Assessment of Road Pricing for Jakarta Metropolitan Area
Using Multi Class Assignment

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Abstract
Following the intensive Jabodetabek (Jakarta Metropolitan Area) origin-destination data from Bappenas-JICA, this paper reviews the impact of road pricing schemes located in the city center of trip attraction, using multi class assignment model. Focusing on an area section located in the center part of Jakarta, the paper analyzes cordon pricing and its impact to wide Jakarta network using route choice model. The impact to public transport busway services serving the area of pricing would also be estimated.

Keywords: Road pricing; multi class assignment.

1. INTRODUCTION

Jakarta currently has a traffic restraint scheme that has been in place since April 1992. From 6.30 am until 10 am, the city's most heavily trafficked corridor is out of bounds to cars with fewer than three occupants. It is known as the 'three in one' policy. Early results 3 months after the policy was imposed showed a decrease of 24 percent in the number of private cars entering the zone, and dramatic increases (over 150 percent) in average travel speed by private cars. However, in the popular mind at least, the scheme has not been considered a success. Traffic growth between 1992 and 1997 was very high so much of the benefit was probably overwhelmed by increasing traffic. In addition, a practice emerged of youths offering to ride as passengers for a small fee ("jockeys") to allow drivers to meet the occupancy requirement. This also undermined the image of the scheme (although it demonstrated some willingness to pay on the part of drivers).

In 1998, the City Administration has proposed to replace the 3-in-1 policy with an area pricing scheme (or "sticker" scheme) taking in a similar area. The scheme sounds much like the Singapore Area Licensing Scheme. Cars will need to buy and display stickers to enter the area in peak hours (7.30 - 9.30 am and 5.00 – 7.00 pm). This proposal has generated controversy (Barter, 1998). Opposition politicians and a major consumer’s organization have come out against the scheme. They say, among other things, that the system would discriminate against the poor. On the other hand, Jakarta's Governor argues that the scheme would hurt only the rich who are the ones who drive cars. But the opposition leader also argued that public transport was
insufficient, saying that more buses should be put onto the road before the scheme is implemented.

In Jakarta, the first 12.9 km initial closed system BRT corridor began operation on January 15, 2004, which starts from Blok M bus terminal and ended at Kota Station (from north to south on the main road corridors) operated by Trans Jakarta company. The Jakarta city government provided all the initial construction costs for the infrastructure and the buses. In the first year of operation (2004), 15.9 million passengers traveled by this system (approximately 44,000 passengers per day or 3,600 persons/hour/two directions). The average busway load factor during the week is 91% and during the weekend is 75%, with the highest load factor during the evening peak on weekdays, up to 143% (BP Trans Jakarta Bus Way, 2005). Since the system was just initiated four years ago and the Jakarta city government is still completing the whole planned BRT routes.

This study is aiming at to assess the evaluation of implementation of Road Pricing with/without busway under single/multi-class equilibrium assignment.

2 MODEL DEVELOPMENT

The model of research is firstly understanding the travel pattern model, followed by estimation of O-D estimation data, and finally with multi class assignment model.

2.1 Jakarta Activity-Based Travel Pattern

The travel pattern in a transport system is often described in terms of flows (vehicles, travelers or commodities) which move from locations of origins to points of destinations, within a particular area of interest and during a specified period of time. To model travel pattern in Jakarta, HTS (Home Travel Survey) and ADS (Average Daily Survey) were conducted together with Joint Mode-Distribution Data (Bappenas, 2004). The model is comprised of Daily Activity Pattern, Time of Day, Mode-Distribution and Sub-Work Based Tour (Yagi, 2006). Nested Logit and Multinomial Logit Model are used to analyze the O-D on mode, time and level of income.

