FSTPT

Inter-university Forum for Transportation Studies

# THE 11th FSTPT INTERNATIONAL SYMPOSIUM

## THE DEVELOPMENT OF TRANSPORTATION INFRASTRUCTURE FOR EMPOWERING LOCAL ECONOMY

## SYMPOSIUM GUIDE

Semarang, October 29-30th 2008

# LEMBAR PENGESAHAN

| | | |
|---|---|---|
| Judul | : | The Application of Gravity Model Combined With Multinomial Logit Model Under Equilibrium Assignment |
| Penulis | : | Rahayu Sulistyorini |
| NIP | : | 19741004 2000032002 |
| Instansi | : | Fakultas Teknik, Universitas Lampung |
| Publikasi | : | Prosiding Internasional |
| | : | ISBN: 979-95721-2-11 |
| | : | Hal. 1-11, Bulan Oktober dan Tahun 2008 |
| Penerbit | : | Fakultas Teknik Sipil Universitas Diponegoro Semarang |

Bandar Lampung, 21 Januari 2011

Mengetahui,
A.n. Dekan Fakultas Teknik
Universitas Lampung
Pembantu Dekan I

Dr. Eng. Helmy Fitriawan, S.T, M.Sc.
NIP. 197509282001121002

Penulis,

Dr. Rahayu Sulistyorini, S.T, M.T.
NIP. 19741004 2000032002

**Menyetujui:**

A.n. Ketua Lembaga Penelitian
Sekretaris Lembaga Penelitian Unila

Drs. Mardi Syahperi
NIP. 195801001980031001

## JADWAL KEGIATAN

## WORKSHOP/PELATIHAN

### Rabu, 29 Oktober 2008

| Waktu | Acara | Fasilitator |
|---|---|---|
| 08.00-08.30 | Registrasi | |
| 08.30-09.00 | Sambutan Pembukaan Oleh Dekan Fakultas Teknik UNDIP | |
| 09.00-12.00 | Workshop Internasional<br>Governance Reform Initiative in Transport Sector (GREAT) Project | - Prof. John Black<br>- Prof. Danang Parikesit |
| STREAM 1 (Paralel) : Infrastruktur dan Pembangunan Masyarakat | | |
| 13.00 – 14.30 | Workshop<br>Infrastruktur dan Pembangunan Masyarakat : Transportasi Perdesaan Dalam Mendukung Pembangunan Masyarakat | - Prof. Sunyoto Usman<br>- Ir. Arif Wismadi, M.Sc |
| 14.30 – 16.00 | Pelatihan<br>Pendanaan Infrastruktur Berbasis Pengembangan Wilayah | - Ir. Arif Wismadi, M.Sc<br>- Lilik Wachid, ST, MT<br>- Dr. Ir. Agus Taufik Mulyono, MT |
| STREAM 2 (Paralel) : Keselamatan Infrastruktur Jalan | | |
| 13.00 – 14.30 | Workshop<br>Pengelolaan Dana dan Penjaminan Korban Kecelakaan yang Manusiawi | - Dr. Heru Sutomo<br>- Hengki Purwoto, SE, MA |
| 14.30 – 16.00 | Pelatihan<br>Implementasi Inspeksi Keselamatan Jalan (IKJ) Dalam Penyelenggaraan Jalan Berkeselamatan | - Dr. Ir. Agus Taufik Mulyono, MT<br>- Berlian Kushari, ST, M.Sc<br>- Ir. Faisol, MT |

## SIMPOSIUM

### Kamis, 30 Oktober 2008

| Waktu | Acara |
|---|---|
| 08.00 – 08.30 | Registrasi |
| 08.30 – 09.00 | Pembukaan |
| | - Laporan Ketua Panitia |
| | - Sambutan Pembukaan "SIMPOSIUM" Secara Resmi Oleh Rektor UNDIP |
| | |
| 09.00 – 10.30 | *Keynote Speech* |
| | 1. Menteri Perekonomian, oleh : Deputy Menteri |
| | 2. Prof John Black |
| | 3. Prof. Danang Parikesit |
| | |
| 10.30 – 11.00 | Coffee Break |
| 11.00 – 12.30 | Paralel 6 Ruang |
| 11.00 – 12.30 | Presentasi Sesi I |
| 12.30 – 13.00 | Ishoma |

| | |
|---|---|
| 13.00 – 16.45 | Paralel 6 Ruang |
| 13.00 – 15.00 | Presentasi Sesi II |
| 15.00 – 15.15 | Coffee Break |
| 15.15 – 16.45 | Presentasi Sesi III |
| 16.45 – 17.00 | Penutupan |

