosing an intercity mode which connects both intracity transport systems. The equation is given below:

$$P(MNO_i \cap MND_i \cap M_i) = \frac{e^{UMNO_i}}{\sum_{a=1,k} e^{UMNO_a}} \cdot \frac{e^{UMND_i}}{\sum_{b=1,k} e^{UMND_b}} \cdot \frac{e^{UM_i}}{\sum_{c=1,k} e^{UM_c}} \tag{4}$$

where  $P(MNO_i \cap MND_i \cap M_i)$  is the probability of the intersection of 3 events related to mode  $i$ .  $UMNO_i$  is the utility value related to mode  $i$  taking into account the travel conditions from origin to modal node  $i$  at the departure city.  $UMND_i$  is the utility value related to mode  $i$ , taking

into account the travel conditions from modal node  $i$  to the destination.  $UM_i$  is the utility value related to mode  $i$  of intercity transport.  $k$  is the number of modes in competition on the intercity link.  $UMNO_i$ ,  $UMND_i$ ,  $UM_i$  are obtained using Equation 2.

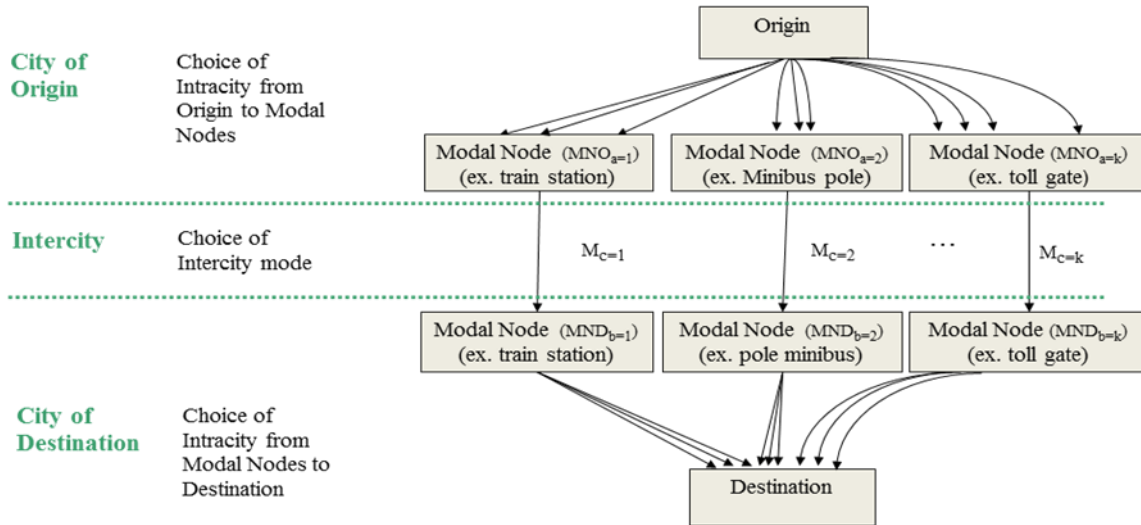


Figure 2 Transportation steps from origin to destination

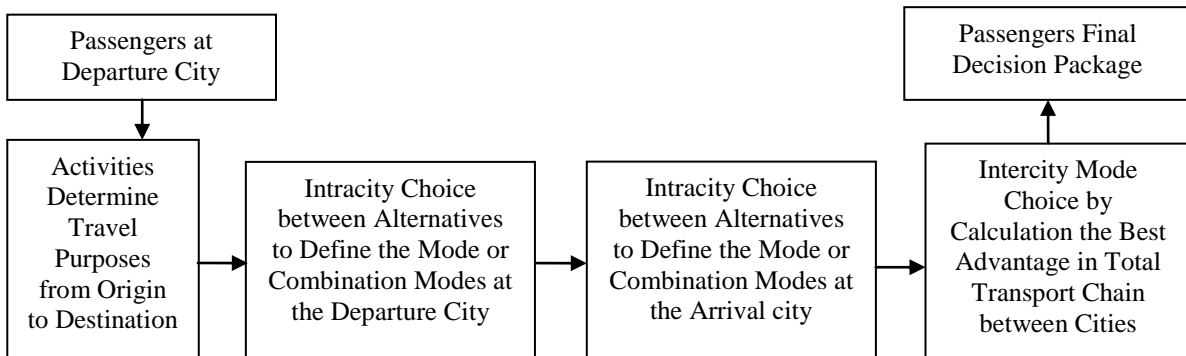


Figure 3 Decision making process in mode choice from origin to destination

In a situation of more than 3 events, the final probability of choice could be obtained by a generalization of Equation 4, involving as many terms as there are conditions influencing the main choice.

### 3. ADAPTED MIXED MULTINOMIAL LOGIT MODEL (AMML) APPLICATION WITH THE JAKARTA-BANDUNG CORRIDOR

Jakarta and Bandung are two main cities in Indonesia separated by nearly 200 km. Their economic growth boosts the number of trips between both cities. Nowadays, the increasing transport demand selects for the offered services. The transport modes on the corridor are in a situation of high competition, boosted by the new additional route of the toll road and the closure of the air transport service between the two cities. The expression of travelers' preferences and priorities is fundamental in order to define the suitable mode of transport for a market segment (Barus, 2015). Even if there is a political willingness of the Indonesian government to improve its rapid mass transportation and to protect the environment from

pollution (Presidential Decree No. 44, 1997), it is still necessary that it be followed by significant solutions and a good strategy for renewing and developing the rail system. Without them rail transport will continuously decline, losing demand and incomes, while the rail infrastructures and the trains continue to age.

