Development of gravity theory application in the internal-regional inter-zone commodity movement distribution with the origin zone movement generation boundary

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Abstract. Zones that produce land fishery commodity and its yields have characteristics that is limited in distribution capability because infrastructure conditions availability. High demand for fishery commodities caused to a growing distribution at inefficient distribution distance. The development of the gravity theory with the limitation of movement generation from the production zone can increase the interaction inter-zones by distribution distances effectively and efficiently with shorter movement distribution distances. Regression analysis method with multiple variable of transportation infrastructure condition based on service level and quantitative capacity is determined to estimate the ‘mass’ of movement generation that is formed. The resulting movement distribution (Tid) model has the equation Tid = 27.04 -0.49 tid. Based on barrier function of power model with calibration value β = 0.0496. In the way of development of the movement generation ‘mass’ boundary at production zone will shorten the distribution distance effectively with shorter distribution distances. Shorter distribution distances will increase the accessibility inter-zones to interact according to the magnitude of the movement generation ‘mass’.

1. Introduction

The production of land fishery commodities and its yields develop with the regional potential characteristics. Development of land fishery commodities production and its yields requires a policy strategy related to supply and demand from the development of commodity production. The characteristics of land fishery production in a regional internal zone should be able to meet a demand for demand especially within the internal zone for a policy of availability to the aquaculture commodity. Distribution of movements based on zone within the internal-regional scope of Central Java Province is strongly influenced to require identification that is capable representing magnitudes in transport movement.

Based on the estimation of the movement magnitude based on the analogy of the ‘mass’ estimation in gravity theory, the movement production can be known in magnitude by the gravity theory application approach that is built. In the mass movements distribution that is pulled or attract requires the behavioral characteristics of needs and demands of the land fishery commodity and its yields at the production zone as well as the broader regional internal zone. To maintain the policy of availability of need and demand...
for the production of land fishery commodities in the regional internal of Central Java province requires adequate availability from the production zone to the closer zone in accordance with the direction of movement.

To direct the movement that occurs between 'mass' of movement generation probabilistically because the supply and demand needs of land fishery commodities and its yields at that zone. There is a need to develop the direction of movement generation by limiting the movement generation from the origin zone to be able to distribute to more efficient zones in the transportation movement based on the movement generation 'mass' of the production zone. The development of movement generation boundary based on the application of gravity theory remains influenced by the characteristics of transportation infrastructure conditions in establishing the balance of movement from the movement distribution. By development of the gravity theory application with the limitation of movement generation 'mass' will encourage the strategy of transportation policy to fulfill the need of land fishery commodity with transportation system effectively and efficiently based on the interaction of movement generation 'mass' of the movement according to the effective distance for the distribution of movement from the commodity production zone [1-7].

This model uses the concept of gravity introduced by Newton in 1686 developed from the analogy of gravity law.

\[ F_{id} = G \frac{m_i m_d}{d_{id}^2} \]  

(1)

Where \( G \) is the gravitational constant

In geography, force can be considered as a movement between two regions; while mass can be replaced with variables such as population or movement generating and attraction, as well as distance, time, or cost as a measure of accessibility. Thus, for transportation purposes, the GR model is expressed as

\[ T_{id} = k \frac{a_i a_d}{d_{id}^2} \]

(2)

Where \( k \) is a constant

Thus, in mathematical form, the model GR can be expressed as:

\[ T_{id} = O_i \cdot D_d \cdot A_i \cdot f(C_{id}) \]

(3)

Where: \( T_{id} \) = Movement Distribution

The PCGR (Production Constraint of Gravity Model) method defines that the movement attraction is not necessary. By using the basic formula of Gravity Model used the restriction provisions that by the formula, for all \( i \) and \( d \)

\[ A_{id} = \frac{1}{\sum_{d=1}^{n}(B_d a_d f_{id})} \]  

and \( B_d = 1 \) for whole \( d \)

(4)

By using Negative Exponential Barrier Function of PCGR stages are as follows, by using the basic equation of gravity model, the matrix iteration calculation is done until the value of \( \beta \) in convergent matrix condition. Where \( \alpha \) is coefficient model [7].