## Ruang 01

## Makalah Berbahasa Inggris

## Pukul : 11.00 – 17.00

| No. | Judul Makalah | Penulis | Institusi |
|---|---|---|---|
| 1 | Violation Rate Of The Non-Bus Rapid Transit (BRT) Vehicles On The Jakarta BRT, Line Three | Leksmono Suryo Putranto | Universitas Tarumanagara |
| 2 | Reliability Estimation In Pavement Performance Prediction With | Suherman | Politeknik Negeri Bandung |
| 3 | Stable Crack Length On Pull-Out Problem-Significant Factor Of Pull-Out Modeling For Concrete Pavement Structure's Element - | Retno Susilorini | Unika Soegijapranata |
| 4 | The Application Of Gravity Model Combined With Multinomial Logit Model Under Equilibrium Assignment | Rahayu Sulistyorini<br>Ofyar Z. Tamin | Institut Teknologi Bandung |
| 5 | Background For Optimization Of Fuel Consumption At Congested Network Using Hydrodynamic Traffic Theory | M. Nanang Prayudyanto, dkk | Institut Teknologi Bandung |
| 6 | Exploring Jakarta's Bus Rapid Transit User Preference Using Stated Preferene Method | Adi Prasetio Raharjo<br>Tri Basuki Joewono<br>Wimpy Santosa | Universitas Katolik Parahyangan |
| | Ishoma | | |
| 7 | The Relation Of The Image And Fact Of The Quality Of Service Of Busway With User Loyalty | Dhany Utami Ningtyas<br>Tri Basuki Joewono | Universitas Katolik Parahyangan |
| 8 | Willingness To Pay Of Bus Rapid Transit User Using Stated Preferences Technique | Finna Octoprina Arifin<br>Tri Basuki Joewono | Universitas Katolik Parahyangan |
| 9 | Preference Of User Regarding The Future Of Bus Rapid Transit In Jakarta | Almeida Andes Sudrajat<br>Tri Basuki Joewono | Universitas Katolik Parahyangan |
| 10 | Passenger Respon To The Safety Aspect Of New Public Transportation In Yogyakarta | Prima Juanita Romadhona<br>Sigit Priyanto | Universitas Gadjah Mada |
| 11 | Optimum Adaptive Traffic Control On Saturated Two Way Two Lane Roads Work Zones | Endang Widjajanti<br>Sutanto Soehodho<br>Tri Tjahjono | Institut Sains & Teknologi Nasional |
| 12 | Coping With Problems Of Implementing Public Transport Routes In Palembang, Indonesia | Erika Buchari<br>Charlemagne Danoh | Universitas Sriwijaya |
| 13 | Strategic Design Of Distribution System Of State-Owned Companies: Preliminary Stage Of Logistics Research Series | Sutanto Soehodho<br>Nahry | Universitas Indonesia |
| 14 | Tendency Of World Container Transportation And It's Impact On Indonesia Container Network And Port Development | Syafi'i | Universitas Sebelas Maret |
| | Coffee Break | | |
| 15 | Understanding The Ownersip And Use Of Motorcycle In Greater Jakarta | Ellen Sophie Wulan Tangkudung, dkk | Universitas Indonesia |
| 16 | Software Development For Enhancing Traffic Management In Batu Pahat | Mohd Ezree bin Abdullah, dkk | University Tun Hussein Onn |

# THE APPLICATION OF GRAVITY MODEL COMBINED WITH MULTINOMIAL LOGIT MODEL UNDER EQUILIBRIUM ASSIGNMENT

*Rahayu Sulistyorini*
*Mahasiswa S3 Transportasi*
*Jurusan Teknik Sipil - ITB*
*Jl. Ganesha No. 10, Bandung*
*Telp : 2512395; Fax : 2502350*
*sulistyorini_smd@yahoo.co.uk*

***Ofyar Z. Tamin***
*Program S-2 Transportasi*
*Jurusan Teknik Sipil – ITB*
*Jl. Ganesha No. 10, Bandung*
*Telp : 2512395; Fax : 2502350*
*ofyar@trans.si.itb.ac.id*

**Abstract**

The idea of combining '**traditional**' data sources (home or roadside interviews) with low cost data like traffic counts is not entirely new. However, the previous research still in a burden condition of “All or Nothing” which is not realistic for some congested road networks in urban area. The main objective of this research is the application of gravity with multinomial logit under equilibrium assignment. The estimation methods, namely: Non-Linear-Least-Squares (NLLS) will be used to estimate the parameters of transport demand models. The first stage of model implementation is to code the algorithm into computer program, use C++ language. The hypothetical network contents of nodes, 8 links and 4 zones. The output program from experiment results and analysis can be resumed as the mathematical formula of TDMC Model Development can be applied in artificial network. For detailed application in real network with equilibrium assignment, would be use computer software like EMME/2.