### 3.1. Data Collection

Previous researchers have used “stated preference” and “revealed preference” studies to explore different modal attributes (Ahern & Tapley, 2008). In this study, we adopted the same approaches. In 2014, we distributed questionnaires to passengers in order to obtain their transport preferences for the Jakarta-Bandung corridor. The needed number of questionnaires was counted according to “probability sample equation” (Lind et al., 2007). Accordingly, we needed 780 questionnaires as the minimum number in total, but 900 questionnaires were distributed to avoid the risk of errors, and finally 453 answers were verified for the Jakarta-Bandung route and 437 for the Bandung-Jakarta route (890 in total). The questionnaires were randomly distributed in three different locations: railway stations, minibus stops, and toll road rest areas. In each location, the respondents were represented all 5 zones in Jakarta and Bandung: the north, the south, the east, the west, and the center. The questionnaires were designed with ranking questions about the transport characteristics of each mode in competition on the corridor. For example the real total travel time has a range between 1 and 4, with 4 corresponding to much less time compared to 1. The utility values for the private car mode are used as the reference of comparison (Therefore the values for that mode are all zero in the presentation of the results).

### 3.2. Analysis of Utility Functions for the Jakarta-Bandung Route

Utility values were used to measure the degree of satisfaction felt by persons choosing one mode of intercity transport (see Equation 2). The independent variables or “choice factors” which were observed for intracity transport at the points of origin and destination are: “transport time from home to the modal node 1” (VIO<sub>1</sub> and VID<sub>1</sub>), “the travel cost between home and modal node 1” (VIO<sub>2</sub> and VID<sub>2</sub>), “the travel safety between home and modal node 1” (VIO<sub>3</sub> and VID<sub>3</sub>), “the availability of information between home and modal node 1” (VIO<sub>4</sub> and VID<sub>4</sub>), “the transport connection facilities between home and modal node 1” (VIO<sub>5</sub> and VID<sub>5</sub>). The intercity transport modes variables are: “transport time from the modal node 1 to modal node 2” (VM<sub>1</sub>), “the travel cost between modal node 1 and modal node 2” (VM<sub>2</sub>), “the travel safety between modal node 1 and modal node 2” (VM<sub>3</sub>), “the availability of information between modal node 1 and modal node 2” (VM<sub>4</sub>).

