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## LEMBAR PENGESAHAN

Judul : The Estimation of Combined Trip Distribution-Mode Choice Model  
Estimated from Traffic Count under Equilibrium Condition

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## ▼ C: Travel Demand Analysis and Forecast

### ▼ Academic Paper

- 
- |  |    |
|--|----|
| <b>Transport Mode Choice Models for Metro Manila and Urban Transport Policy Applications</b> | 79 |
| <i>*Alexis Morales Fillone, Cresencio M., Jr Montalbo and Noriel Christopher Tiglao</i>      |    |
| <a href="#">[Abstract]</a> <a href="#">[PDF (349K)]</a>                                      |    |
- 
- |  |    |
|--|----|
| <b>INVESTIGATING THE TEMPORAL TRANSFERABILITY OF TRANSPORT MODAL CHOICE MODELS: AN APPROACH BASED ON GIS DATA BASE</b> | 80 |
| <i>*Katia Andrade, Seiichi Kagaya, Kenetsu Uchida, Andre Dantas and Alan Nicholson</i>                                 |    |
| <a href="#">[Abstract]</a> <a href="#">[PDF (385K)]</a>  |    |
- 
- |  |    |
|--|----|
| <b>PASSENGERS' BEHAVIORAL INTENTIONS FOR INTERCITY BUS SERVICE IN TAIWAN: APPLICATION AND COMPARISON OF THE LISREL AND NEURAL NETWORKS</b> | 81 |
| <i>*Kai Chieh Hu and William Jen</i>   |    |
| <a href="#">[Abstract]</a> <a href="#">[PDF (217K)]</a>  |    |
- 
- |   |    |
|---|----|
| <b>Incorporating Differences in Marginal Utilities of Time across Activities in a Time Allocation Model</b> | 82 |
| <i>*Kali Prasad NEPAL, Daisuke FUKUDA and Testuo YAI</i>  |    |
| <a href="#">[Abstract]</a> <a href="#">[PDF (353K)]</a>   |    |
- 
- |  |    |
|--|----|
| <b>LOGIT DEMAND SUPPLY CHAIN NETWORK EQUILIBRIUM PROBLEM</b> | 83 |
| <i>*Huey-Kuo Chen and Huey-Wen Chou</i>                      |    |
| <a href="#">[Abstract]</a> <a href="#">[PDF (180K)]</a>      |    |
- 
- |  |    |
|--|----|
| <b>A STUDY ON THE MOTORCYCLE OWNERSHIP: A CASE STUDY IN PENANG STATE, MALAYSIA</b> | 84 |
| <i>*Lee Vien Leong and Ahmad Farhan Mohd Sadullah</i>                              |    |
| <a href="#">[Abstract]</a> <a href="#">[PDF (140K)]</a>                            |    |
- 
- |   |    |
|---|----|
| <b>Characteristics of Private Car and Motorcycle Ownership in Indonesia</b> | 85 |
| <i>*Leksmono Suryo Putranto, Susan Grant-Muller and Frank Montgomery</i>    |    |
| <a href="#">[Abstract]</a> <a href="#">[PDF (194K)]</a>                     |    |
- 
- |  |    |
|--|----|
| <b>Indonesian Domestic Sea Freight Movement Modelling Based on Stramindo Data (2003)</b> | 86 |
| <i>*Ofyar Z Tamin and Rusmadi Suyuti</i>   |    |
| <a href="#">[Abstract]</a> <a href="#">[PDF (286K)]</a>                                  |    |
-



