Modeling Origin Destination Matrix in the Inter Island Cluster of North Liukang Using Gravity Model

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Abstract. Trip Distribution is one of the step in the Four-Step Transportation Planning Model. The modelling of inter-zone trip patterns considered several things as the effect of the inter-zone accessibility network system level as well as each-zone production and attraction level. The trip distribution model that used in this study is gravity model (GR) which is classified in synthetic method group. The aims of this study is to estimate the distribution trip model into origin-destination matrix form in both the passengers and cargo trip flow at archipelago North Liukang Tupabbiring sub-district region, Pangkep Regency, South Sulawesi. Determination the number of trip is using Production Constraint Gravity Models with exponential barrier function to estimate inter-island traffic distance. The results showed that the total number of passenger trip from the urban capital to Pangkajene Regency was around 137 passengers per day and the inter-island trip was around 41 passengers per day while the total of cargo trip from the capital sub-district to the city of Pangkajene was around 0.96 tons per day and the inter-islands trip was around 0.28 tons. The result of this distribution trip matrix will be used as a basis for capacity planning of inter-island passenger transport fleets in the North Liukang Tupabbiring sub-district.

1. Background
Pangkep Regency archipelago have enormous complexity and regional potential that could be more optimally developed. There are 13 sub-districts within the administrative area of Pangkajene Regency where 4 sub-districts are in the sub-district islands. One of the them is The North Liukang Tupabbiring sub-district with 74 km² area, consisting of 22 islands which are included in 7 villages including Mattiro Bulu village, Mattiro Labangeng village, Mattiro Uleng village, Mattiro Kanja village, Mattiro Baji village, Mattiro Bombang village and Mattiro Walie's village. The capital of the sub-district located in Mattiro Kanja village precisely on Sabutung Island. Based on Central Bureau of Statistics Indonesia data the population of Liukang District Tupabbiring Utara is 11,538 with the population density is 154 individuals per square kilometer.

The planning model that generally used in in transportation planning is the four-stage planning model. One of the stage model is the trip distribution which represented in the form of Origin-Destination Matrix or OD matrix. The OD matrix visualizes the amount of trip from the origin zone to the destination zone, therefore it plays an important role in the transportation planning process [1]. The purpose of OD matrix imposition to a transportation network is to obtain the trip in each segment and the total of entire trip within the analysed network. In this study, the Gravity Model is used with production trip constrain. Both of the value production/attraction trip inter-zone and the
production/attraction trip to centre area or district capital are an important to perceive due to a plan of the fleet needs as supporting trip system thus will support connectivity between islands.

![Figure 1. Pangkep Regency islands](image)

Based on the background above, the objective of this study is to determine the distribution model of the passenger and cargo trip between islands and determine the size of the inter-island trip in the Liukang District Tupabbing archipelago and the number of the trip to the district capital.

2. Methods

2.1. Data Collection

Data collection on passenger and cargo flows were observe at four ports, which are Pangkajene, Maccini Baji, Kassi Kebo and Kali Bone Pier. The secondary data was taken from the relevant agencies, including the Balitbang in Pangkep regency. As well as data that could be taken from previous reports.

2.2. Trip Production Modeling

Trip production is a stage of modeling that estimates the number of trip originating from a zone or land use or the number of trip that are attracted to a land use or zone. It is also an analysis process of that establishes or produces a relation between activity and trip. Production and trip attraction are used to indicate the current movements, which will be used to forecast future movements [1].
2.3. Trip Distribution Model

The distribution model is used to estimate the number of the trip from each origin zone to each different destination zone, which is affected by the number of the production in each origin zone and also the level of accessibility of the inter-zone network system that usually expressed by distance, time, or cost (combined costs). Meanwhile the distribution trip model in the transportation system is expressed in the trip flow form (vehicles, passengers and cargo) that moving from the origin zone to the destination zone in a particular area and over a certain period of time. Trip Matrix or Origin-Destination (OD) Matrix is a two-dimensional matrix that is most often used to describe trip patterns that contain information of the number of trip between zones. Lines in the OD matrix show the origin zones and columns show the destination zone, therefore each cell in the OD matrix describe the amount of trip flow which are current move from origin zone \(i\) to the destination zone \(j\) for a certain interval time [2].

