Network integration modelling of feeder and BRT (bus rapid transit) to reduce the usage of private vehicles in Palembang’s suburban area

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Abstract. The aim of this research is to determine the optimal feeder network route that integrates with BRT (Bus Rapid Transit). Palembang, a high growing population city with unresolved transportation demand sector. BRT as main public transportation could not fulfill people’s demand in transportation, especially in Alang-Alang Lebar sub-district. As an impact, the usage of private vehicles increases along the movement toward the city center. The concept of Network Integration that integrates feeder network with BRT is expected to be a solution to suppress the rate of private vehicles’ usage and to improve public transportation service, so that the use of BRT will be increased in the suburban area of Palembang. The method used to identifying the optimal route using Route Analysis method is route analysis using Tranetsim 0.4. The best route is obtained based on 156 movement samples. The result is 58.7% from 199 mobility’s potency of private vehicle usage’s can be reduced if there is a feeder network’s route in Alang-Alang Lebar’s sub-district. From the result, the existance of integration between feeder network and BRT is potential enough to reduce the usage of private vehicles and supports the sustainability of transportation mobility in Palembang City.

Keyword : BRT, private vehicles, tranetsim

1. Introduction
The main problem in a developing city is transportation [1]. According to that, public transportation has a big role in a developing city to solve transportation problems. The development of public transportation in Palembang, South Sumatera, has started in 2002. However, congestion and private vehicle user are increasing. To solve it, in the beginning of 2010, a public transportation of Bus Rapid Transit (BRT) called Bus Trans Musi has developed. Despite that, the aim of BRT as the main transportation in Palembang City is not yet optimal. Based on the previous research, 33% of the transportation user used motorcycle as the main vehicle and 31% used Angkutan Kota (Angkot), because it is easier for mobilization and time efficiency of using private vehicle [2]. Around 41,040 of Alang-Alang Lebar sub-district’s resident have the potency of mobilization to the city center and the congestion from suburban area to the city center [3]. The change of transportation mode from private vehicle to BRT as mobilization potency in Alang-Alang Lebar sub-district will be able to reduce the city problem.

To reduce the number of private vehicle usage in suburban area of Palembang, needs a handling concept. In connection with the development of the Palembang’s density and the high demand of...
transportation, according to researcher [1], the integration of public transportation is the most rational solution to solve the urban transportation problem. This also supported by strategy and policy of the transportation development in RPJMD Palembang 2013-2018 to integrate the public transportation in Palembang, as also mentioned by the head of Palembang’s Transportation Department [4] about the instruction of feeder usage in 2016 and public transportation usage in the suburban area of Palembang in 2016.

The ideal integrated public transportation concept that should be applied in Alang-Alang Lebar sub-district is Network Integration. The concept of Network Integration is able to increase the usage of public transportation in London by 40% from 1982 to 2001 with a developed road network [5]. However, an analysis of the best network to suppress the usage of private vehicle in Alang-Alang Lebar sub-district is needed. According to the problems that have been described, a study of private vehicles’ reduction in suburban area of Palembang by applying public transportation feeder to BRT, which can be the main public transportation in Palembang to suppress the transport density in Palembang, will be conducted.

The concept of integrated public transportation modes has been applied in big cities such as Curitiba, Brazil. With the concept of integrated public transportation, transportation’s flow is getting well although the population in the city is increasing every year. The integrated transportation system in Curitiba has increased the resident’s quality of life and also public transportation user [6]. Integrated public transportation modes can defined as a combination of two or more types of transportation modes in serving the resident that mobilizes in one way of origin-destination [1], [7].

In a few big cities in Indonesia, the stagnation of network integration indicated by overlapped path of public transportation and it’s inability to reach every area in the city. Therefore, private vehicle becomes the main option in mobilization. As mentioned by Gwilliam (2008) in [7], it will be better if public transportation network applies the service hierarchy based on the main mode, branch mode, and feeder mode; so that the distribution of service area becomes clearer and the integration of public transportation’s service network can be implemented easily, so the determination of transportation mode’s transfer point and the stop can be more optimal. However, to determine the compatible network for public transportation optimization, optimal network analysis is required to increase the usage of public transportation in a city.