<b>A BEHAVIORAL ANALYSIS OF PASSENGERS' RAILWAY STATION FACILITIES VISITING CHARACTERISTICS</b>	113
*Yoshihisa Yamashita, Naohiko Hibino and Hisao Uchiyama	
<a href="#">[Abstract]</a> <a href="#">[PDF (223K)]</a>	
<b>Modeling Repeated Choice Behaviors of Physical Damage Coverage for New Car Owners</b>	114
Chieh-Hua WEN, *Ming-Jyh WANG, Lawrence and W. LAN	
<a href="#">[Abstract]</a> <a href="#">[PDF (86K)]</a>	
<b>MODELING PUBLIC TRANSPORT CHAINS IN DEVELOPING CITIES</b>	115
*CAESAR PASCUAL RUBITE and YASUNORI MUROMACHI	
<a href="#">[Abstract]</a> <a href="#">[PDF (405K)]</a>	
<b>Forecasting Transportation Demand by Binary Logit Model, Light Rail System</b>	116
Jaisung Choi, Yongeun Shin, *Cheolgyu Eun and Jaehoon Oh	
<a href="#">[Abstract]</a> <a href="#">[PDF (431K)]</a>	
<b>A STUDY ON THE TRIP GENERATION CHARACTERISTICS OF BUSINESS PROCESS OUTSOURCING (BPO) COMPANIES IN THE PHILIPPINES</b>	117
*Jose Regin Fajardo Regidor	
<a href="#">[Abstract]</a> <a href="#">[PDF (186K)]</a>	
<b>THE ESTIMATION OF COMBINED TRIP DISTRIBUTION-MODE CHOICE MODEL ESTIMATED FROM TRAFFIC COUNT UNDER EQUILIBRIUM CONDITION</b>	118
*Rahayu sulistyorini and Ofyar Tamin	
<a href="#">[Abstract]</a> <a href="#">[PDF (163K)]</a>	



## THE ESTIMATION OF COMBINED TRIP DISTRIBUTION- MODE CHOICE MODEL ESTIMATED FROM TRAFFIC COUNT UNDER EQUILIBRIUM CONDITION

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**Abstract:** The development of techniques for calibrating the trip distribution models from traffic volumes to obtain the O-D matrices is well advanced (see Tamin, 1988; Tamin and Willumsen, 1988; Tamin, 1992). Therefore, positive results on this development will be further developed by combining trip distribution and mode choice model (TDMC) and calibrating it using low cost traffic (passenger) volumes information (see Tamin 1997; Tamin and Purwanti, O 2002). As usual, the traffic (passenger) counts are expressed as a function of model form and relevant parameters. In this case, the TDMC model is represented by a function of a model form and relevant parameters. The previous research still in a burden condition of "All or Nothing" which is not realistic for some road network in urban area. So, the main objective of this research is the application of a combined trip distribution-mode choice model estimated from traffic count under equilibrium condition.

**Key Words:** *Combined Trip Distribution-Mode Choice Model, Traffic Count, Equilibrium Assignment*

### 1. INTRODUCTION

One can interpret link flows (or traffic counts) as resulting from a combination of two elements: an **O-D matrix** and the **route choice** pattern selected by drivers on the network. These two elements may be linearly related to traffic counts, see equation (1) below, but under normal circumstances there will never be enough traffic counts to identify a single O-D matrix as the only possible source of the observed flows. Traffic counts alone are not enough to estimate O-D matrices, something else is needed.

The idea of combining 'traditional' data sources (home or roadside interviews) with low cost data like traffic counts is not entirely new (see **Van Zuylen and Willumsen, 1980** and **Tamin 1988, 1990**) in **figure 1**. The models can be used to combine, for example, roadside interview data with traffic (passenger) counts and this can be achieved with or without an explicit travel demand model (trip distribution model). For the purpose of public transport demand estimation, this idea can be extended to the development of a practical estimation approach to calibrate the combined **Trip Distribution and Mode Choice (TDMC)** model with traffic (passenger) counts and other simple zonal planning data.

This approach assumes that either trip distribution or mode choice model is represented by certain model forms. As usual, the traffic (passenger) counts are expressed as a function of the TDMC model. In this case, the TDMC model is represented by a function of a model form