**Keywords:** Gravity, Multinomial Logit Model, Equilibrium

## I. INTRODUCTION

### I.1 Background

Urban transport study need model to predict movement. On planning work in the context of future time it traffic volume determined from estimation result that use modeling. This traffic volume estimating is very useful for transport network system planning and traffic management. The idea of combining '**traditional**' data sources (home or roadside interviews) with low cost data like traffic counts is not entirely new (see **Tamin, 1988**, see also **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.

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 and relevant parameters. The parameters of the postulated model are then estimated, so that the errors between the estimated and observed traffic (passenger) counts are minimized.

The standard approach of transport demand modeling is well known as the sequential model consisting of trip generation, trip distribution, modal split and trip assignment. The models are analyzed sequentially, where the output of the first sub-model (trip generation) is used as input to the second sub-model (trip distribution) then the output of the second sub-model (trip distribution) is used as input to the third sub-model (modal split).

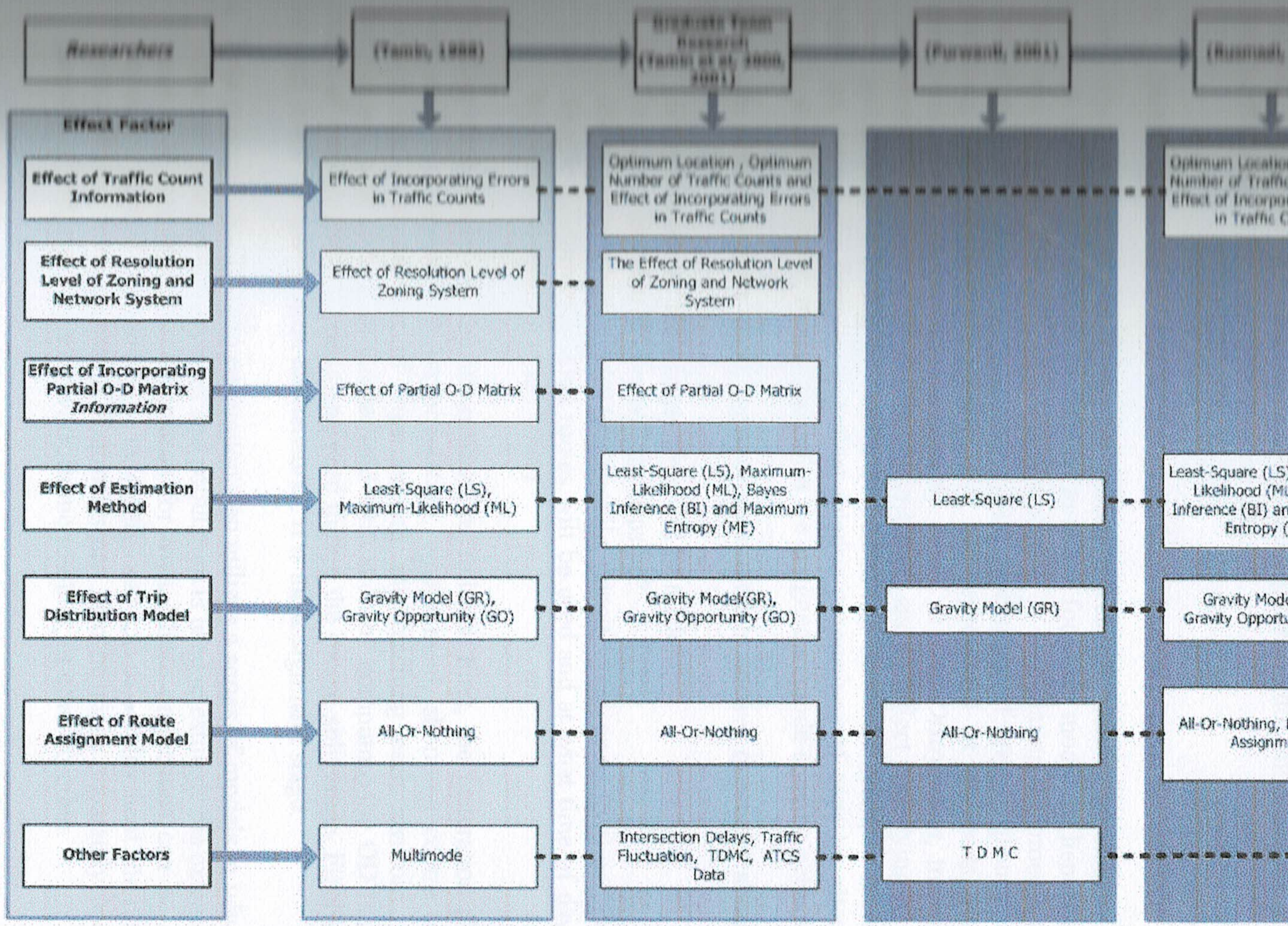



**Figure 1** Roadmap On Transport Demand Model Estimation Research Agenda

### 1.2 Objectives

Research development about combination modeling has the important role in transport modeling for use in effective and efficient transport system planning. Route Choice is a major element which has to be considered carefully by travelers 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 congested road network in urban area because it never consider to the traffic jam effect and various 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 OVERVIEW OF FOUR-STEP TRAVEL DEMAND FORECASTING

