

# Investigating the Utilisation of Different Variables for Direct Gravity Trip Distribution Model for Air Passenger Demand

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**Abstract**—Air Passenger Demand Model for prediction is a capital knowledge. Direct Gravity Trip Distribution Model seems the most appropriate for this prediction. Direct Gravity Trip Distribution model was tried to be developed, calculated by using iterative method. The research give indication that the Direct Gravity Trip Distribution can be developed and used. The general formula has been developed. A good combination of variables are still needs to be investigated. The calculation method has been refined by using the Mean Absolute Error as accuracy indicator. The research indicated that using single variables for each attraction mass and the impedance is better. For the research case, combination of population and ticket tariff give the best model. The Direct Gravity Trip Distribution Model is appropriate to be used for the case of point to point transportation service.

**Keywords:** *transport model, trip distribution, direct gravity trip distribution, air passenger*

## I. INTRODUCTION

According to the Transport Planning Principle [1] and the Infrastructure and Facility Asset Management Principle [2,3], the Airport Transportation System need to be assessed and planned periodically. This includes the airport, the airport network, and the commercial flight service. The planning must be based on Prediction of Passenger Demand. Thus, the ability to make a Prediction of Transport Demand is capital. This research is a continuation research on Direct Gravity Trip Distribution Model (DGTDM) for predicting Air Passenger Demand [4].

It has been explained in the previous research that the Conventional 4 Steps Model has been researched a lot for all of the steps. Various research on Conventional 4 Steps Gravity Trip Distribution Model has been executed. These discuss stratification of the trip distribution based on trip purpose, the difference formulation for passenger and freight, the trip length distribution pattern, the various deterrence function, the method to define the minimum sample size in getting a good deterrence function, etc. It has been shown also that the Conventional 4 Steps Model need a lot of calculation to produce the Trip Distribution [5-11]. It has been shown that the DGTDM calculation is much easier than the Conventional 4 Steps Model [4,12]. Eventhough, the DGTDM is not yet researched deeply and extensively enough.

The previous research found that the DGTDM can be easily developed. The DGTDM used the attraction masses and the impedance elements. The population and the economic masses can be used for attraction masses, and the distances and the tariffs can be used for the impedance elements. A certain iterative successive calculation method has been used, with a certain measure of minimization parameter and a measure of accuracy. The previous experiment try several composition of four variables, which all were put in once into the model. The composition variation lay on the various different powering mode. The previous best model of that four variations has been found as presented below [4].

$$T_{ij} = 1.0E-17 \times (P_i P_j)^{0.930} \times (E_i E_j)^{0.995} \times D_{ij}^{-0.999} \times T a_{ij}^{-1.000} \quad (1)$$

Now, it is necessary to evaluate the utilization of different combination of variables.

This paper present the result of an attempt to evaluate the utilization of different variables for Direct Gravity Trip Distribution Model for Air Passenger Demand. The previous reserach case, Blangkajeren Air Passenger Demand is taken also for this research.

## II. RESEARCH METHOD

This research is aimed to evaluate the result of utilizing different variables for Direct Gravity Trip Distribution Modeling. This research is a continuation of the previous research, in which the Model Formula has been developed and tested. This research method is practically the same as the previous one, except that the formula development was not yet necessary [4]. On the other hand, the accuracy measure was improved in this research.

## III. RESEARCH ANALYSIS

### A. Blangkajeren Commercial Flight Services

As a continuation research, this research used the same case as the previous one, the two commercial flights from Blangkajeren to Banda Aceh and to Medan. Blangkajeren is a district in Aceh Province [4]. It has an airport, the Senubung Airport. The flight map is presented in Figure 1 below.