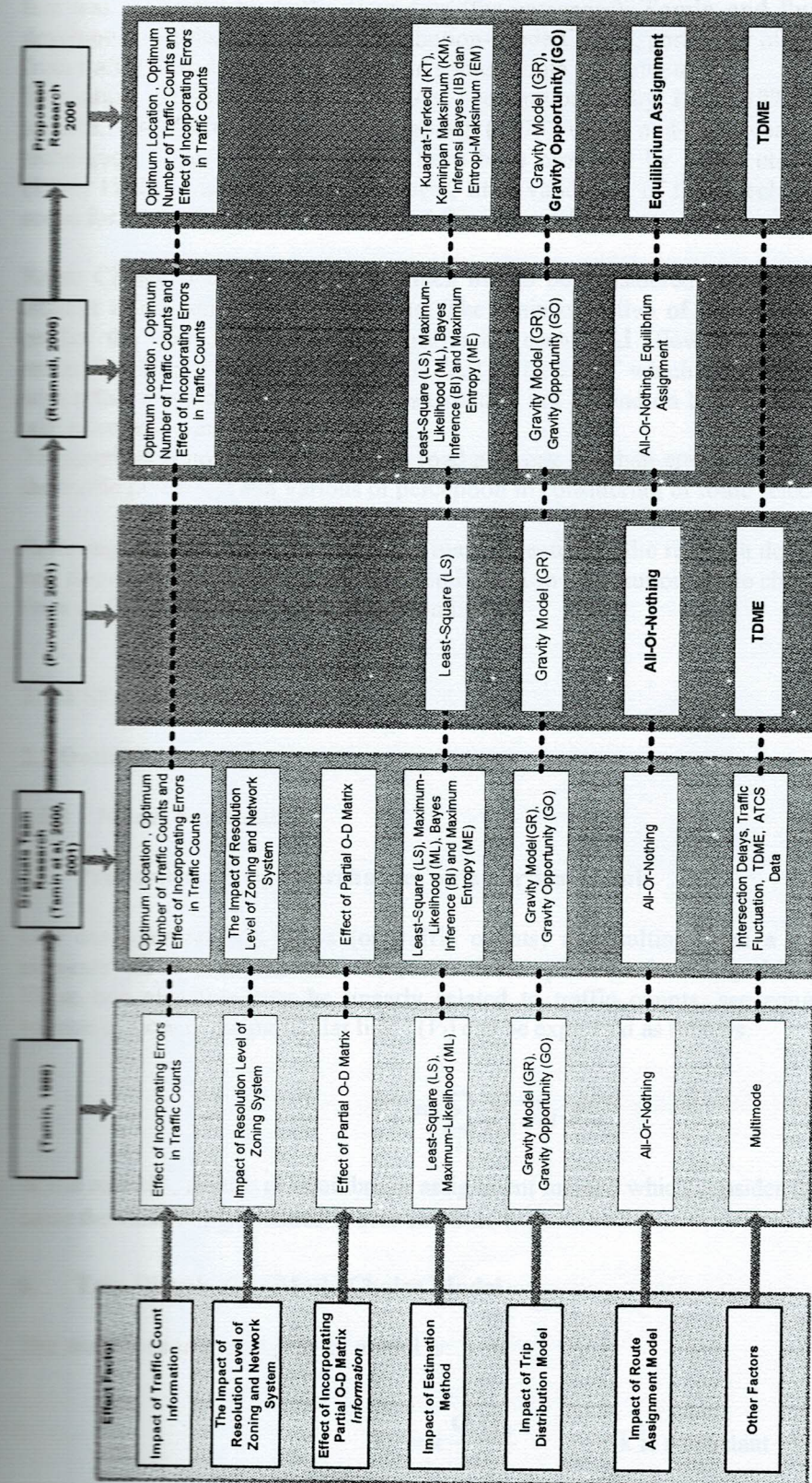


Figure 1 Roadmap on transport demand and model estimation research agenda



Tamin (1997) developed aggregate model which was combined with logit model selection that was calibrated by traffic flow data (for passenger). Tamin and Purwanti O. (2002) developed combination of Trip Distribution-Mode Choice, parameter of model was calibrated from traffic flow data or passenger and some simple planning data. Estimation methods of this kind have been proposed by Low (1972) using linear-least-squares, Robillard (1975) and Högberg (1976) using non-linear-least-squares estimation techniques. Other relevant methods have been proposed by Holm et al (1976) and Tamin (1988, 1992). There has been, however, little validation of these techniques and there is a scope for exploring more advanced and flexible model forms.

Route Choice is a major element which has to be considered carefully by travellers as an attempt to minimize their travel time. The main objective of the route choice model is to predict the correct throughput of traffic on each road (flow distribution). The previous research still in a burden condition of "All or Nothing" which was assumption that driver who select a route try to minimize its expense, not depend on traffic flow level, so all driver will select the same route.

This method is not realistic for some road network in urban area because it never consider to the traffic jam effect and various of perception in considering of route selection.

Referring to the previous research, the main objective of the research development is develop and demonstrate the application of a combined trip distribution-mode choice model estimated from traffic count under equilibrium condition.

