Effect of TOD on traffic in Banda Aceh City

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Abstract. Transit Oriented Development (TOD) can eliminate urban sprawl and turn it into a compact city area. The results obtained are generated and traction models obtained are, $O_i = -37.126 + 58.723X_3 + 17.968X_6$, where the performance of the road and land use coefficient suggests the number of trip generation increases. The trip figure is obtained by the model $D_d = -20.351 + 30.903X_6$ where only one significant variable causes the trip generation, which is the dominant land use. With the TOD concept, the model obtained is $O_i = 32.180 + 0.002X_4 - 7.017X_5$ where the cost of travel and the distance of the trip indicate the amount of trip generation incrementally, and trip generation will decrease compared to the base year. The trip is obtained by the model $D_d = 48.474 -0.671X_1 + 0.003X_4 -9.299X_5$, meaning that trip distribution without population density, travel costs and travel distance, the trip pulls occur at 48 trip distribution. If influenced by population density, travel and the distance of the trip, the trip will decrease. It can be interpreted that this independent variable can affect the attraction of the city of Banda Aceh and the TOD concept can be applied there.

1. Introduction
The city of Banda Aceh after experiencing the tsunami disaster in 2004, experienced changes in spatial patterns and spatial structure and in terms of transportation experienced changes in both facilities and infrastructure. Transportation development is very influential in the course of regional development, and this is evident in the city of Banda Aceh which has changed its centers of activity and land use patterns. Development of transportation infrastructure the city of Banda Aceh is seen from three conditions, namely: (1) Complementarities, the relative attractiveness between two or more destinations; (2) transferability, want to overcome distance constraints, measured by the time and money needed, and the technology to make it; and (3) competition between several locations to meet demand and supply [1].

Transportation infrastructure development that occurred in Banda Aceh unplanned is not being integrated between existing sub-districts and between activity centers, so that the performance of the road network causes congestion in several sub-districts during rush hour, namely at KutaAlam sub-district with a level of service (LOS) E - F (V/C ratio = 0.98). This means’ that the current infrastructure is unstable and dominant stops, and the current starts to be unstable in the districts of Banda Raya, Jaya Baru, Baiturrahman, Lueng Bata with LOS D (V/C ratio = 0.8 - 0.9) [2]. The growth of transportation infrastructure in the city of Banda Aceh has resulted in urban sprawl which has an impact on congestion problems that arise. Urban sprawl has resulted in inefficient regulation of the urban transportation system with an increase in the number of vehicles of 6% per year [3]. The rate of increase in economic growth has attracted a flow of urbanization to the city of
Banda Aceh, and this is a reflection of the results of the interaction between increasing living standards and the mobility needs of the population. Transportation infrastructure planning and urban spatial structure can regulate the location of spatial structure activities while simultaneously regulating the accessibility of the city due to the fact that each spatial structure has an impact on the generation and attraction of traffic as well as the distribution of its movements [4].

Traffic problems in the city of Banda Aceh can be solved by developing transportation that synergizes with spatial planning to recommend new growth by strengthening the housing environment and expanding choices and benefits through optimizing the mass public transport network. This will make it easier for residents to use city resources. This concept is known as transit-oriented development, or (TOD) [1].

2. Literature review

2.1. Transportation infrastructure development

The geographical distribution between layouts and the capacity and location of transportation facilities are combined together to measure the volume and pattern of traffic flow. The volume and pattern of traffic flow on the transportation network will have a feedback effect on the new layout and the need to improve transportation infrastructure [5]. Thus, the interrelationship between the layout and transportation can be divided into:

- The spatial structure determines the location of activities;
- Distribution of activities in space requires/causes spatial interactions in the transportation system;
- Distribution of infrastructure from the transportation system creates the level of spatial connectivity of a location (which assessed as the level of accessibility);
- Distribution of accessibility in space determines site selection that results in changes in the space system.

2.2. Location theory

Von Thunen's theory creates land use zones by intersecting different rental rate curves. Assuming that a city has one central business district where all work is located and all transportation costs are linearly related to the distance of the central business district (DPB), rental rates and land use patterns are related in three types of land use: retail, industrial and residential areas [6].

![Figure 1. Von Thunen's model with the spread of land use.](image)

2.3. Trip distribution

Travel distribution is an analysis stage to find out the number of trip results and trip attractions owned by each zone. Travel distribution procedures find the destination of the trip generated in each trip zone, and the resulting trip results are divided between zones within the study area which show the
flow of travel between each pair of zones, which is then divided into generating zones and withdrawal zones [7].

2.4. Mode used
The factors that influence mode choice can be divided into three broad categories, namely:
- Travel characteristics (family income, number of cars available, family size, settlement density)
- Trip characteristics (the distance of travel, time to start a trip)
- Characteristics of the transportation system (ride time, excess time)

The approach to urban areas without large transit services can be in the form of an equation that connects population trips (POP), income (INC), and cars/automobiles (AUTO).