When the  $\beta$  coefficients are positive for the “minibus” or the “train”, it means that users have current preferences for the “private car” mode. Positive coefficients for the “minibus” or the “train” mean that the associated variables should be improved to increase the performance of the mode. If the variable value could be increase then the utility value can be increased too. It means variables which have to increase were in low performance in current situation. In other words, a positive coefficient related to a given variable shows the weakness of that variable in the studied situation. When coefficients are negative for the “minibus” or the “train”, it means that users have current preferences for the associated variables in comparison with the same variables for the “private car”. So, the negative coefficients for the “minibus” and the “train” mean that the variables or factors for that mode are “strong”: these factors do not need to be improved, or the improvements are not a priority

(i) For the intracity transport with origin at Jakarta (JBO  $\equiv$  Jakarta Bandung Origin):

$$U_{\text{go to rail station}} = 9.166 + 0.337VIO_1 - 0.205VIO_2 - 0.759VIO_3 + 0.704VIO_4 - 1.548VIO_5 \quad (5)$$

$$U_{\text{go to minibus stop}} = 4.535 + 0.994VIO_1 - 0.697VIO_2 - 0.769VIO_3 + 0.017VIO_4 - 0.367VIO_5 \quad (6)$$

$U_{\text{go to toll gate}} \text{ is reference} = 0$

where:  $VIO_1 \equiv$  travel time,  $VIO_2 \equiv$  cost,  $VIO_3 \equiv$  safety,  $VIO_4 \equiv$  information,  $VIO_5 \equiv$  connection.

(ii) For the intracity transport with destination at Bandung (JBD  $\equiv$  Jakarta Bandung Destination):

$$U_{\text{from rail station}} = -6.288 + 0.425VID_1 + 0.115VID_2 - 0.807VID_3 + 0.425VID_4 + 0.795VID_5 \quad (7)$$

$$U_{\text{from mini bus stop}} = -14.307 + 0.654VID_1 + 0.003VID_2 - 0.620VID_3 + 0.442VID_4 + 1.715VID_5 \quad (8)$$

$U_{\text{from toll gate}}$  is reference = 0

where:  $VID_1 \equiv$  travel time,  $VID_2 \equiv$  cost,  $VID_3 \equiv$  safety,  $VID_4 \equiv$  information,  $VID_5 \equiv$  connection.

(iii) For intercity transport modes which serve the link Jakarta-Bandung (JBI  $\equiv$  Jakarta Bandung Intercity):

$$U_{\text{train}} = 4.010 - 0.672VM_1 + 0VM_2 + 0.342VM_3 - 0.539VM_4 \quad (9)$$

$$U_{\text{minibus}} = 2.231 - 0.193VM_1 + 0VM_2 + 0.337VM_3 - 0.556VM_4 \quad (10)$$

$U_{\text{car}}$  is reference = 0

where:  $VM_1 \equiv$  travel time,  $VM_2 \equiv$  cost,  $VM_3 \equiv$  safety,  $VM_4 \equiv$  information.

The results were statistically tested using indicators, such as the index value of the likelihood ratio ( $\rho$ -squared =  $\rho^2$ ).  $\rho^2$  is in the range 0 to 1. Rho squared ( $\rho^2$ ) value is similar to  $r^2$  in linear regression. An index likelihood ratio  $\rho^2$  interval between 0.15 and 0.2 indicates the relevance of the data (Hu et al., 2006). In our case,  $\rho^2$  is found to be relevant, indicating that the data is excellent (Tables 1, 2, and 3). A chi-square ( $\chi^2$ ) test was used to check the accuracy of the models. It should be that the  $\chi^2$  value count >  $\chi^2$  value table, and in this research, -2 Log Likelihood of Reduced Model ( $\chi^2$  value count) > Chi-square ( $\chi^2$  value table). So the resulting model can be used to predict the value of the dependent function (Tables 4, 5, and 6).