## 2. RESEARCH PLAN

### 2.1 Outline

#### 2.1.1 Model Formulation

##### a. Proportion of trip interchanges on a particular link

One can interpret link flows (or traffic counts) as resulting from a combination of two elements: an O-D matrix and the route choice pattern selected by drivers on the network. These two elements may be linearly related to traffic counts, see equation (1), the total volume of flow in the particular link  $l$  ( $V_l$ ) can be expressed as follows:

$$V_l = \sum_i \sum_d T_{id} \cdot p_{id}^l \quad (1)$$

In this research, the use of equilibrium assignment method which consider the congestion effect cause the value of  $p_{id}^l$  obtained is between 0-1.

##### b. Trip Distribution-Mode Choice Model

The analogous transport gravity model is:

$$T_{id} = k \frac{O_i O_d}{d_{id}^2} \quad k \text{ is a constant} \quad (2)$$



Suppose now there are  $M$  modes travelling between zones, the modified gravity model (**Doubly-Constrained Gravity Model**) can then be expressed as:

$$T_{id} = \sum_m (O_i^m \cdot D_d^m \cdot A_i^m \cdot B_d^m \cdot f_{id}^m) \quad (3)$$

where:  $A_i^m$  and  $B_d^m$  = the balancing factors expressed as:

$$A_i^m = \left[ \sum_d (B_d^m \cdot D_d^m \cdot f_{id}^m) \right]^{-1} \text{ and } B_d^m = \left[ \sum_i (A_i^m \cdot O_i^m \cdot f_{id}^m) \right]^{-1} \quad (4)$$

This process is repeated until the values of  $A_i^m$  and  $B_d^m$  converge to certain unique values.

### c. Multi-Nomial-Logit model (MNL) as a mode choice model

The most general and simplest mode choice model (Multi-Nomial Logit Model) was used in this study. It can be expressed as:

$$T_{id}^k = T_{id} \cdot \frac{\exp(-\beta \cdot C_{id}^k)}{\sum_m \exp(-\beta \cdot C_{id}^m)} \quad (5)$$

By substituting equations (2)-(5) to equation (1), then 'the fundamental equation' for the estimation of a combined transport demand model from traffic counts is:

$$V_i^k = \sum_d \sum_i \left[ O_i^k \cdot D_d^k \cdot A_i^k \cdot B_d^k \cdot f_{id}^k \cdot p_{id}^k \cdot \frac{\exp(-\beta \cdot C_{id}^k)}{\sum_m \exp(-\beta \cdot C_{id}^m)} \right] \quad (6)$$

Equation (6) is a system of  $L$  simultaneous equations with only one (1) unknown parameter ( $\beta$ ) need to be estimated. There are four methods to estimate the unknown parameter so that the model reproduces the estimated traffic (passenger) counts as close as possible to the observed ones (see Tamin 2000).

#### 2.1.2 Estimation Methods

There are four estimation methods to estimate the unknown parameter so that the model reproduces the estimated traffic (passenger) counts as close as possible to the observed ones (see Tamin, 2000).

- Least-Squares estimation method (LLS or NLLS)
- Maximum-Likelihood estimation method (ML)
- Bayes-Inference estimation method (BI)
- Maximum-Entropy estimation method (ME)

#### 1. Non-Linear-Least-Squares Estimation Method (NLLS)

The main idea of this method is to estimate the unknown parameter which minimises the sum of the squared differences between the estimated and observed traffic counts. The problem now is:



$$\text{to minimise } S = \sum_l [V_l^{+k} - V_l^k]^2 \quad (7)$$

$\hat{V}_l^k$  = observed traffic flows for mode  $k$

$V_l^k$  = estimated traffic flows for mode  $k$

Having substituted (6) to (7), the following set of equation is required in order to find a set of unknown parameter  $\beta$  which minimises eq. (8):

$$\frac{\partial S}{\partial \beta} = \sum_l \left[ \left( 2 \sum_i \sum_d T_{id}^k \cdot p_{id}^{lk} - V_l^k \right) \left( \frac{\sum_i \sum_d \delta T_{id}^k}{\delta \beta \cdot p_{id}^{lk}} \right) \right] = 0 \quad (8)$$

Equation (8) is an equation which has only one (1) unknown parameter  $\beta$  need to be estimated. Then it is possible to determine uniquely all the parameters, provided that  $L > 1$ . Newton-Raphson's method combined with the Gauss-Jordan Matrix Elimination technique can then be used to solve equation (8).