The history of demand modeling for person travel has been dominated by the modeling approach which has come to be referred to as the four step model, or henceforth, 4SM. The 4SM was developed to deal with this complexity by formulating the process as a sequential four step model. First, in *Trip Generation*, measures of trip frequency are developed providing the propensity to travel. Trips are represented as trip ends, productions and attractions, which are estimated separately. Next, in *Trip Distribution*, trip productions are distributed to match the trip attraction distribution and to reflect underlying travel impedance (time and/or cost), yielding trip tables of person-trip demands. Next, in *Mode Choice*, trip tables are essentially factored to reflect relative proportions of trips by alternative modes. Finally, in *Route Choice*, modal trip tables are assigned to mode-specific networks.

Using the following four steps, transportation models answer questions about future travel patterns:

- ***Trip Generation:*** How many trips will be made?
- ***Trip Distribution:*** Where will the trips be?
- ***Mode Split:*** Which modes (automobile, transit, cycle, or on foot) will be used?
- ***Traffic Assignment:*** What routes will be used and at what time of day will the trips be taken? (Beimborn et al., 1996)

The four-stage model can be summarized as follows. First, the generation phase provides, from socio-economical data on population, employment, shopping centre or schools, for instance, the total number of trips leaving and reaching each centroid. Secondly, the distribution phase completes the demand estimation by computing the OD matrix. Next, the choice of transportation mode is analyzed during the modal split stage. Finally, traffic flows for each mode are assigned on the networks. It is the assignment stage.

a. **Trip generation** - The trip generation step utilizes a series of models in which zone-based information about employment and population is used to estimate the extent to which each zone is an origin and/or destination for trips. These projections can be disaggregated, depending upon data availability, to identify sub-sets of employment and population types with different travel behavior. Estimates can also be made separately according to the purpose of trip, e.g., home-to-work, home-to-other, or other-to-other.

b. **Trip distribution** - The trip distribution steps links the trip origins and destinations for each type of trip through a gravity, or spatial interaction model, in which the demand for travel between any two points is positively correlated with the number of trip origins and destinations for the zone pair, and negatively correlated with the impedance between the two zones. The results are commonly called "trip tables". Typically travel time is used as a measure of impedance or accessibility.

c. **Modal choice** - The mode choice step disaggregates trips between the highway and other modes. Mode choice models may include such factors as demographic group, cost, relative travel times, and trip purpose.

d. **Trip assignment** - The assignment, or loading, of vehicle trips to specific links in the highway network and person trips to links in the transit network occurs in this step. The assignment algorithm is usually based on the assumption that people try to minimize travel time. There are several different approaches that can be used to determine the traffic assignment that results in the smallest travel times. For example, the model may repetitively assign a user-selected percentage of trips incrementally along the network paths that result in the minimum travel time. As certain links fill up with traffic, the speeds on them are reduced and travel time increases, until other links become more attractive. The process continues until all trips are assigned.

## 3. 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 tha particular link l ($V_l$) can be expressed as follows:

$$V_l = \sum_i \sum_d T_{id} . p^l_{id} \quad (1)$$

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

### b. Trip Distribution-Mode Choice Model

The analogous transport gravity model is:

: *k* is a constant (2)

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

(3)

where and = the balancing factors expressed as:

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

This process would be iterated 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:

$$T_{id}^k = T_{id} \cdot \frac{\exp\left(-\gamma_k . C_{id}^k\right)}{\sum_m \exp\left(-\gamma_m . C_{id}^m\right)} \quad (5)$$

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:

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

**d. Estimation Method**

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)

**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:

to minimise (7)

= **observed traffic flows for mode <u>k</u>**

= **estimated traffic flows for mode <u>k</u>**

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

(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)**.