One of the distribution models that commonly used is the Gravity Model. The Gravity Model explains that the characteristics of production and attraction are related to some origin zone parameters, such as population and OD matrix cell values that are also related to accessibility (ease) as a distance, time, or cost function. This method is applied based on Newton’s formula which is the gravitation formula which states that \(F_{id}\) the attraction or repulsion force between two poles of mass is equal to its mass, \(m_i\) and \(m_d\), also inversely quadratic to the distance between two mass, \(d_{id}^2\), which could be expressed with:

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

where

\(G\) : Universal gravitation constant

Force can be considered as a trip between two regions, while the mass can be replaced with variables such as population or production and attraction trip and distance, time, or cost as a measure of accessibility (convenience) [3]. So, for transportation purposes, the GR model is stated as:

\[
T_{id} = k \frac{O_i O_d}{d_{id}^2}
\]

where \(k\) is universal gravitation constant

In the mathematical form, the GR model can be stated in:

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

There is the development of equations due to constrain which are the accessibility of two origin and destination zones, so as to produce the following equation:

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

Constrain Function is always used in determining the number of production and attraction using the GR model where \(f_{id}\) must be considered as a measure of accessibility between zones \(i\) and zones \(d\) [4].

- \(f (C_{id}) = C_{id}^{-\alpha}\) (Power Function)
- \(f (C_{id}) = e^{-\beta C_{id}}\) (Exp-Negative Function)
- \(f (C_{id}) = C_{id}^{-\alpha} \cdot e^{-\beta C_{id}}\) (Tanner Function)
In this model there is a parameter of $\beta$ which functions as a determining factor in the number of movements in each zone. $\beta$ values can be obtained empirically with the following equation:

$$\beta = \frac{k}{C_{id}}$$

where

- $k = 2 \sim 3$
- $C$ = average value of $C_{id}$ (Constrain Matrix)

PCGR Model (Product Construction Gravity Model) a model in which the total trip resulting from the generation of the trip must be equal to the total trip produced by modeling; Likewise, the generation of the resulting trip of the model must be the same as the result of the desired trip generation [5]. However, the pull of trip does not need to be the same. The equations used but with different restrictions, that is

$$B_d = 1 \text{ for the all of } d \text{ and } A_i = \frac{1}{\sum_d (B_d D_d F_{id})} \text{ for the all of } i$$

3. Results and Discussion

3.1. Overview of the Study Area

The north Liukang Tupabbiring District is an area expansion of sub-district of Liukang Tupabbiring District since 2001. It has an area of 74.00 km$^2$ and is an archipelago with the following administrative boundaries: bordering the Barru Regency in the north, Ma’rang District in the east, Liukang Tupabbiring District in the south and Liukang Kalmas District in the west.

![Figure 2. Island cluster area of the North Liukang Tupabbiring District](image)

The North Liukang Tupabbiring have 7 villages such as Mattiro Bulu Mattiro Labangeng, Mattiro Uleng, Mattiro Kanja, Mattiro Baji, Mattiro Bombang and Mattiro Walie. The total population of The North Liukang Tapabbiring in 2017 is 11,538 people with the highest population in Mattiro Bulu Village with a density of 1,043 people / km$^2$ which is the region with the largest population in the district.
Table 1. Administrative Areas of the North Liukang Tupabbiring District in 2017

| No. | Village     | Area (km²) | Number of Households | Total Population | Population Density (people/km²) |
|-----|-------------|------------|----------------------|------------------|---------------------------------|
| 1   | Mattiro Bulu | 3.00       | 606                  | 3,129            | 1,043                           |
| 2   | Mattiro Labangeng | 4.00 | 179                  | 815              | 204                            |
| 3   | Mattiro Uleng | 5.00       | 387                  | 1,757            | 351                            |
| 4   | Mattiro Kanja | 4.72       | 338                  | 1,371            | 290                            |
| 5   | Mattiro Baji | 4.28       | 346                  | 1,375            | 321                            |
| 6   | Mattiro Bombang | 22.00 | 658                  | 1,448            | 66                             |
| 7   | Mattiro Walie | 31.00      | 402                  | 1,643            | 53                             |