2. Research Method
This research is descriptive and experimental which based on positivist paradigm. The population of this research is the head of household in Alang-Alang Lebar sub-district, with the number of 17,527 head of households. Sample determination is differed by the goal of this research. The first and fourth goals are identifying resident’s mobility characteristic and calculating the potency of private vehicle usage’s reduction, using purposive sampling technique with sampling criteria: a) Private vehicle user in Alang-Alang Lebar sub-district b) The mobility’s destination is to the Palembang City center c) Resident’s mobility destination have been accommodated by BRT or other feeder.

Then, in determining the sample for the first and fourth goal, random sampling technique is used to limit the sample quantity in Alang-Alang Lebar sub-district with calculation using Slovin’s equation, as follows:

\[ n = \frac{17527}{(1 + 17527 \times (0.08)^2)} \]
\[ n = 156 \] (1)

From 156 samples, sample determination process based on each kelurahan in Alang-Alang Lebar sub-district. In determining sample quantity for the second goal, stakeholder analysis are used to identify related stakeholders in determining feeder network’s route in Alang-Alang Lebar sub-district. The chosen stakeholders are Palembang’s Department of Transportation, Palembang’s Department of Binamarga, PT SP2J, Palembang City and stakeholder in Alang-Alang Lebar sub-district. The method used for identifying the optimal route is route analysis using Tranetsim 0.4.
3. Results and Discussion

3.1. Identifying Resident’s Mobility Characteristic in Alang-Alang Lebar sub-district, Palembang

The population’s mobility characteristics are obtained from samples’ questionnaires. From 156 head of households’ samples, it is known that there are 239 mobilities. Mobility is being dominated in Kelurahan Karya Baru, with the total of 100 mobilities. From 239 mobility samples, 233 mobilities are using private vehicle, which most of them are motorcycle. Most of the resident goes to the city center to work with the samples of 72.5%. Meanwhile 199 of 233 samples that use private vehicle are willing to use BRT if there is a feeder network, that is become next step samples. There are 19 of 63 city road becomes road segment based on the sample’s route to other place.

3.2. Weighting the Indicator, Variable and Sub-Variable From the Determination of Integrated Feeder Network with BRT

The next step is to weighting the indicator, variable and sub-variable. Whereas indicator, variable and sub variable are obtained from the result of references synthesis. The process of determining the weight is interview with stakeholders, then, the result is being processed using Expertchoice 11. The results of indicator’s weighting, variable and sub-variable are listed in Table 1.

| Indicator | Variable | Sub-Variable |
|-----------|----------|--------------|
| Area’s Characteristics (0.568) | Land Use (0.457) | Residential (0.343) |
| | | Commercial (0.202) |
| | | Office and Institutional (0.213) |
| | | Industrial (0.182) |
| | | Community Facilities and Public Lands (0.06) |
| Road Network (0.543) | Local Road (0.707) | |
| | Collector Road (0.209) | |
| | Arterial Road (0.085) | |
| Coverage Area (0.432) | Public Transport Demand Pattern (0.333) | - |
| | Population (0.359) | - |
| | Service Area (0.317) | - |

Based on the table above, it could be known that indicator with highest weight is area’s characteristics (0.568%). However, sub-variable with highest weight is local road (0.707%). The approach in this step is the higher the weight then the road segment’s potency to become the most optimal feeder network is also higher, based on indicator, variable and sub-variable.