2.1.1 Upper-tier Alternatives

Marginal choice probabilities for Out of Home (upper tier) DAP is presented by the equation of:

\[ Pr(Out) = \frac{e^{V_{Out} + \theta_{Out}}}{e^{V_{Out} + \theta_{Out}} + e^{V_{Home} + \theta_{Home}}} \]  

(1)

\[ Pr(H) = \frac{e^{V_{Home}}}{e^{V_{Out}} + e^{V_{Home}}} \]  

(2)

Pr(H) is the probability of having a home DAP; Pr(Out) is the probability of having an out-of-home DAP; VH is the individual’s utility for the home DAP; VOut is the individual’s utility for the out-of-home DAP; \( \Gamma_{Out} \) is the logsum variable for the out-of-home DAP nest; \( \theta_{Out} \) is the logsum parameter for \( \Gamma_{Out} \).
\( \tau_{\text{out}} = \ln \left\{ \sum_{(p,s) \in A_i} \left[ e^{\left( \frac{V_p + s - \Gamma_p - \Gamma_s}{\theta_p + \theta_s} \right)} \right] \right\} \)  

(3)

\( V_p, s \) is the individual’s utility for the DAP consisting of primary tour pattern \( p \) and secondary tour pattern \( s \); \( \Gamma_p \) is the logsum variable computed from the lower TOD choice utilities for primary tour pattern \( p \); \( \Gamma_s \) is the logsum variable computed from the lower TOD choice utilities for secondary tour pattern \( s \); \( \theta_p \) is the logsum parameter for \( \Gamma_p \); \( \theta_s \) is the logsum parameter for \( \Gamma_s \); and \( A_i \) represents the set of all primary and secondary tour patterns available for individual \( i \).

### 2.1.2 Lower-tier Alternatives:

\[
Pr(p, s|\text{out}) = \frac{e^{\left( \frac{V_p + s - \Gamma_p - \Gamma_s}{\theta_p + \theta_s} \right)}}{\sum_{p,s \in A_i} e^{\left( \frac{V_p + s - \Gamma_p - \Gamma_s}{\theta_p + \theta_s} \right)}}
\]

(4)

\( Pr(p,s|\text{out}) \) is the probability of having a DAP consisting of primary tour pattern \( p \) and secondary tour pattern \( s \), conditional on choice of the out-of-home DAPs. \( \Gamma_p \) and \( \Gamma_s \) represent the expected values of the maximum utility of the lower TOD choice and can be expressed as:

\[
\tau_p = \ln \left\{ \sum_{t \in T_i} \left[ e^{\left( \frac{V_t - \Gamma_s}{\theta_t} \right)} \right] \right\}
\]

(5)

\[
\tau_s = \ln \left\{ \sum_{t \in T_i} \left[ e^{\left( \frac{V_t - \Gamma_p}{\theta_t} \right)} \right] \right\}
\]

(6)

\( V_t \) is the individual’s utility for TOD combination (i.e., start of the tour and start of the returning segment of the tour) \( t \); \( \Gamma_t \) is the logsum variable computed from the lower (home-based tour) mode and destination choice utilities for TOD combination \( t \); \( \theta_t \) is the logsum parameter for \( \Gamma_t \); and \( T_i \) represents the set of all TOD combinations available for individual \( i \). The individual’s utilities in this model, \( V_H \), \( V_{\text{Out}} \), and \( V_p, s \), can be represented by:

\[
V_a = \beta X_a
\]

(7)

Where, \( V_a \) is the systematic utility of alternative \( a \), \( \beta \) is a vector of parameters to be estimated, and \( X_a \) is a vector of variables representing attributes of the household and the individual.

### 2.1.3 Time of Day Model

TOD choice is a multinomial logit model with 15 alternatives, and it is estimated separately for each purpose (i.e., work, school, maintenance, and discretionary). The marginal choice probabilities in the TOD choice are given by:

\[
Pr(t|a) = \frac{e^{\left( \frac{V_t - \Gamma_a}{\theta_t} \right)}}{\sum_{t \in T_i} e^{\left( \frac{V_t - \Gamma_a}{\theta_t} \right)}}
\]