## 2. Maximum-Likelihood Estimation Method (ML)

Tamin (1988, 2000) have also developed an estimation method which tries to maximise the probability as expressed in equation (9).

$$\text{to maximize } L = c \cdot \prod_l p_l^{\hat{V}_l^k} \quad (9)$$

$$\text{subject to: } \sum_l V_l^k - \hat{V}_T^k = 0 \quad (10)$$

The main idea of this method is to estimate the unknown parameter which maximise  $L$ .

$$\text{Max } L_1 = \sum_l \left[ \hat{V}_l^k \cdot \log_e \left( \sum_i \sum_d T_{id}^k \cdot p_{id}^{lk} \right) - \theta \cdot \sum_i \sum_d T_{id}^k \cdot p_{id}^{lk} \right] + \theta \cdot \hat{V}_T^k - \hat{V}_T^k \cdot \log_e \hat{V}_T^k + \log_e c \quad (11)$$

$$\frac{\partial L_1}{\partial \beta} = f\beta = \sum_l \left[ V_l^m \cdot \frac{\sum_i \sum_d \delta T_{id}^m}{\delta \beta \cdot p_{id}^{lm}} \right] - \theta \cdot \sum_i \sum_d \frac{\delta T_{id}^m \cdot p_{id}^{lm}}{\delta \beta \cdot p_{id}^{lm}} = 0 \quad (12a)$$

$$\frac{\partial L_1}{\partial \theta} = f\theta = -\theta \left[ \sum_i \sum_d T_{id}^m \cdot p_{id}^{lm} - V_T^m \right] = 0 \quad (12b)$$

Equation (12ab) is in effect a system of 2 (two) simultaneous equations which has 2 (two) parameters  $\beta$  and  $\theta$  need to be estimated. Again, the Newton's method combined with the Gauss-Jordan Matrix Elimination technique can then be used to solve for equation (12ab).

## 3. Bayes-Inference Estimation Method (BI)

The objective function of the Bayes-Inference (BI) estimation method can be expressed as:

$$\text{to maximize BI} = \sum_l \left[ \hat{V}_l^k \cdot \log_e \left( \sum_i \sum_d T_{id}^k \cdot p_{id}^{lk} \right) \right] \quad (13)$$



In order to determine uniquely parameter  $\beta$  of the Gravity (GR) model, which maximizes equation (13), the following two sets of equations are then required. They are as follows:

$$\frac{\partial BI}{\partial \beta} = \sum_l \left[ \left( \frac{\hat{V}_l^k}{\sum_i \sum_d (T_{id}^k \cdot P_{id}^{lk})} \right) \left( \sum_i \sum_d \left( \frac{\partial T_{id}^k}{\partial \beta} \cdot P_{id}^{lk} \right) \right) \right] = 0 \quad (14)$$

Equation (14) is an equation which has one (1) unknown parameter  $\beta$  need to be estimated. The Newton's method combined with the Gauss-Jordan Matrix Elimination technique can then be used to solve for equation (14).

#### 4. Maximum-Entropy Estimation Method (ME)

Mathematically, the objective function of the ME estimation method can be expressed as:

$$\text{to maximise } E_1 = - \sum_{l=1}^L \left[ \sum_{i=1}^N \sum_{d=1}^N T_{id} \cdot P_{id}^l \cdot \log_e \left( \frac{\sum_{i=1}^N \sum_{d=1}^N T_{id} \cdot P_{id}^l}{\hat{V}_l} \right) - \left( \sum_{i=1}^N \sum_{d=1}^N T_{id} \cdot P_{id}^l \right) + \hat{V}_l \right] \quad (15)$$

In order to determine uniquely parameter  $\beta$  of the GR model which maximizes the equation (15), the following equation is then required. They are as follows:

$$\frac{\partial E_1}{\partial \beta} = - \sum_l \left[ \left( \sum_i \sum_d \frac{\partial T_{id}^k}{\partial \beta} \cdot P_{id}^{lk} \right) \cdot \log_e \left( \frac{\sum_i \sum_d T_{id}^k \cdot P_{id}^{lk}}{\hat{V}_l^k} \right) \right] = 0 \quad (16)$$

Equation (16) is an equation which has only one (1) unknown parameter  $\beta$  need to be estimated. Newton-Raphson's method combined with the Gauss-Jordan Matrix Elimination technique can then be used to solve equation (16).