Function Obstacles

\[ \text{Barrier Power Function} = f(C_{id}) = C_{id}^{-\alpha} \]

(5)

\[ \text{Negative Exponential Barrier Function} = f(C_{id}) = e^{-\beta C_{id}} \]

(6)

\[ \text{Tanner Barrier Function} = f(C_{id}) = C_{id}^{-\alpha} \cdot e^{-\beta C_{id}} \]

(7)

2. Methods

Approach to research of movement distribution model a very wide area influenced many factors to approach variable of determinant in this research that is: using analysis correlation model based on zone. Determination of Generation Model Variable [1,3,6].

Dependent Variables
Y1 = Oi = Movement Generation of Land Fishery Commodities
Independent Variables
X1 = Variable of free population
X2 = Variable of free PDB (Product Domestic Bruto) Province
X3 = Independent variable of commodity based on IO (Input – Output) of Land Fishery
Commodity in Central Java
X4 = Independent variable of national roads length in the county or city in Central Java,
X5 = Independent variable of provincial roads length in the county and city in Central Java,
X6 = Independent variable of local roads length in the county and City in Central Java,
X7 = Independent variable of road conditions in both the county and the City in Central Java,
X8 = Independent variable of road conditions were in the county and City in Central Java,
X9 = Independent variable of condition of roads damaged in the county and City in Central Java,
X10 = Independent variable of road conditions, every damaged in the county and City in Central Java,
X11 = Independent variable of goods vehicles number in the county and the City of Central Java,
X12 = Independent variable of goods vehicles number with individual ownership status,
X13 = Independent variable of goods vehicles number to the ownership status of the company

2.1. Models test
The relationship between the variables used in modeling must have the level of accuracy and
significance determined by the following test model analysis:

2.1.1. Correlation test. Correlation analysis is a study of the degree of relationship or degree of
association between two or more variables, the purpose of correlation analysis is to see / determine how
closely the relationship between two variables. The correlation coefficient is a measure how close the
relationship between variables in the model.

\[
r = \frac{N \sum_{i=1}^{N}(X_i \cdot Y_i) - \sum_{i=1}^{N}(X_i) \cdot \sum_{i=1}^{N}(Y_i)}{\sqrt{\left(\sum_{i=1}^{N}(X_i)^2 - \left(\sum_{i=1}^{N}(X_i)\right)^2\right)} \left[ N \sum_{i=1}^{N}(Y_i)^2 - \left(\sum_{i=1}^{N}(Y_i)\right)^2 \right]}
\] (8)

2.1.2. Determination test. Determination test analysis used to know the amount of variation model
resulting from the relationship between variables used in modeling. To calculate the result of the model
significance of the determination test shown in the equation

\[
R^2 = 1 - \frac{\sum_{i=1}^{N} \sum_{d=1}^{N}(Y_{i,d} - T_{i,d})^2}{\sum_{i=1}^{N} \sum_{d=1}^{N}(T_{i,d} - T_j)^2}
\] (9)

2.2. Gravity model calibration
Gravity Model Calibration of Linear regression Method with negative exponential barrier function.
Calibration method by linear regression analysis to find the model parameters is done through the steps
in the following equation [3,5,7].

\[
\exp(-\beta C_{id}) = \frac{T_{id}}{A_{id}B_{id}O_{id}D_d}
\]

\[
\log_e(\exp(-\beta C_{id})) = \log_e \left[ \frac{T_{id}}{A_{id}B_{id}O_{id}D_d} \right]
\]

\[
-\beta C_{id} = \log_e T_{id} - \log_e(A_{id}B_{id}O_{id}D_d)
\]

\[
\log_e T_{id} = \log_e(A_{id}B_{id}O_{id}D_d) - \beta C_{id}
\]

With liner transformation[7] then: \( \log_e T_{id} = Yi dan Cid = Xi \)

\[
-\beta = B = \frac{N \sum_{i=1}^{N}(X_i \cdot Y_i) - \sum_{i=1}^{N}(X_i) \cdot \sum_{i=1}^{N}(Y_i)}{N \sum_{i=1}^{N}(X_i)^2 - \left(\sum_{i=1}^{N}(X_i)\right)^2}
\]

\[
A = \bar{Y} - B \bar{X}
\] (11)
Figure 1. Research flow chart.