(8)
Proportion Pr(t/a) is the probability of having TOD combination (i.e., start of the tour and start of the returning segment of the tour) t, conditional on activity pattern a (i.e., primary tour pattern p or secondary tour pattern s); \(V_t\) is the individual’s utility for TOD combination t; \(\Gamma_t\) is the logsum variable computed from the lower (home-based tour) mode and destination choice utilities for TOD combination t; \(\phi_t\) is the logsum parameter for \(\Gamma_t\); \(\theta\) is the logsum parameter estimated for activity pattern a in the upper DAP choice (i.e., \(\theta_p\) or \(\theta_s\)); and \(\mathbf{T}_i\) represents the set of all TOD combinations available for individual i. \(\Gamma_t\) represents the expected value of the maximum utility of the upper tier of the lower mode and destination choice and can be expressed as:

\[
\Gamma_t = \ln \left\{ \sum_{(n,d) \in T} \left[ e^{(\frac{V_{n,d} + \phi_{n,d} - T_{n,d}}{\theta_t})} \right] \right\}
\] (9)

### 2.2 Matrix Estimation from Traffic Counts Model
Considering a trip travelling between zones and it is assumed that the trip interchanges can be represented using transport demand model. Hence, the total number of trips \(T_{id}\) with origin in \(i\) and destination in \(d\) can be expressed as:

\[
T_{id} = O_i \cdot D_d \cdot A_i \cdot B_d \cdot f_{id}
\] (10)

where \(A_i\) and \(B_d\) = balancing factors expressed as:

\[
A_i = \frac{1}{\sum_d (B_d \cdot f_{id})} \quad \text{and} \quad B_d = \frac{1}{\sum_i (A_i \cdot f_{id})}
\] (11)

\(f_{id}\) = the difference function -negative exponential \(\exp(-\beta_i C_{id})\), and hence the traffic counts can be expressed as:

\[
V_i = \sum_i \sum_d O_i \cdot D_d \cdot A_i \cdot B_d \cdot f_{id} \cdot \left( p_{id}^{1 \phi} \right)
\] (12)

Tamin (1988) have developed an estimation method Maximum-Likelihood Estimation Method (ML) using equation below to maximize:

\[
L = c \prod_i p_i^{\phi_i}
\] (13)

subject to \(\sum_i V_i = \Phi_i\) = 0

(14)

Tamin (1997) provides research for public transport O-D estimation by calibrating a trip distribution – mode choice (TDMC) model from passenger counts with a case in Bandung. The research combined a family of aggregate model and a family of mode choice logit model from traffic (passenger) counts and other low cost data.

Tamin (2001) provides an estimation of best number of sample for accurate estimation for O-D matrix, using approaches of (i) proportion factor of trip interchanges for each link, (ii)
independence and inconsistencies conditions, and (iii) physical link condition. The research recommended the proportion of count sample of about 3.6% from total traffic count data.

The development of method was developed by combining trip distribution and mode choice model (TDMC) and calibrating it using low cost traffic (passenger) volumes information (Tamin and Purwanti, 2002 in Tamin, 2008). The application of gravity with multinomial logit under equilibrium assignment using Non-Linear-Least-Squares (NLLS) have been developed (Rahayu, 2008).

2.3 Model for Pricing Assignment

Gomez-Ibanez and Small (1994) in Win (2007) determined the seven basis forms of congestion pricing; point pricing, cordon pricing, zone pricing, parking charges, charge for distance traveled, charge for time spent in the area, and charge for both time spent and distance traveled in the area. All those schemes have their unique characteristics and impact to the city in different ways.

The need for methods which consider congestion effects to be used in urban and other heavily loaded networks is well recognized (Tamin, 1988). Some approaches have been developed to include congestion effects in route choice models and equilibrium assignment seems to be the preferred technique on practical and theoretical grounds. This type of assignment technique is consistent with Wardrop’s equilibrium principle which can be expressed in terms of a mathematical program.

Ho (2007) presented the multi-class congestion-pricing models for the continuum transportation system for monocentric city using the social welfare maximization model and the cordon-based congestion-pricing approaches. The research proved that the use of a continuum approach can help to intuitively identify the level of congestion and the external cost throughout the city.