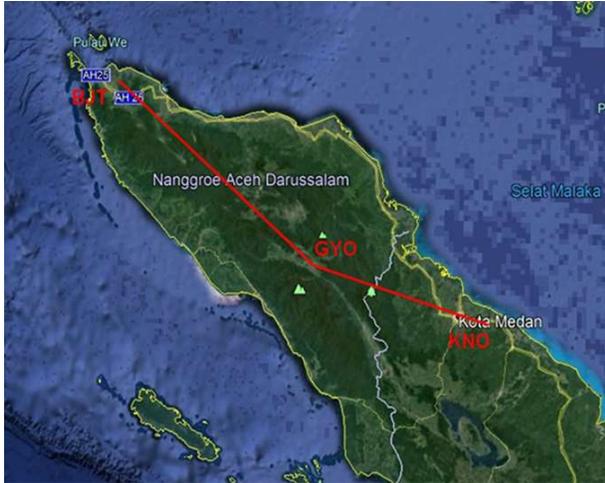


Fig. 1. Flight Map : Blangkajeren – Banda Aceh – Medan.

**B. Four Steps Gravity Trip Distribution Model**

The Conventional 4 Steps Trip Distribution Formula can be divided into two big groups: the Gravity Trip Distribution Model and the Growth Factor Model. The Gravity Trip Distribution Model, often called as synthetic model, is presented in (2) below [1, 8].

$$T_{ij} = P_i \times A_j \times f(C_{ij}) \tag{2}$$

Where:

- $T_{ij}$  : number of trips from zone i to zone j
- $P_i$  : number of Trip Production in zone i
- $A_j$  : number of Trip Attraction in zone j
- $f(C_{ij})$  : the deterrence function

which can be formulized in various formula. The English version use 3 different formula: negative power, negative exponential, and tanner. The American version, call as Friction Function, use various statistical distribution formula.

It can be seen from (2), that the Trip Generation (Trip Production and Trip Attraction) and the Deterrence Function must be calculated first, before the Trip Distribution can be calculated afterward [1].

There are 4 types of overall calculation methods for Conventional Gravity Model, i.e. UCGR (Unconstrained Gravity Model), PCGR (Production Constrained Gravity Model), ACGR (Attraction Constrained Gravity Model), and DCGR (Double Constrained Gravity Model) [1, 8].

**C. Direct Gravity Trip Distribution Model**

Different from the 4 Steps Gravity Trip Distribution Model, the Direct Gravity Trip Distribution Model is developed directly based on data on number of trips, attraction mass and impedance value. That is why this is called Direct Model, since the Model can be gotten directly from a single calculation. The General Formula for Direct

Gravity Model has been developed and tested [4]. The DGTDM general formula can be expressed as (3) below.

$$T_{i,j} \propto K \times M_i^a \times M_j^b \times I_{i,j}^c \tag{3}$$

Where :

- $T_{ij}$  : number of trip from i to j
- $K$  : attraction coefficient
- $M_i$  : mass of i
- $I_{ij}$  : impedance from i to j
- $K,a,b,c$  : constants, the impedance variable is negative powered

For this research, as the previous one, variables of the above Direct Gravity Trip Distribution are defined as follows : Attraction Masses are defined as Population and Economic Mass (Gross Regional Product – GRP), while the Impedances are defined as Distance and Ticket Tarriff [4]. Therefore (3) is modified into (4) below.

$$T_{i,j} \propto K \times P_i^a \times P_j^b \times E_i^c \times E_j^d \times D_{i,j}^e \times Ta_{i,j}^f \tag{4}$$

Where :

- $T_{ij}$  : number of passenger trip from i to j
- $P_i$  : population of i
- $E_i$  : economic condition (GRP) of zone i
- $D_{ij}$  : distance between zone i to zone j
- $Ta_{ij}$  : ticket tarriff from zone i to zone j
- $K,a,b,c,d,e,f$  : constants, the impedance are powered by negative value

**D. Calculation Method**

The same calculation method as used in previous research still used here [4]. In order to be mentioned easily, it is better to give a name to this calculation method. In this paper the calculation method is named Successive Iterative Calculation to Minimize Error (SICME). It is about finding the constant values of a nonlinear formula with several variables. The constants can be a multiplication, addition or a powering constant. The constant values are search one by one, successively, by holding the other constant value at a certain fix value. In each iteration a constant value is calculated to minimize the Sum of Square Error (SSE) of the model value to the real value. The accuracy is measured by Mean Absolute Error (MAE). The MAE formula is presented in (5) below.