Gravity modelling in land fishery commodities movement

Determination of Variable Tid, Di, Oi dan Ci,d

Data
1. Number of population
2. PDB (Product Domestic Bruto) of Provience
3. Comodities Input – Output of land fishery
4. OD (Origin – Destination) Matrix of land fishery commodities
5. Matric Distance
6. OD (Origin- Destination) Matrix of movement cost

Data compilation

Validation test and Data Realiability

Corelation analyze

Multiple regression analyze

Model of movement Generation and Attraction

Model Signification test

Preparation of the OD matrix

Determination of Growth zone based on GDP (Gross Domestic Product) growth, Input - Output of fishery Commodity

Iteration

Convergen Matric

OD Matrix selected

OD Matric calibration

End
3. Results and Discussion

3.1. Model of movement generating

The result of the correlation test is expressed by the correlation coefficient, it can be known the relation level between the dependent variable and the independent variable to analyze the relation level. The relation between free variables will be selected independent variables that have a correlation value is not strong in an equation, whereas the relation between independent and free variables will be selected independent variables that have a strong correlation in an equation. Variable X11 and X12 occur multicollinearity because it has high coefficient value between independent variables so that variable X11 and X12 removed [1,2,6].

Table 1. Results of phase II multiple regression analysis.

| Predictor | Coef | SE Coef | T   | P    | VIF |
|-----------|------|---------|-----|------|-----|
| Constant  | 3.274| 2.055   | 1.59| 0.125|     |
| X1        | 0.9354| 0.1320  | 7.08| 0.000| 5.3 |
| X2        | 0.12351| 0.09202| 1.34| 0.193| 1.7 |
| X3        | 0.01830| 0.03206| 0.57| 0.574| 3.5 |
| X4        | 0.03486| 0.03295| 1.06| 0.301| 1.7 |
| X5        | 0.00499| 0.05528| 0.09| 0.929| 3.3 |
| X6        | -0.0833| 0.1409  | -0.59| 0.560| 7.0 |
| X7        | 0.01668| 0.07241| 0.23| 0.820| 2.0 |
| X8        | -0.04817| 0.08405| -0.57| 0.572| 3.3 |
| X9        | 0.02619| 0.09139| 0.29| 0.777| 5.6 |
| X10       | -0.01822| 0.02760| -0.66| 0.516| 1.5 |
| X13       | -0.10744| 0.06907| -1.36| 0.133| 1.9 |

S = 0.202854  R-Sq = 90.2%  R-Sq(adj) = 85.6%

Analysis of Variance

| Source   | DF | SS   | MS    | F     | P    |
|----------|----|------|-------|-------|------|
| Regression| 11| 8.74171| 0.79470| 19.31| 0.000|
| Residual Error | 23| 0.94644| 0.04115| | |
| Total    | 34| 9.68815| | | |

3.2. Simulation result of land fishery commodity movement generation and other land waters yield

Estimation of land fishery commodity movement generation and other land waters yield model are further computed based on each zone. The estimation result of movement generation value of land fishery commodities and other yield by using computational programming simulation of the land fishery commodity movement generation and other land waters yield is shown in the Figure 2.
3.3. Movement distribution model

The movement distribution model by development of the gravity model with movement generation limit by estimating the balancing factor of the movement generation shown in equation (12).