3.3. Determining Feeder Network Route that Integrates with BRT

In this process, researcher determines the feeder network route based on indicator, variable, and sub-variable using Tranetsim 0.4. The early stage of the determination is identifying road in Alang-Alang Lebar sub-district. It is identified that 39 road segment’s point and 110 road segment will be the input data to Tranetsim 0.4. Road segment is the intersection that samples go through. Road segment that becomes the origin is road segment’s point with the distribution of samples that’s covering it’s area. On the other hand, road segment that becomes the feeder network’s destination is BRT stop in Alang-Alang Lebar sub-district.

After submitting road segment’s point as the input of Tranetsim 0.4, then valuate the road segment. The valuation process of road segment is done by calculating feeder network’s variable and sub-variable. After the buffering process in 500 m radius, sub-variable for each road segment is being calculated. Here are the examples of sub-variable’s calculation in each road segment (Table 2).
Table 2. Example of land use’s calculation in road segment 10-11.

| Variable                                | Buffer500 m’s Area (ha) |
|-----------------------------------------|--------------------------|
| Residential                             | 19.8                     |
| Commercial                              | 11.4                     |
| Office and Institutional                | 0                        |
| Industrial                              | 0                        |
| Community Facilities and Public Lands   | 0                        |

After calculating each road segment based on indicator, variable dan sub variable, then standardize the values with the equation as follows:

\[ N_{X_1} = \left( \frac{X_1}{X_{a_{max}}} \right) \times 100 \]

\[ N_{X_1} = \text{Variable Value of Road Segment 1} \]
\[ X_{1a} = \text{Variable a’s Value of Road Segment 1} \]
\[ X_{a_{max}} = \text{Maximum Value of Variable a} \]

The aim of the standardization is to calculate the value of each variables and sub-variables as a whole. Afterwards, the next step is calculating each road segment. The example of road segment 10-11’s calculation are listed in Table 3.

Table 3. Example of road segment 10-11’s calculation.

| Variable and Sub-Variable | Value | Standardization Value | Sub-Variable’s Weight | Variable’s Weight | Indicator’s Weight | Sub-Variable’s Total |
|---------------------------|-------|------------------------|-----------------------|-------------------|-------------------|---------------------|
| A                        | B     | C                      | D                     | E                 | F                 | G                   |
| Residential              | 19.8  | 15.1                   | 0.343                 | 0.457             | 0.568             | 1.3                 |
| Commercial               | 11.4  | 38.9                   | 0.202                 | 0.457             | 0.568             | 2.0                 |
| Office and Institutional | 0.0   | 0.0                    | 0.213                 | 0.457             | 0.568             | 0.0                 |
| Industrial               | 0.0   | 0.0                    | 0.182                 | 0.457             | 0.568             | 0.0                 |
| Community Facilities and Public Lands | 0.0 | 0.0 | 0.060 | 0.457 | 0.568 | 0.0 |
| Arterial Road            |       |                        | 0.085                 | 0.543             | 0.568             | 0.0                 |
| Collector Road           |       |                        | 0.209                 | 0.543             | 0.568             | 0.0                 |
| Local Road               | 1.0   |                        | 0.707                 | 0.543             | 0.568             | 0.2                 |
| Public Transport Demand Pattern | 2.0 | 1.0 | 3.033 | 0.432 | 0.368 | 2.3 |
| Service Area             | 31.2  | 21.2                   | 0.317                 | 0.432             |                   | 2.9                 |
| Population               | 602.2 | 15.1                   | 0.359                 | 0.432             |                   | 2.3                 |

Total 9.1

After the value of each segment is acquired, another standardization process needs to be done so the value will be the input data to Tranetsim 0.4. The difference between each value’s approach in segment based on indicator, variable, and sub-variable, will be equalized by the standardization process. Standardization’s equation for the input of Tranetsim 0.4 is:
\[ NY_1 = \left( \frac{Y_{1 \text{min}}}{Y_1} \right) \times 100 \]  

NY\textsubscript{1} = Tranetsim’s input data of road segment 1  
Y\textsubscript{1\text{min}} = Minimum value of variable and sub-variable  
Y\textsubscript{1} = Total value of variable and sub-variable in road segment 1  