#### 3. OUTPUT TARGET

The use of all or nothing assignment for estimating the transport demand model can no longer be used for congested road networks. The research will develop the methodology and algorithms to cooperate the effect of equilibrium assignment. Therefore, the major contribution of this research is to enrich the knowledge on transport demand model estimation by cooperating the congestion effect using the application of the equilibrium assignment.

Figure 2 Research methodology



#### 4. METHODOLOGY

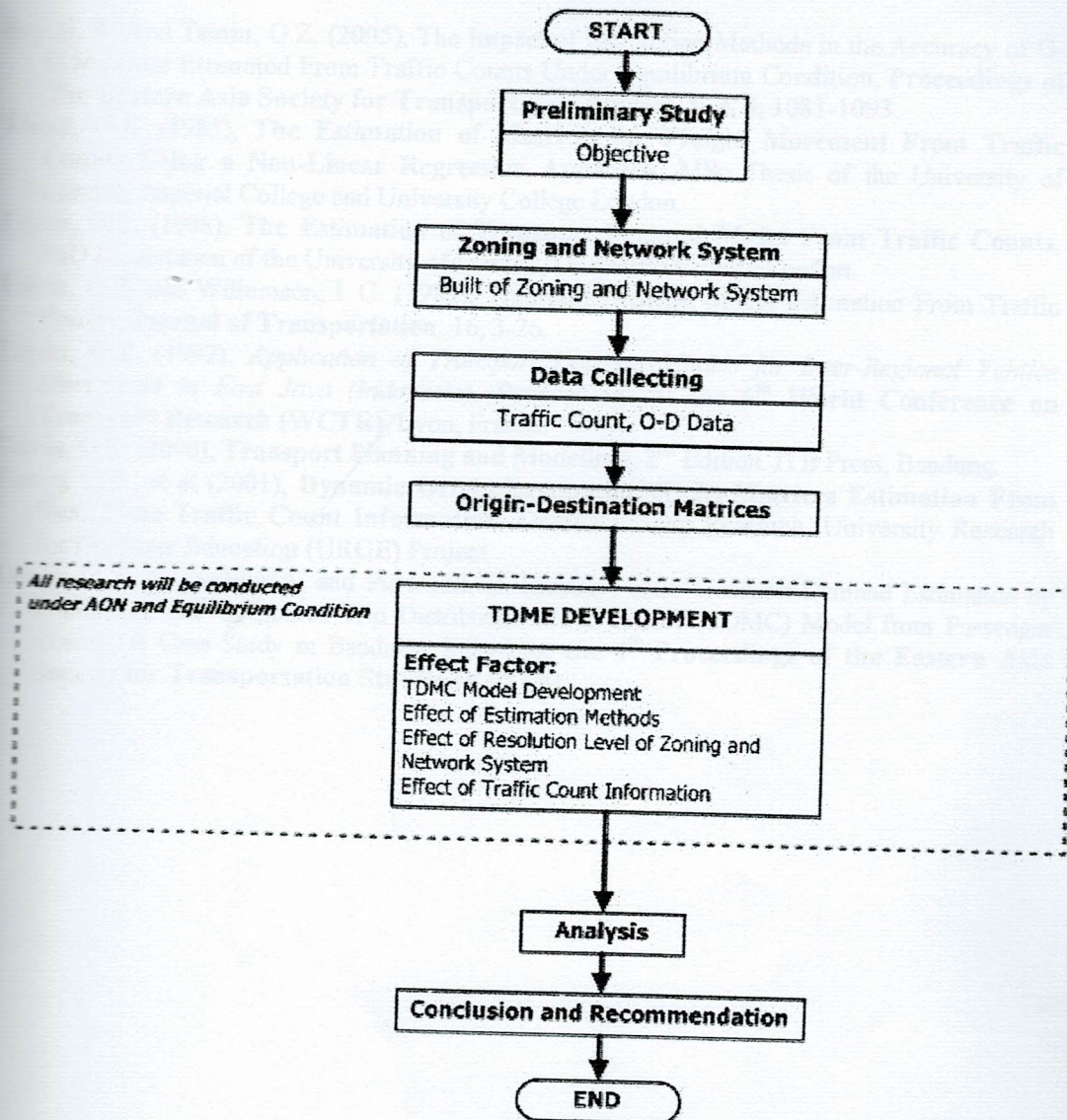


Figure 2 Research methodology



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