$$MAE = \sum_1^n \frac{|e_i|}{n} \tag{5}$$

Where:

- MAE : mean absolute error

$e_i$  : error of model value  $i^{th}$   
 $n$  : number of OD points

E. Research Data

As a continuation experiment, this research used the same data as the data of the previous one [4]. The data are flight related data and gravity force related data. The data are presented in TABLE I and TABLE II below.

TABLE I. FLIGHT DATA

No	Flight	Passenger pass/month	Distance km	Tariff thousand-rupiah/flight
1	GYO – BJT	28.75	288.47	372
2	GYO - KNO	29.50	154.61	342

TABLE II. ATTRACTION MASSES [13 – 15]

No	Zone	Population person	GRP million rupiah
1	Blangkajeren	95379	2438949
2	Banda Aceh	356983	16808137
3	Medan	2210624	204299850

F. Evaluation of Utilization of Different Variables

1) Direct Gravity Trip Distribution Model: As developed and used in the previous research, the Direct Gravity Trip Distribution Model used is presented in the following (6) [4].

$$T_{ij} = K \times P_i^a \times P_j^b \times E_i^c \times E_j^d \times D_{ij}^e \times Ta_{ij}^f \quad (6)$$

Where:

- $T_{ij}$  : number of air person trip from i to j
- $P_i$  : population of i
- $E_i$  : GRP of i
- $D_{ij}$  : distance between i to j
- $Ta_{ij}$  : air ticket tariff from i to j
- $K, a, b, c, d, e, f$  : constant, the e & f are negative powers

Notation for the next four models are the same as the above notation, thus the notations are not repeated for the next four formula.

Four different models as variations of the General Model are then developed. Each model were developed by using attraction masses variable an impedance elements. The population and economic mass were used for attraction masses. While distances and ticket tariffs were used for impedance. The four model is then compared to the best of the four previous model. In this case, it is named as Model 0. Calculation and comparison are presented below.

2) Model 0 : The Best Model from Previous Research: The best Model of the previous experiment used population and economic as attraction mass and distances and tariffs as

the impedance elements [4]. The populations and the economics are each grouped together and powered differently. The experiment gave the P is powered by 0.930, the economic is powered by 0.995, while the impedance elements, the distances and the tariff are each powered by -0.999 and -1.000 respectively. In term of accuracy, this model give errors of 99.3% and 0.5%. The Model is presented in (7) below, while the accuracy calculation result is presented in TABLE III as follows.

$$T_{ij} = 1 (E-17) \times (P_i P_j)^{0.930} \times (E_i E_j)^{0.995} \times D_{ij}^{-0.999} \times Ta_{ij}^{-1.000} \quad (7)$$

TABLE III. ACCURACY CALCULATION FOR PREVIOUS MODEL

SSE	Flight	$T_{ij}$ pax/month	$T_{ij}'$ pax/month	D	D% %	MAE %
814.770	GYO-BJT	28.75	0.210	28.540	99.27	49.87
	GYO-KNO	29.50	29.360	0.140	0.47	

3) Model 1 : Population and Distance: The Model 1 use the population for attraction mass and the distance as impedance. Each are powered differently. Model development produce this result. The powered are 1.001 for  $P_i$ , 0.999 for  $P_j$ , and -0.995 for  $D_{ij}$ . The coefficient K is of 2.3 E-8. This give a SSE of 680.554 and the error of 90.3% for GYO-BJT, and of 8.7% for GYO-KNO. The Model is presented in (8) below, while the accuracy calculation result is presented in TABLE IV as follows.

$$T_{ij} = 2.3(E - 8) \times P_i^{1.001} \times P_j^{0.999} \times D_{ij}^{-0.995} \quad (8)$$