Table 1  $\rho^2$  value for the JBO data

Cox and Snell	0.280
Nagelkerke	0.315
McFadden	0.150

Table 2  $\rho^2$  value for the JBD data

Cox and Snell	0.271
Nagelkerke	0.305
McFadden	0.144

Table 3  $\rho^2$  value for the JBI data

Cox and Snell	0.133
Nagelkerke	0.150
McFadden	0.065

Table 4 Model Fitting Test JBO

Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	371.051	14.581	2	0.001
VIO <sub>1</sub>	381.678	25.209	2	0.000
VIO <sub>2</sub>	375.186	18.716	2	0.000
VIO <sub>3</sub>	371.869	15.400	2	0.000
VIO <sub>4</sub>	367.259	10.790	2	0.005
VIO <sub>5</sub>	396.602	40.133	2	0.000

Table 5 Model Fitting Test JBD

Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	371.051	14.581	2	0.001
VIO <sub>1</sub>	381.678	25.209	2	0.000
VIO <sub>2</sub>	375.186	18.716	2	0.000
VIO <sub>3</sub>	371.869	15.400	2	0.000
VIO <sub>4</sub>	367.259	10.790	2	0.005
VIO <sub>5</sub>	396.602	40.133	2	0.000

Table 6 Model Fitting Test JBI

Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	117.686	5.605	2	0.061
VM <sub>1</sub>	148.737	36.656	2	0.000
VM <sub>3</sub>	113.457	1.376	2	0.503
VM <sub>4</sub>	116.105	4.024	2	0.134

### 3.3. Results of the AMML Model for the direction Jakarta-Bandung

As described in Table 7, the best intracity transport alternatives for connecting to intercity transport in Jakarta are the rail station and the minibus stop (using Equation 3). They were the first choice for intracity transport from the point of origin. The alternative of the toll gate appears to be the worst. At the Bandung intracity link, the first choice is the minibus. For the intercity mode choice, the first choice is the train, but the final result for the choice in the total transport chain (using Equation 4) shows that the intercity minibus transport is the most favorable for passengers. Although the interurban train service is the best transport alternative (the highest choice probability value [0.42] in comparison with the other modes), it progressively loses its share of passengers in favor of minibus transport service: The AMML Model allows us to appreciate in a detailed way the influence of each choice factor of intracity transport on the intercity transport modes. In this case, it is clear that the train transport system cannot progress in modal competition if there are no improvements in the intracity transport systems connecting in Bandung via the rail stations.

Table 7 Final Modal Choice for the Jakarta-Bandung Route (AMML Model application)

Jakarta Intracity Link			Bandung Intracity Link			Intercity Transport		Intercity Modal Competition			
Link 1	Probability of Choice	Choice Intracity A	Link 2	Probability of Choice	Choice Intracity B	Modes	Probability of Choice	Choice Intercity	Modes	Conditional Probability of Choice	Final Choice
Home to rail station	0.4000	1	Rail station to destination	0.3100	2	Train	0.4200	1	Train	0.4241	II
Home to minibus stop	0.4000	1	Minibus pole to destination	0.5000	1	Minibus	0.3000	2	Minibus	0.4893	I
Home to highway toll gate	0.2000	2	Highway toll gate to destination	0.1900	3	Car	0.2800	3	Car	0.0846	III

These results were validated by an external data survey and run of the AMML Model (using Equation 4). The external data was obtained from the data survey using the split-half method. The differences between the two survey results at the final choice are not significant (0.96–5.48

%). The model is pertinent to identifying the strengths and weaknesses of the different modes in transport competition. The minibus was confirmed as the most competitive transport mode on the Jakarta-Bandung route (see Table 8). These indicators allow the transit operators to target investment and define the best actions for improving the different transport services. The model could be used after the improvements to evaluate the positive impact of the investments.