Multi Class assignment with path analysis to compute the gradient matrix:

\[ \nabla Z(g)^{mi} = \frac{\partial Z(g)^{mi}}{\partial g^{m_i}} = \sum_{k} \alpha_{k} m_i \cdot \nu_k^{m_i} \cdot \sum_{a} \alpha_{a} \cdot \phi_a^{m_i} \cdot (\nu_a^{m_i} - \phi_a^{m_i}) \]  

Multi Class assignment with path analysis to obtain the derivates:

\[ \nu_a^{m_i} = -\sum_{k} \alpha_{k} m_i \cdot \nabla Z(g)^{mi} \cdot \sum_{a} \alpha_{a} \cdot \phi_a^{m_i} \cdot \nu_k^{m_i} \]  

3. DATA COLLECTION AND FINDING

3.1 Jakarta Activity-Based Trip Pattern Data

The Jakarta Transport Demand Model was developed using Tour Based Model (Yagi, 2006). Comparing this to conventional four step model, the method has many advantages (see Table 1).
Table 1 Comparison Tour Based Model

<table>
<thead>
<tr>
<th>FOUR-STEP MODEL</th>
<th>TOUR-BASED MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip Production</td>
<td>Daily Activity Travel Pattern</td>
</tr>
<tr>
<td>Trip Attraction</td>
<td>Activity Type and Primary/Secondary Role in the Tour Structure</td>
</tr>
<tr>
<td>Trip Distribution</td>
<td>Non-Home Based Trips O-D is linked to Home Based Trips in the same tour</td>
</tr>
</tbody>
</table>
| Mode Choice                              | 1. Mode related decision is modeled at the level of entire tour  
                                         2. Time of day choices is modeled |
| Trip Assignment                          | Micro-simulation assignment procedure                |

This structure considers activity choice, destination choice, and mode choice and route choice behavior.

The estimation of trips using micro simulation model (Yagi, 2006) is as shown in Figure 2.
3.2 Trips Movement

Estimation of trips movement for Jakarta Metropolitan Area (JMA) is presented using socio economic data. JMA is forecasted of 45.2 million trips/day and 50.4 million trips/day for 2010 and 2020 respectively (Figure 4).

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Trips (mil/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>36.7</td>
</tr>
<tr>
<td>2010</td>
<td>45.2</td>
</tr>
<tr>
<td>2020</td>
<td>50.4</td>
</tr>
</tbody>
</table>

Travel speed is reduced significantly, as 60% from 1985 data (Bappenas, 2004). On the other way, traffic volume of car in Jakarta is slightly increased or is almost the same. On the other hand, traffic volume of motorcycle in 2007 surged about 1.7 to 2.8 times by 2002 (JETRO, 2008).

3.3 Public Transport- Busway Corridor

The Jakarta Strategic Transport Plan (PTM) makes best endeavor to accommodate trip makers, with low and medium income class levels, with 15 busway corridors covering the major trunks cope with heavy trips in the network (Soehodho, 2007). The complete corridors are expected to be finished by the year of 2010, while by the end of 2007 it is expected that 10 corridors are already in place.

3.4 Pricing Area Scheme

The pricing area is set for the movement of most attracted traffic flows in JMA. Two options of pricing Area are presented. First, by Bappenas (20040 incorporating the new CBD in southern part of Jakarta, while secondly, is regulated by “Perda 6/99” which is formally contained in the Jakarta Structure Plan. While the first have been supported by busway, as the new favourite bus services in Jakarta, there is great chance for private passenger movement to shift to public transport, therefore alternative 2 is selected.

Figure 5 JMA Restraint Area
4. ANALYSIS

4.1 Matrix Calibration
Prior O-D matrix for JMA 2008 is interpolated using two consecutives matrices 2002 and 2010, based on Bappenas data. Matrix comprises O-D for car vehicles, motor cycles and small/light truck. Public transport movement is represented by person trips movement that will be preloaded to the road network assignment. The screen and cordon lines uses for O-D matrix calibration. This would come up with base year traffic data. Calibration between observed and modeled flow are presented in figure 6.

The assignment for JMA in light of macro Do Nothing Scenario is presented in figure 7.
5. **SUMMARY**
The flow of logical framework of multi class assignment for pricing is provided.

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**REFERENCES**