Source: Kecamatan Liukang Tupabbiring Utara dalam Angka, 2017

The population distribution per island in 2017 is shown in the following table

Table 2. Demography of the Islands of each Village in the North Liukang Tupabbiring District

| No. | Village     | Island Name        | Inhabited / Uninhabited | Total Population (People) |
|-----|-------------|--------------------|-------------------------|---------------------------|
| 1   | Mattiro Walie | Samatellu Lompo  | Inhabited               | 1,193                     |
|     |              | Samatellu Pe’da   | Inhabited               | 47                        |
|     |              | Samatellu Borong  | Inhabited               | 251                       |
|     |              | Salebbo            | Inhabited               | 438                       |
|     |              | Reang-Reang        | Uninhabited             | -                         |
|     |              | Bone Banoang       | Uninhabited             | -                         |
|     |              | Jangan-jangan      | Uninhabited             | -                         |
|     |              | Salemo             | Inhabited               | 1,571                     |
|     |              | Sakuala            | Inhabited               | 552                       |
| 2   | Mattiro Bombang | Sagara           | Inhabited               | 403                       |
|     |              | Sabangko          | Inhabited               | 228                       |
|     |              | Gusung Torajae    | Uninhabited             | -                         |
| 3   | Mattiro Kanja | Sabutung          | Inhabited               | 1,709                     |
| 4   | Mattiro Uleng | Kulambing         | Inhabited               | 1,742                     |
| 5   | Mattiro Labangen | Laiya            | Inhabited               | 251                       |
|     |              | Polewali          | Inhabited               | 759                       |
| 6   | Mattiro Bulu | Karanrang         | Inhabited               | 193                       |
|     |              | Satando           | Inhabited               | 570                       |
| 7   | Mattiro Baji | Saugi             | Inhabited               | 434                       |
|     |              | Camba-Cambang     | Uninhabited             | -                         |
|     |              | Sapuli            | Inhabited               | 379                       |

3.2. Transportation Network in The North Liukang Tupabbiring District

Support facilities of the maritime transportation in The North Liukang Tupabbiring area are wooden boats measuring 1-3 GT, some of which operate regularly. In The North Liukang Tupabbiring in 2017,
the ownership of the fleet by type such as 819 motor boats, 40 layer motor boats, 1,393 jolloro, and 567 boats.

There are 26 fleets of ships operating from The North Liukang Tupabbiring to the capital of Pangkep Regency which operate regularly. Commodities transported in the form of seafood include fish, squid, crabs; building materials in the form of cement, wood, iron, zinc; and other commodities in the form of gas, motorcycles, mineral water (gallons), rice, groceries and others.

As for the fleet that serves The North Liukang Tupabbiring Islands Group are as follows

| No | Ship Name       | Ship Capacity | Passenger (People) | Cargo (Ton) | Year Making | Route                     |
|----|----------------|---------------|--------------------|-------------|-------------|---------------------------|
| 1  | KM. Karunia     | 12            | 1                  |             | 2010        | Pangkajene – P.Kulambing  |
| 2  | KM. Halilintar  | 10            | 1                  |             | 2008        | Pangkajene – P.Karanrang  |
| 3  | KM. Karmila 2   | 10            | 1                  |             | 2000        | Pangkajene – Samatelu Lompo|
| 4  | KM.Rama Saputra | 20            | 3                  |             | 2004        | Pangkajene – P. Kulambing |
| 5  | KM. Musdalifah  | -             | 3                  |             | 2017        | Pangkajene – Laiya (ikan) |
| 6  | KM. Putra AWF   | 2             | -                  |             | 2011        | Pangkajene - Samatelu     |
| 7  | KM. Sinar Laut  | 15            | 1                  |             | 2014        | Pangkajene – P.Karanrang  |
| 8  | KM. Rahmat Jaya | 30            | 3                  |             | 2000        | Pangkajene – Laiya (ikan) |
| 9  | KM. Anuar       | 13            | 2                  |             | 2012        | Maccini Baji – P.Sapuli   |
| 10 | KM. Fitri Pangkep| 13            | 2                  |             | 2013        | Maccini Baji – P.Sapuli   |
| 11 | KM. Yus Amalia  | 20            | 1                  |             | 2017        | Pangkajene – P.Karanrang  |
| 12 | KM. Fitri Jaya  | 13            | 2                  |             | 2015        | Maccini Baji – P.Saogi    |
| 13 | KM. Rahmi Ilahi | 10            | 1                  |             | 2008        | Maccini Baji – P.Saogi    |
| 14 | KM. Saogi Bahari| 13            | 2                  |             | 2004        | Maccini Baji – P.Saogi    |
| 15 | KM. 39          | 13            | 1                  |             | 2010        | Maccini Baji - CambaCambang|
| 16 | KM. Putra Labbixkang| 13       | 2                  |             | 2000        | Maccini Baji - CambaCambang|
| 17 | KM. Jamidding   | 13            | 1                  |             | 1970        | Maccini Baji - CambaCambang|
| 18 | KM. 42          | 13            | 1                  |             | 2004        | Maccini Baji - CambaCambang|
| 19 | KM. 43          | 13            | 1                  |             | 1980        | Maccini Baji - CambaCambang|
| 20 | KM. Suci        | 15            | 2                  |             | 2012        | Maccini Baji – P.Saogi    |
| 21 | KM. 46          | 13            | 1                  |             | 2010        | Maccini Baji – P.Salebo   |
| 22 | KM. Aspal       | 5             | 1                  |             | 2005        | Maccini Baji – P.Satando  |
| 23 | KM. Tunas Muda  | 5             | 1                  |             | 2007        | Maccini Baji – P.Satando  |
| 24 | KM. Cahaya      | 12            | -                  |             | 2014        | Maccini Baji – P.Saogi    |
| 25 | KM. Fajar Indah | 20            | 1                  |             | 2003        | Pangkajene – P.Kulambing  |
| 26 | KM. 44          | 13            | 1                  |             | 1980        | Maccini Baji - CambaCambang|
| 27 | Karmila 1       | 50            | 10                 |             | 1973        | Pangkajene – P. Kulambing |