Table 8 External Validation of Final Modal Choice for the direction Jakarta-Bandung

Model Validation Statistic (External Data)											
Jakarta Intracity Link			Bandung Intracity Link			Intercity Transport			Intercity Modal Competition		
Link 1	Probability of Choice	Choice Intracity A	Link 2	Probability of Choice	Choice Intracity B	Modes	Probability of Choice	Choice Intercity	Modes	Conditional Probability of Choice	Final Choice
Home to rail station	0.3900	2	Rail station to destination	0.3900	1	Train	0.3400	2	Train	0.4337	II
Home to minibus stop	0.4000	1	Minibus stop to destination	0.3600	2	Minibus	0.3600	1	Minibus	0.4345	I
Home to highway toll gate	0.2100	3	Highway toll gate to destination	0.2500	3	Car	0.3000	3	Car	0.1317	III
Differences											
Jakarta Intracity Link			Bandung Intracity Link			Intercity Transport			Intercity Modal Competition		
Link 1	$\delta$	%	Link 2	$\delta$	%	Modes	$\delta$	%	Modes	$\delta$	%
Home to rail station	0.0100	1	Rail station to destination	0.0800	8	Train	0.0800	8	Train	0.0096	0.96
Home to minibus stop	0.0000	0	Minibus stop to destination	0.1400	14	Minibus	0.0600	6	Minibus	0.0548	5.48
Home to highway toll gate	0.0100	1	Highway toll gate to destination	0.0600	6	Car	0.0200	2	Car	0.0471	4.71

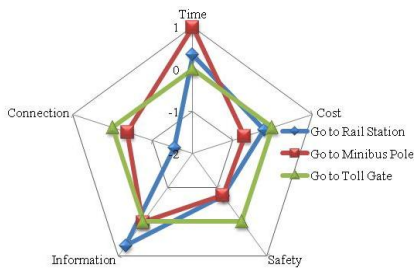
### 3.4. Results of AMML Model for the Bandung-Jakarta Route

The analysis of transport modal competition was performed for the case of passengers traveling from Bandung to Jakarta. The same applied methodology and data sources were used for the route from Jakarta to Bandung, but in this case, the AMML Model results in a different mode being the most competitive. It is interesting to observe that the best transport mode for the same corridor but the other direction is the private car. Even if the intracity public transport systems in the two cities are well connected, and the minibus and the train are less expensive than the car, the cost of the private car is more advantageous for the intercity segment of the travel. The car is the best choice for the Bandung-Jakarta route.

## 4. INTERPRETATION OF THE UTILITY FUNCTION: THE STRENGTHS AND WEAKNESSES OF EACH TRANSPORT MODE

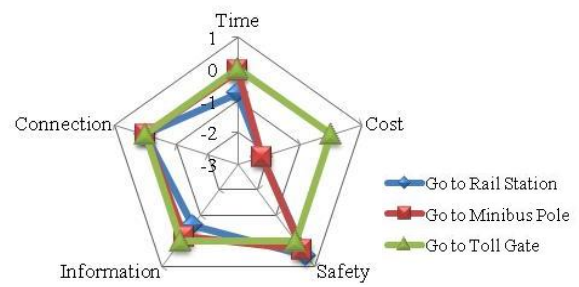
The next six graphics show the coefficients of each transport service. There are three graphics for each direction of travel, “Jakarta-Bandung” (Figures 8, 10, and 12) or “Bandung-Jakarta” (Figures 9, 11, and 13), which correspond with the 3 segments of travel “door-to-door”. They indicate which services to continue (the “strengths”) and which services to improve (the “weaknesses”).





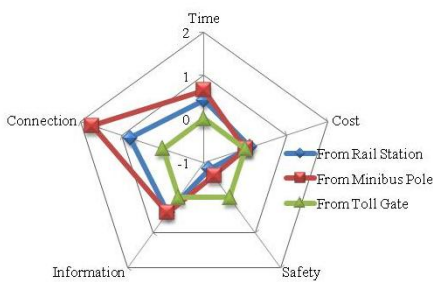
Note: Strengths of going to rail station at Jakarta are connection, safety, and cost

Figure 8 Utility Function Coefficients for Intracity Transport with Jakarta as Origin