TABLE IV. ACCURACY CALCULATION FOR MODEL 1

SSE	Flight	$T_{ij}$ pax/month	$T_{ij}'$ pax/month	D	D% %	MAE %
680.554	GYO-BJT	28.750	2.790	25.960	90.30	49.50
	GYO-KNO	29.500	32.070	2.570	8.71	

4) Model 2 : Economics and Distance: The Model 2 use the economic values as attraction mass, but the same distances as impedance elements. This model has a coefficient value K equal to 1.00 E-11. The power values are of 0.997 for  $E_i$ , of 1.000 for  $E_j$ , and of -1.000 for  $D_{ij}$ . This model produced SSE value of 752.013, and error value of 95.3% for GYO-BJT, and 4.5% for GYO-KNO. The Model is presented in (9) below, while the accuracy calculation result is presented in TABLE V.

$$T_{ij} = 1.00(E - 11) \times E_i^{0.997} \times E_j^{1.000} \times D_{ij}^{-1.000} \quad (9)$$

TABLE V. ACCURACY CALCULATION FOR MODEL 2

SSE	Flight	$T_{ij}$ pax/month	$T_{ij}'$ pax/month	D	D% %	MAE %
752.013	GYO-BJT	28.750	1.360	27.390	95.27	49.91
	GYO-KNO	29.500	30.840	1.340	4.54	

5) *Model 3 : Population and Ticket Tariff*: Third combination of variables is applied to the Model 3, by using populations as attraction mass and ticket tariffs as impedance elements. The modeling produced a coefficient value K of 7.0E-5, the powers values of 0.980 for Pi, of 0.997 for Pj, and of -0.991 for Taij. The model has a SSE value of 579.848, and errors values of 82.7% for GYO-BJT flight, and 12.7% for GYO-KNO flight. The Model is presented in (10), while the accuracy calculation result is presented in TABLE VI.

$$T_{ij} = 7.00(E - 5) \times P_i^{0.980} \times P_j^{0.997} \times T a_{ij}^{-0.991} \quad (10)$$

TABLE VI. ACCURACY CALCULATION FOR MODEL 3

SSE	Flight	Tij pax/month	Tij' pax/month	D	D% %	MAE %
579.848	GYO-BJT	28.750	4.970	23.780	82.71	47.73
	GYO-KNO	29.500	33.260	3.760	12.75	

6) *Model 4 : Economics and Tariff*: The last combination of variables applied to the Model 4 is by using the economics values as attraction mass and the ticket tariffs as impedance elements. The Model 4 has a coefficient value K of 2.2E-8, the powers values of 0.999 for Ei, of 0.999 for Ej, and of -0.991 for Taij. The model has a SSE value of 698.930, and errors values of 91.7% for GYO-BJT flight, and 6.4% for GYO-KNO flight. The Model is presented in (11) below, while the accuracy calculation result is presented in TABLE VII as follows.

$$T_{ij} = 2.20(E - 8) \times E_i^{0.999} \times E_j^{0.999} \times T a_{ij}^{-0.999} \quad (11)$$

TABLE VII. ACCURACY CALCULATION FOR MODEL 4

SSE	Flight	Tij pax/month	Tij' pax/month	D	D% %	MAE %
698.930	GYO-BJT	28.750	2.380	26.370	91.72	49.05
	GYO-KNO	29.500	31.380	1.880	6.37	

7) *Comparison of Different Variables Utilization*: The first fact to be noted is that the best previous model is still worse compare to the all four new models. The best previous model gives Mean Absolute Error (MAE) of 49.88%, while the best of the new four models produce MAE of 47.74%. This fact indicates that utilising more complete possible variables does not always give a better model. The experiment case, among the four developed models, the Model 3 incorporating the population and ticket tariff give the best accuracy indicated by the least MAE and the least SSE. It can be noted also that less SSE produce less MAE. The accuracy comparison are presented in TABLE VIII and Fig. 2 below.