Source: Dinas Perhubungan Pangkep Regency

3.3. Trip Distribution of Passenger and Cargo Analysis
There are 2 Characteristic about trip distribution in The North Liukang Tupabbiring which are inter island trip distribution and trip distribution to the capital of Pangkep Regency. This analysis using model gravity with variable costraint is the distance between the island. The determine of the trip distribution using PCGR model with the constrain using by power function.
Table 4. The Distance between the capital of the village matrix. (Sea Mile)

|                | Mattiro Walie | Mattiro Bombang | Mattiro Kanja | Mattiro Uleng | Mattiro Labangen | Mattiro Bulu | Mattiro Baji | Pangkajene |
|----------------|---------------|-----------------|---------------|---------------|------------------|--------------|--------------|------------|
| Mattiro Walie  | 0.00          | 8.50            | 6.79          | 7.59          | 8.80             | 9.69         | 8.84         | 12.84      |
| Mattiro Bombang| 8.50          | 0.00            | 4.22          | 5.42          | 8.37             | 11.20        | 4.65         | 8.94       |
| Mattiro Kanja  | 6.79          | 4.22            | 0.00          | 1.35          | 4.25             | 6.97         | 2.03         | 6.48       |
| Mattiro Uleng  | 7.59          | 5.42            | 1.35          | 0.00          | 3.00             | 5.89         | 1.67         | 5.33       |
| Mattiro Labangen| 8.80         | 8.37            | 4.25          | 3.00          | 0.00             | 4.13         | 4.64         |            |
| Mattiro Bulu   | 9.69          | 11.20           | 6.97          | 5.89          | 3.02             | 7.15         | 4.86         |            |
| Mattiro Baji   | 8.84          | 4.65            | 2.03          | 1.67          | 4.13             | 7.15         | 0.00         | 6.98       |
| Pangkajene     | 12.84         | 8.94            | 6.48          | 5.33          | 4.64             | 4.86         | 6.98         | 0.00       |

Source: Dinas Perhubungan Pangkep Regency

Final distribution matrix of passenger and cargo trip inter-zone in island cluster area of North Liukang Tupabbiring district and passenger trip from island area to Capital of Pangkep regency (Pangkajene) determined by β value 0.368, this would be one of the variable in determined constrain function.

While the matrix constrain function in determine passenger and cargo trip is shown in the table below:

Table 5. Exponential function constrain matrix

|                | Mattiro Walie | Mattiro Bombang | Mattiro Kanja | Mattiro Uleng | Mattiro Labangen | Mattiro Bulu | Mattiro Baji | Pangkajene |
|----------------|---------------|-----------------|---------------|---------------|------------------|--------------|--------------|------------|
| Mattiro Walie  | 0.000         | 0.454           | 0.493         | 0.474         | 0.449            | 0.433        | 0.448        | 0.390      |
| Mattiro Bombang| 0.454         | 0.000           | 0.588         | 0.536         | 0.457            | 0.410        | 0.567        | 0.446      |
| Mattiro Kanja  | 0.493         | 0.588           | 0.000         | 0.895         | 0.587            | 0.489        | 0.770        | 0.502      |
| Mattiro Uleng  | 0.474         | 0.536           | 0.895         | 0.000         | 0.667            | 0.520        | 0.827        | 0.540      |
| Mattiro Labangen| 0.449        | 0.457           | 0.587         | 0.667         | 0.000            | 0.665        | 0.593        | 0.568      |
| Mattiro Bulu   | 0.433         | 0.410           | 0.489         | 0.520         | 0.665            | 0.000        | 0.484        | 0.558      |
| Mattiro Baji   | 0.448         | 0.567           | 0.770         | 0.827         | 0.593            | 0.484        | 0.000        | 0.489      |
| Pangkajene     | 0.390         | 0.446           | 0.502         | 0.540         | 0.568            | 0.558        | 0.489        | 0.000      |