### Newton–Raphson's method and the Gauss–Jordan Matrix Elimination technique

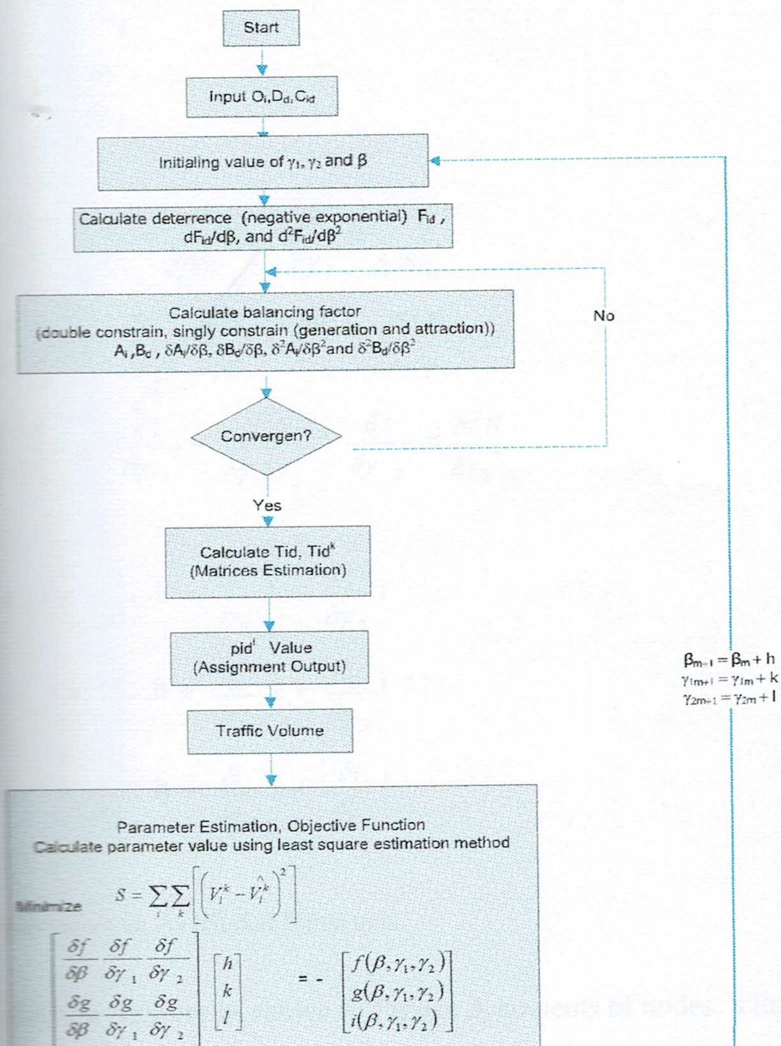



Figure 2 Newton–Raphson's Combine with The Gauss–Jordan Matrix Elimination Technique

Furthermore O-D Matrices Elimination Technique concept could be implemented in the following algorithm. (see **Figure 2.**) For futher explanation , is shown as bellow

$$f(\beta, \gamma_1, \gamma_2) = \frac{\delta S}{\delta \beta}$$

$$g(\beta, \gamma_1, \gamma_2) = \frac{\delta S}{\delta \gamma_1}$$

$$i(\beta, \gamma_1, \gamma_2) = \frac{\delta S}{\delta \gamma_2}$$

$$\frac{\delta f}{\delta \beta} = \frac{\delta^2 S}{\delta \beta^2} \; ; \quad \frac{\delta f}{\delta \gamma_1} = \frac{\delta^2 S}{\delta \beta \delta \gamma_1} \; ; \quad \frac{\delta f}{\delta \gamma_2} = \frac{\delta^2 S}{\delta \beta \delta \gamma_2}$$

$$\frac{\delta g}{\delta \beta} = \frac{\delta^2 S}{\delta \beta \delta \gamma_1} \; ; \quad \frac{\delta g}{\delta \gamma_1} = \frac{\delta^2 S}{\delta \gamma_1^2} \; ; \quad \frac{\delta g}{\delta \gamma_2} = \frac{\delta^2 S}{\delta \gamma_1 \delta \gamma_2}$$

$$\frac{\delta i}{\delta \beta} = \frac{\delta^2 S}{\delta \beta \delta \gamma_2} \; ; \quad \frac{\delta i}{\delta \gamma_1} = \frac{\delta^2 S}{\delta \gamma_1 \delta \gamma_2} \; ; \quad \frac{\delta i}{\delta \gamma_2} = \frac{\delta^2 S}{\delta \gamma_2^2}$$

$$f(\beta, \gamma_1, \gamma_2) = \frac{\delta f}{\delta \beta}.h + \frac{\delta f}{\delta \gamma_1}.k + \frac{\delta f}{\delta \gamma_2} i$$

$$g(\beta, \gamma_1, \gamma_2) = \frac{\delta g}{\delta \beta}.h + \frac{\delta g}{\delta \gamma_1}.k + \frac{\delta g}{\delta \gamma_2} i$$

$$i(\beta, \gamma_1, \gamma_2) = \frac{\delta i}{\delta \beta}.h + \frac{\delta i}{\delta \gamma_1}.k + \frac{\delta i}{\delta \gamma_2} i$$

### f. Application in Artificial Network

The hypothetical network as shown in **Figure 3**, contents of nodes, 8 links and 4 zones.