The input data for Tranetsim 0.4 are the origin and destination point. Then, Tranetsim will determine the route with the lowest value. The lowest value is the value for each road segment that has been inputted in Tranetsim system. Tranetsim will determine the route with the lowest value and the most optimal BRT stop based on the lowest value. The lowest value will become the best route for integrated feeder network with BRT. As seen in Tranetsim 0.4, mobility from segment point 1 to segment point 18 is the destination, which is BRT stop. In this process, feeder network route is acquired from sample’s origin to feeder network’s destination. 13 (thirteen) road segment’s points are the origin of the mobility. The destination or chosen stop is road segment’s point, which is a BRT stop. As the result of Tranetsim’s process, there are 13 best route which will be the base calculation of the potency of private vehicle usage’s reduction in Alang-AlangLebar’s sub-district.  

3.4. Calculating the Potency of Private Vehicle Usage’s Reduction Based on Integrated Feeder Network with BRT  
In this stage, calculation process of the potency of private vehicle usage’s reduction will be executed. The research’s approach is listed in Table 4.  

| Potential | Not Potential |
|-----------|---------------|
| Maximum distance based on community’s preference ≥ distance to the nearest BRT (hate) using feeder’s route | Maximum distance based on community’s preference ≤ distance to the nearest BRT (hate) using feeder’s route |

Maximum distance based on community’s preference is acquired from the questionnaire in Step 1. On the contrary, the distance to the nearest BRT stop is calculated from sample’s origin point by feeder network that has been determined in the previous step. Here is the example of the calculation of potency of private vehicle usage’s reduction (Table 5).  

| No | Sample | Shortest Feeder Network (km) | Community’s Preferred Distance (km) | The Potency of Private Vehicle Usage’s Reduction |
|----|--------|-------------------------------|-------------------------------------|-----------------------------------------------|
| 1  | 1.08   | 2                             | Potential                           |                                               |
|    | 1.08   | 2                             | Potential                           |                                               |
|    | 1.08   | 2                             | Potential                           |                                               |
| 3  | 1.27   | 1                             | Not Potential                       |                                               |
|    | 1.27   | 1                             | Not Potential                       |                                               |

As the result of the previous calculation, 58.7% is potential to private vehicle usage’s reduction, while the other 41.2% is not potential because of the long distance between the origin and BRT stop. Therefore, the concept of integrated feeder network with BRT can be developed to reduce the usage of private vehicle in Alang-Alang Lebar sub-district.
4. Conclusion
From the research above, there are 4 conclusions. First, the majority of mobilities in Alang-Alang Lebar sub-district is using private vehicle. The high number of private vehicle usage is caused by the public transportation that have not been able to reach mobility’s origin in Alang-Alang Lebar sub-district. Second, Based on AHP analysis using Expertchoice 11, sub-variable with highest weight in indicator: area’s characteristic is local road network (0.707%). On the other hand, for indicator: coverage area, sub-variable with highest weight is population (0.359%). That weight determines best road as a feeder network route in Alang-Alang Lebar sub-district. Third, the outcomes of road’s valuation are 13 road segments. Those road segments are Jalan Lorong Masjid, Kol. H. Burlian, Mitra Hj, Jenderal Murod, HBR Motik, Sulaiman Amin, Perumdam 1, Srijaya, Mandi Api, Bypass Alang-AlangLebar, Jalan Sepakat, Jalan Mahoni Raya and Jalan Kelapa Gading 5. Fourth, after determining the best route, estimating the potency of private vehicle usage’s reduction with comparing distances from samples’ origin using integrated feeder network with BRT to the preferred distance by mobility’s sample. The result is 58.7% from 199 mobility’s potency is the potency of private vehicle usage’s reduction if there is a feeder network’s route in Alang-AlangLebar’s sub-district.

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