Source: Data Analysis, 2018

Power function constrain matrix determined passenger and cargo trip distribution inter-zone in island area of The North Liukang Tupabbiring district as well as passenger trip from island area to Capital of Pangkep Regency (Pangkajene) per day. While the number for passenger trip distribution matrix is shown in the table below.
Table 6. Passenger trip distribution matrix in inter-island cluster in North Liukang Tupabbiring District

|          | Mattiro Walie | Mattiro Bombang | Mattiro Kanja | Mattiro Uleng | Mattiro Labangen | Mattiro Bulu | Mattiro Baji | Pangkajene |
|----------|---------------|-----------------|---------------|---------------|-----------------|--------------|--------------|------------|
| Mattiro Walie | 0              | 1               | 1             | 1             | 0               | 2            | 1            | 4          |
| Mattiro Bombang | 1              | 0               | 1             | 1             | 0               | 1            | 1            | 4          |
| Mattiro Kanja   | 1              | 1               | 0             | 1             | 0               | 1            | 1            | 3          |
| Mattiro Uleng    | 1              | 1               | 1             | 0             | 1               | 2            | 1            | 4          |
| Mattiro Labangen | 0              | 0               | 0             | 1             | 0               | 1            | 0            | 2          |
| Mattiro Bulu     | 2              | 1               | 2             | 2             | 1               | 0            | 2            | 10         |
| Mattiro Baji     | 1              | 1               | 1             | 1             | 0               | 1            | 0            | 3          |
| Pangkajene       | 12             | 12              | 13            | 17            | 8               | 33           | 12           | 0          |

Source: Data analysis, 2018

Based on passenger trip distribution matrix 77% trip or 137 people headed to Capital of Pangkep regency (Pangkajene) per day, whereas the number of inter-island trip is 41 passenger per day. Based on field observation showed that most of all trip of passenger to Capital of Pangkep Regency (Pangkajene) were to buying everyday needs or to resell. Meanwhile most of all inter-island trip were to visited relatives.

Table 7. Cargo Trip Distribution matrix in inter-island cluster in North Liukang Tupabbiring District

|          | Mattiro Walie | Mattiro Bombang | Mattiro Kanja | Mattiro Uleng | Mattiro Labangen | Mattiro Bulu | Mattiro Baji | Pangkajene |
|----------|---------------|-----------------|---------------|---------------|-----------------|--------------|--------------|------------|
| Mattiro Walie | 0.000         | 0.006           | 0.006         | 0.008         | 0.003           | 0.013        | 0.006        | 0.063      |
| Mattiro Bombang | 0.005         | 0.000           | 0.006         | 0.007         | 0.003           | 0.010        | 0.006        | 0.056      |
| Mattiro Kanja   | 0.005         | 0.005           | 0.000         | 0.009         | 0.003           | 0.009        | 0.006        | 0.050      |
| Mattiro Uleng    | 0.006         | 0.006           | 0.009         | 0.000         | 0.004           | 0.012        | 0.008        | 0.068      |
| Mattiro Labangen | 0.002         | 0.002           | 0.003         | 0.004         | 0.000           | 0.007        | 0.003        | 0.032      |
| Mattiro Bulu     | 0.011         | 0.009           | 0.010         | 0.014         | 0.008           | 0.000        | 0.010        | 0.144      |
| Mattiro Baji     | 0.004         | 0.005           | 0.006         | 0.009         | 0.003           | 0.009        | 0.000        | 0.051      |
| Pangkajene       | 0.054         | 0.054           | 0.058         | 0.080         | 0.039           | 0.151        | 0.056        | 0.000      |

Source: Data Analysis, 2018

As much as 77% distribution trip cargo is headed to Capital of Pangkep regency (Pangkep) or 0.96 ton per day. The common load that usually carried from island cluster area were sea products as fish, squid, and crab also primary needs and building material as well.

The illustration of distribution passenger trip in imposition trip maps represent as below
4. Conclusion
The trip distribution of the island cluster area in North Liukang Tupabbiring, trip distribution of passenger or trip distribution of cargo still dominated trip from the inter island cluster to capital of Pangkep Regency by the total trip are 77% trips of passenger and 77% trips of cargo. The rest was distributed to the inter region islands.

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