**Figure 3** Artificial Network

The first stage of model implementation is to code the algorithm into computer program which is used the coding with C++ language.

1. Matrices $C_{id}^1$

| From/to | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 15 | 20 | 30 | 60 |
| 2 | 35 | 15 | 50 | 55 |
| 3 | 60 | 45 | 20 | 45 |
| 4 | 35 | 50 | 45 | 15 |

2. Matrices $C_{id}^2$

| From/to | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 5 | 10 | 20 | 50 |
| 2 | 25 | 5 | 40 | 45 |
| 3 | 50 | 35 | 10 | 35 |
| 4 | 25 | 40 | 35 | 5 |

3. Matrices $C_{id}$

Assumption to get $C_{id}$ value

$$C_{id} = \frac{\left(C_{id}^1 + C_{id}^2\right)}{2}$$

| From/to | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 10 | 15 | 25 | 55 |
| 2 | 30 | 10 | 45 | 50 |
| 3 | 55 | 40 | 15 | 40 |
| 4 | 30 | 45 | 40 | 10 |

Simplification process to get $p_{id}^{l}$ value:

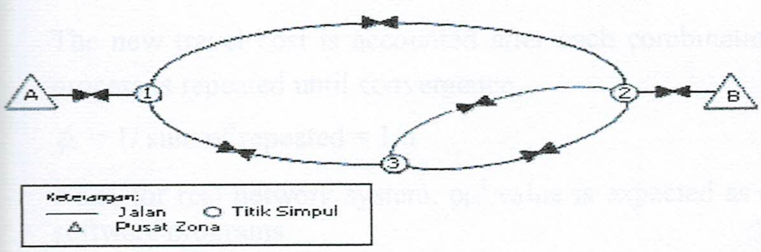



**Figure 4** Artificial Network to get value:

Where:

$T_{12} = 810$

Cost Function in each route is:

Route 1 : $C_{12} + 0.005\ V_1$

Route 2 : $C_{12} + 0.02\ V_2$

Route 3 : $C_{12} + 0.015\ V_3$

Using Repetitive Assignment Method, Origin Destination Matrices is assigned in network system continuously. Start with an all or nothing assignment, and then follow the rule developed by Frank-Wolfe to iterate toward the minimum value of the objective function. The new traffic volume is accounted as linear combination between $V_n$ and $V_{(n-1)}$ in each assignment procedure.

This algorithm as bellow:

1. Choice 1 set cost data
2. Build 1 set minimum cost, set n=n+1
3. Assign Origin Destination Matrices using all or nothing assignment to get Flow (Fi) value
4. Calculate volume existing

   $$V_l^{(n)} = (1-\phi).V_l^{(n-1)} + \phi.F_l$$

   $\phi$ : Parameter (with value = 0-1)

   $V_l^{(n)}$ : Traffic flow in stage n

   $F_l$ : Traffic flow from all or nothing assignment with travel cost from stage (n-1)

   $V_l^{(n-1)}$ : Traffic flow in stage (n-1)
5. Calculate new travel cost base on flow $V_l^{(n)}$ . The procedure is stopped when the flow for two successive iteration are quasi-equal. If not, go on stage (2).

The new travel cost is accounted after each combination of flow ($V_l^{(n)}$) is assigned. The process is repeated until convergence.