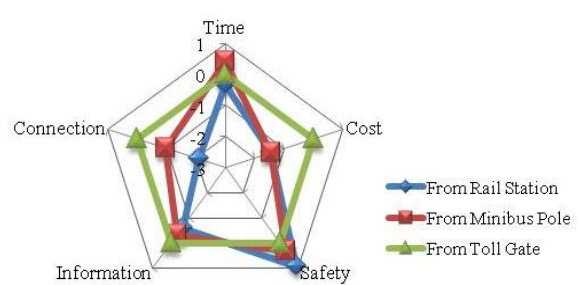
Note: Strengths of going to rail station at Bandung are cost, travel time and information

Figure 9 Utility Function Coefficients for Intracity Transport with Bandung as Origin



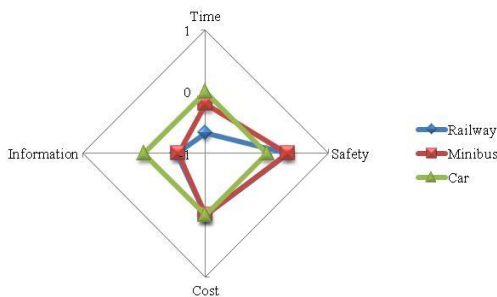
Note: Strength of going to destination from rail station at Bandung is only safety

Figure 10 Utility Function Coefficients for Intracity Transport with Bandung as Destination



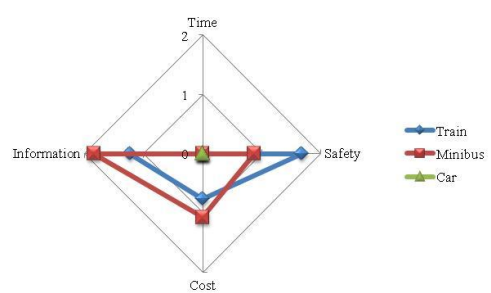
Note: Strengths of going to destination from rail station at Jakarta are all factors except safety

Figure 11 Utility Function Coefficients for Intracity Transport with Jakarta as Destination



Note: Strengths of train for the transport service Jakarta-Bandung are travel time, and available information

Figure 12 Utility Function Coefficients for Intercity Transport on the direction Jakarta-Bandung



The train's only weakness for the transport service Bandung-Jakarta is in comparison with the car

Figure 13 Utility Function Coefficients for Intercity Transport on the direction Bandung-Jakarta

### 5. CONCLUSION

The present study deals with the competition among three transport modes between two major cities, taking into account accessibility to the modal nodes. For that purpose, the approach based on conditional probabilities of mode choice, combined with a logit model, was applied to the total chain (Intracity A – Intercity – Intracity B). The identified variables of the decision process were obtained from questionnaires filled out by travelers on the total chain of transport (from Origin to Destination). The model is called AMML (Adapted Mixed Multinomial Model), and it was applied to the Jakarta-Bandung corridor.

The AMML Model results highlight the relationships between the modal competition of the intercity transport services and that of the local transport services available in the cities. This model could be used to define the weaknesses of a transport mode and the best solutions to deal with modal competition. The model can also measure the impact of the solutions and investments for a transport service as a function of transport demand evolution.

As recommendations to increase the competitiveness of the train transport services between Jakarta and Bandung, it is necessary to improve the safety of the trains. At Jakarta the cost of intracity transport is competitive; however any efforts at improvement must be oriented to reducing the travel time to the rail station. At Bandung, it is necessary to increase the transport alternatives to make the rail stations more accessible and to diminish the cost of the intracity travels.

For the travels from Bandung to Jakarta, the recommendations for increasing the competitiveness of the train transport services are to better inform passengers, improve the safety on the total travel chain, and diminish the high rail travel costs (which are due to intermediary agents).

The perspectives for the application of the AMML Model are diverse. The methodology and the model can be used to assess the characteristics of modal competition for any transport system, to recommend improvements for a particular transport mode as a function of the transport services in competition, and/or to continue to improve a transport mode after investments are made to modify the services.

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