\[
A_1 = \frac{1}{[B_1 D_1 \exp(-\beta C_{1,1}) + B_2 D_2 \exp(-\beta C_{1,2}) + \ldots + B_{35} D_{35} \exp(-\beta C_{1,35})]}
\]

\[
A_2 = \frac{1}{[B_1 D_1 \exp(-\beta C_{2,1}) + B_2 D_2 \exp(-\beta C_{2,2}) + \ldots + B_{35} D_{35} \exp(-\beta C_{2,35})]}
\]

\[
A_3 = \frac{1}{[B_1 D_1 \exp(-\beta C_{3,1}) + B_2 D_2 \exp(-\beta C_{3,2}) + \ldots + B_{35} D_{35} \exp(-\beta C_{3,35})]}
\]

\[
\ldots
\]

\[
A_{35} = \frac{1}{[B_1 D_1 \exp(-\beta C_{35,1}) + B_2 D_2 \exp(-\beta C_{35,2}) + \ldots + B_{35} D_{35} \exp(-\beta C_{35,35})]}
\]

The value of \( A_i \) obtained is then used to calculate the value of each matrix cell using the basic formula of the gravity model. Using the basic equation of the gravity model, the mathematical iteration calculation is done by computing programming with MATLAB 2012 so as to obtain the \( \beta \) value in convergent matrix condition. The distribution model results are shown in Table 2[1,4,7]

| Constraint Function | Model Parameter Calibration |
|---------------------|-----------------------------|
|                     | B   | A     | B     |
| Power               | -0.49662 | 27.0352 | 0.49662 |
| Negative Exponential| -9.361 x 10^{-10} | 20.6739 | 9.361 x 10^{-10} |
| Tanner              | -9.361 x 10^{-10} | 20.6739 | 9.361 x 10^{-10} |
Figure 3. Distribution simulation result of land fishery commodity movement from the origin zone.

Figure 4. Result of distribution and distance simulation of land fishery commodities total movement.

Figure 4 shows that the movement of inter-zone distributions occurring in the province of Central Java is dominated by inter-zone movements closer to indicated by the desire line extent of the zone and the distance of 200 km. Based on the result of modeling simulation obtained by showing the application of gravity theory with movement generation boundary will result the distribution distance movement efficiently interzone from production zone of land fishery commodity. With movement effective distance of distribution model results 200 km \[1,4,6,7\].

4. Conclusion
Based on the analysis results of the gravity theory application development on the commodity movement distribution system of regional internal interzone with the movement generation limit from the origin zone can be drawn an inference as following:

1. Inter-zones interaction based on the magnitude of the "mass" of land fishery commodities movement generation have characteristics that influenced by the consumption and demand of land fishery commodities with the influence of road length condition variable and road pavement conditions in the production zone.

2. The distribution model by the gravity theory development with the generation limit has contribute to reducing the movement of long distance with the zones interaction with shorter distances.
3. With shorter distribution movement distances, generation 'mass' will encourage the balance inter-zones in fill the needs and demand of commodities more quickly.

5. References
[1] Igor Y D, Lóránt A T and Peter S G M S 2012 Commodity Freight and Trip Generation by Logistics Distribution Centers Based on Sectorial employment Data
[2] Keith H and Thierry M 2014 Gravity equations: Workhorse, toolkit, and cookbook Handbook of international economics 4 131-195
[3] Daniel H and Daniel M 2008 Is gravity linear? Journal of Applied Economics 23 137–172
[4] José H, et al. 2012. Powers. Freight Trip Generation and Land Use Handbook, NCFRP and NCHRP (Rensselaer Polytechnic Institute University at Albany TNO Delft 1-64)
[5] Y Jin, I Williams, M Shahkarami 2005 Integrated regional economic and freight logistics modelling: results from a model for the Trans-Pennine Corridor UK, European Transport Conference
[6] J Akbardin 2013 Variable Relationships Estimation Of Cargo Transportation Network System To The Number Of Internal Regional Cargo Mode (Case Study Of Road Network System in Central Java Province) Jurnal eco Rekayasa 9 1
[7] Tamim Z O 2000 Perencanaan dan Pemodelan Transportasi, Edisi kedua (ITB Bandung)

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