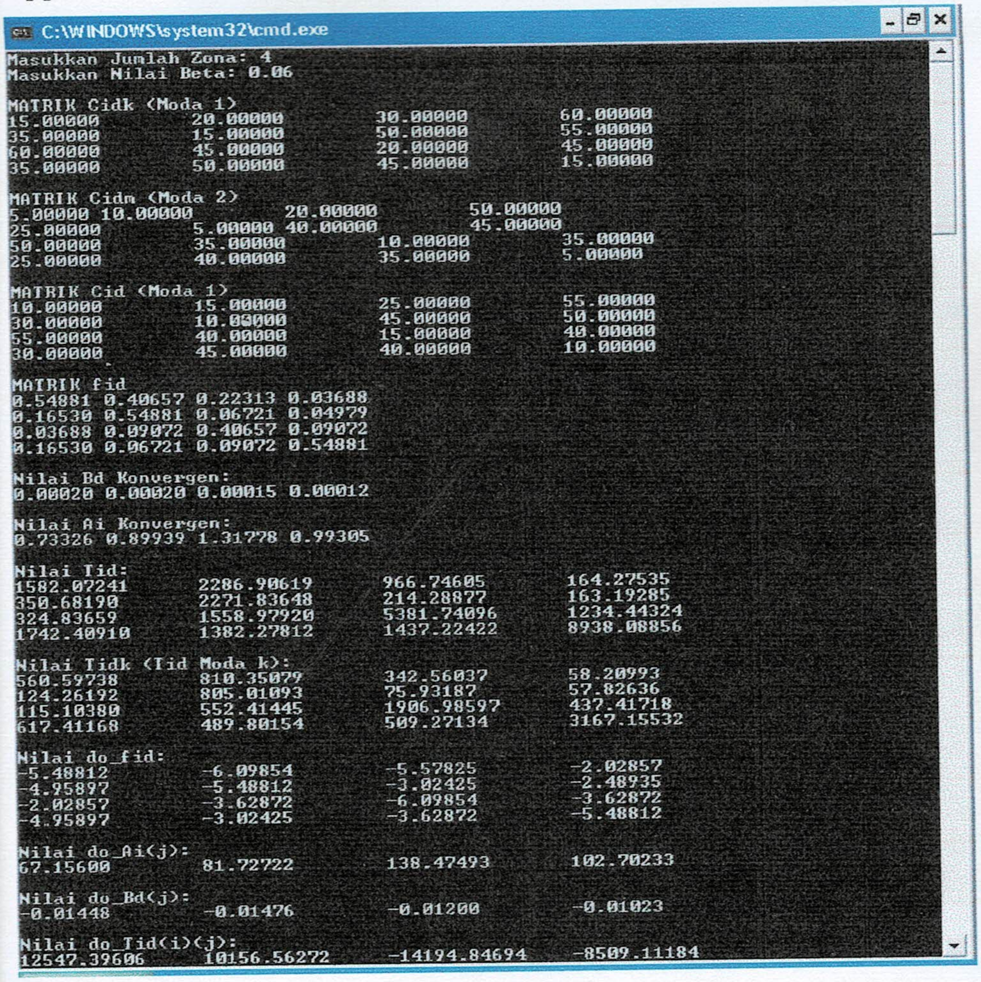
$\phi$ = 1/ sum of repeated = 1/n

Next, for real network system, $p_{id}^1$ value is expected as output of assignment from EMME/2 software programs.

## Conclusion

The standard approach of transport demand modeling is well known as four step model. Recently, development about combination modeling has the important role in transport modeling for use in effective and efficient transport system planning. This research is an application of combined gravity with multinomial logit model under equilibrium assignment. Using Non-Linear-Least-Squares (NLLS) as estimated method, and combined Newton–Raphson's with Gauss–Jordan Matrix Elimination technique, three unknown parameters have estimated. Model applied in artificial network with the algorithm using C++ . The output program from experiment results are the value of three parameters which was showed by convergence in iteration (see Figure 5 and Figure 6 in appendix). It could be resumed that mathematical formula of TDMC Model Development can be applied in artificial network. Detailed application in real network would be doing in next stage use computer software like EMME/2.

## Appendix



```
C:\WINDOWS\system32\cmd.exe
Masukkan Jumlah Zona: 4
Masukkan Nilai Beta: 0.06

MATRIK Cidk (Moda 1)
15.00000        20.00000        30.00000        60.00000
35.00000        15.00000        50.00000        55.00000
60.00000        45.00000        20.00000        45.00000
35.00000        50.00000        45.00000        15.00000

MATRIK Cidm (Moda 2)
5.00000 10.00000        20.00000        50.00000
25.00000        5.00000 40.00000        45.00000
50.00000        35.00000        10.00000        35.00000
25.00000        40.00000        35.00000        5.00000

MATRIK Cid (Moda 1)
10.00000        15.00000        25.00000        55.00000
30.00000        10.00000        45.00000        50.00000
55.00000        40.00000        15.00000        40.00000
30.00000        45.00000        40.00000        10.00000

MATRIK fid
0.54881 0.40657 0.22313 0.03688
0.16530 0.54881 0.06721 0.04979
0.03688 0.09072 0.40657 0.09072
0.16530 0.06721 0.09072 0.54881

Nilai Bd Konvergen:
0.00020 0.00020 0.00015 0.00012

Nilai Ai Konvergen:
0.73326 0.89939 1.31778 0.99305

Nilai Tid:
1582.07241      2286.90619      966.74605       164.27535
350.68190       2271.83648      214.28877       163.19285
324.83659       1558.97920      5381.74096      1234.44324
1742.40910      1382.27812      1437.22422      8938.08856

Nilai Tidk (Tid Moda k):
560.59738       810.35079       342.56037       58.20993
124.26192       805.01093       75.93187        57.82636
115.10380       552.41445       1906.98597      437.41718
617.41168       489.80154       509.27134       3167.15532

Nilai do_fid:
-5.48812        -6.09854        -5.57825        -2.02857
-4.95897        -5.48812        -3.02425        -2.48935
-2.02857        -3.62872        -6.09854        -3.62872
-4.95897        -3.02425        -3.62872        -5.48812

Nilai do_Ai(j):
67.15600        81.72722        138.47493       102.70233

Nilai do_Bd(j):
-0.01448        -0.01476        -0.01200        -0.01023

Nilai do_Tid(i)(j):
12547.39606     10156.56272     -14194.84694    -8509.11184
```