TABLE VIII. ACCURACY COMPARAISON

Model	Variables	SSE	Error 1 %	Error 2 %	MAE %
0	PE/DTa	814.770	99.3%	0.5%	49.88%
1	P/D	680.554	90.3%	8.7%	49.50%
2	E/D	752.013	95.3%	4.5%	49.90%
3	P/Ta	579.848	82.7%	12.8%	47.74%
4	E/Ta	698.930	91.7%	6.4%	49.05%

Note : P = population, E = economic, D = distance, Ta = ticket tariff

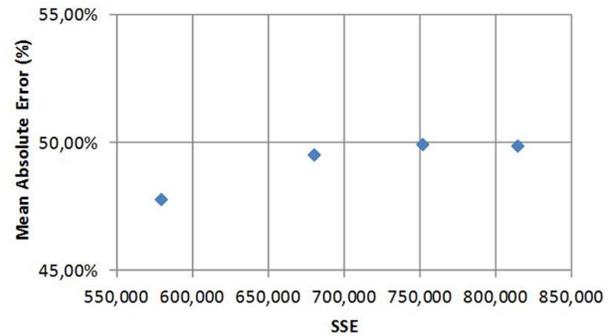


Fig. 2. Relation between the MAE and the SSE.

#### IV. CONCLUSIONS

Several important points can be concluded from this research. Those remarks are presented as follows. Utilisation of different variables produce different model accuracy level. Utilisation of more complete variables does not always give better result. For this case, the best combination of variables is Population and Ticket Tariff. The best DGTDM developed is  $T_{ij} = 7.0E-5 P_i^{0.980} P_j^{0.997} T a_{ij}^{-0.991}$ . The powering values for all variables are all closed to 1. Generally the four variables are appropriate to be used, inwhich better combination should be investigated for each case. It is better to use Mean Absolute Error for measuring overall accuracy.

The research strenghten the previous research conclusions that the Direct Gravity Trip Distribution Model can be used for cases inwhich calculation of Trip Generation, Modal Split, and Traffic Assignment is not an obligation, such for Air Transport and Sea Transport.

Further curiosity was induced, such as investigating of using different measure for minimization, developing the calculation method systematically, and investigating the usage of gravity model for different air and sea transportation demand cases.

#### REFERENCES

- [1] O.Z. Tamin. Transportation Planning and Modeling. ITB Publisher. 2000 (in Indonesian).
- [2] R.A.A. Soemitro & H. Suprayitno. JMAIF 2 (Suplement 1) page : 1-13. 2018.
- [3] H. Suprayitno & R.A.A. Soemitro. JMAIF 2(1) page : 1-10. 2018.
- [4] H. Suprayitno. ICCEE 2019 paper 265. 2019.
- [5] M.M.M. Abdel-Aal, AEJ 53(3). 2014.
- [6] H. Abdel-Latif (1999). Research Gate. Downloaded 18/08/2019.

- [7] G.D. Long, Research Report Number 60-13, Texas A&M University. 1968.
- [8] H. Suprayitno, IPTEK Journal of Engineering 4(3) 2018.
- [9] H. Suprayitno, V. Ratnasari & N. Saraswati, IOP Conference Series : Material Science and Engineering 267(1) 012209. 2017.
- [10] H. Suprayitno, V. Ratnasari & N. Saraswati, IPTEK The Journal of Engineering, 4(1) 2018.
- [11] H. Suprayitno, V. Ratnasari, N. Saraswati & C.P. Fajrinia, IPTEK The Journal for Technology and Science 29(1) 5-10 2018.
- [12] H. Suprayitno, Prosiding Simposium FSTPT 2. 1999.
- [13] BPS Blangkajeren, Blangkajeren Regency in 2018. 2019 (in Indonesian).
- [14] BPS Banda Aceh, Banda Aceh City in 2018. 2019 (in Indonesian).
- [15] BPS Medan , Medan City in 2018. 2019 (in Indonesian).