**Figure 5** Output Program (layer 1)

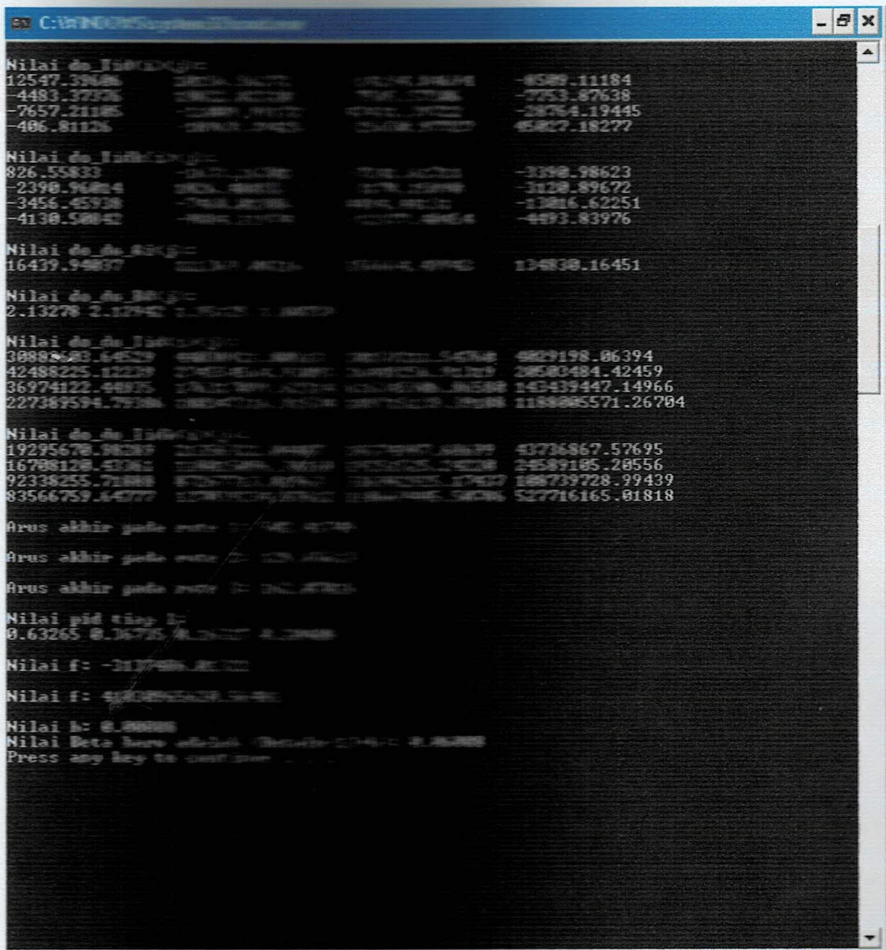


Figure 6 Output Program (layer 2)

## REFERENCE


Purwanti, O. (2002), *Estimasi Model Kombinasi Sebaran Pergerakan dan Pemilihan Moda Berdasarkan Informasi Arus Lalu Lintas,* Tesis Magister, Institut Teknologi Bandung

Suyuti, R. dan Tamin, O.Z. (2006), *Estimasi Parameter Model Kebutuhan Transportasi Berdasarkan Informasi Data Arus Lalu Lintas Pada Kondisi Pemilihan Rute Keseimbangan*, Desertasi Doktor, Institut Teknologi Bandung

Tamin, O.Z. (1985), *The Estimation of Matrices for Freight Movement From Traffic Counts Using a Non-Linear Regression Approach,* MSc Thesis of the University of London, Imperial College and University College London.

Tamin, O.Z. (1988), *The Estimation of Transport Demand Model From Traffic Counts,* PhD Dissertation of the University of London, University College London.

Tamin, O.Z. (2000), *Perencanaan dan Pemodelan Transportasi, Edisi II*, Penerbit ITB, Bandung.