2.5. Transit Oriented Development (TOD)
Some important characteristics of the development of TOD are:
1. Use of mixed space consisting of settlements, offices, and supporting facilities;
2. High population density;
3. Availability of shopping facilities;
4. Availability of health facilities;
5. Availability of educational facilities;
6. Availability of entertainment facilities;
7. Availability of sports facilities;
8. Availability of banking facilities.

The TOD concept is a concept to overcome transportation problems, especially in overcoming the rate of movement of traffic. This concept emphasizes the arrangement environment with mixed land use patterns that are centered on one transit point to maximize transportation access to the transportation system [8].

3. Methodology
This research variable used for trip generation and attraction of the city of Banda Aceh is: population density ($X_1$), building density ($X_2$), road performance / VC ratio ($X_3$), travel costs incurred ($X_4$), distance traveled ($X_5$) and land use type ($X_6$). The use of the TOD concept by analyzing the population and building density for the city of Banda Aceh for the development of 10 years based on the reason for the development in the medium term is 2.4% per year [9]. This study assumes shorter travel distances in the range of 3 to 5 km, so that travel costs are also assumed to be lower by 10% with the TOD concept being applied. The method diagram used can be seen in Figure 3.1.

![Figure 2. Methodology for evaluating the effects of transportation on TOD.](image)

3.1. Research hypothesis
Trip generation and trip distribution will go down by applying the TOD concept, due to the availability of social and public facilities in each sub-district of Banda Aceh. So, events happened in
their own zone. It can be said that the concept of TOD can reduce the generation and pull that will have an impact on traffic congestion.

3.2. Data analysis model
The data used to analyze the stages of trip generation and trip distribution will produce a relationship model that links land use parameters with the amount of movement, which also leads to a zone or the number of movements that leave a zone. The trip generation model consists of six independent variables that related dominantly to the dependent variable, namely: population density, building density, road performance, average travel costs per day, average travel distance per day, and land use.

4. Research result
The trip distribution and trip generation stages produce a model that links movement parameters between zones or the number of movements leaving a zone.

Table 1. Table of trip generation and trip distribution in District Banda Aceh City.

| No | District       | Meuraxa | Jaya Baru | Banda Raya | Baitur rahman | Lueng bata | Kuta Raja | Syiah Kuala | Ulee Kareng | Kuta Alam | Oi |
|----|----------------|---------|-----------|------------|---------------|------------|-----------|-------------|-------------|-----------|----|
| 1  | Meuraxa        | 3       | 1         | 0          | 2             | 0          | 3         | 3           | 0           | 6         | 18 |
| 2  | Jaya Baru      | 1       | 0         | 0          | 5             | 2          | 0         | 4           | 0           | 19        | 31 |
| 3  | Banda Raya     | 0       | 1         | 14         | 3             | 1          | 2         | 0           | 1           | 4         | 26 |
| 4  | Baitur rahman  | 1       | 1         | 0          | 31            | 4          | 0         | 8           | 3           | 15        | 63 |
| 5  | Lueng bata     | 0       | 0         | 0          | 3             | 5          | 0         | 5           | 5           | 11        | 29 |
| 6  | Kuta Raja      | 1       | 0         | 1          | 0             | 1          | 3         | 0           | 3           | 9         | 7  |
| 7  | Syiah Kuala    | 2       | 0         | 2          | 7             | 1          | 0         | 28          | 8           | 12        | 60 |
| 8  | Ulee Kareng    | 0       | 0         | 0          | 1             | 0          | 1         | 4           | 25          | 0         | 31 |
| 9  | Kuta Alam      | 0       | 3         | 0          | 0             | 7          | 1         | 21          | 7           | 77        | 116|
|    | Total          | 8       | 6         | 17         | 52            | 20         | 8         | 76          | 49          | 147       |    |

Figure 3. Desire trip generation and trip distribution in Banda Aceh City.
4.1. Trip generation model existing
From the trip generation coefficients processing results:

| Coefficientsa | Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|---------------|-------|-----------------------------|---------------------------|---|------|
|               | (Constant) | 10.951 * | 52.564 | .208 * | .854 |
| Population Density (Jiwa/Ha) | -.094 | 2.291 | -.072 | -.041 | .971 |
| Building Density (Bang/Ha) | 2.568 | 8.274 | .480 | .310 | .786 |
| 1 | Road Performance (V/C) | 76.532 | 69.175 | .543 | 1.106 | .384 |
| Average Travel Costs (Rp) | -.016 | .009 | -.686 | -1.789 | .215 |
| Average Travel Distance Per Day | 16.643 | 19.280 | .366 | .863 | .479 |
| The dominant landuse | 17.266 | 6.445 | .720 | 2.679 | .116 |
| (Constant) | 11.005 | 42.923 | .256 | .814 |
| Population Density (Jiwa/Ha) | 2.235 | 1.309 | .418 | 1.707 | .186 |
| 2 | Road Performance (V/C) | 74.084 | 28.645 | .526 | 2.586 | .081 |
| Average Travel Costs (Rp) | -.016 | .008 | -.686 | -2.190 | .116 |
| Average Travel Distance Per Day | 16.970 | 14.345 | .373 | 1.183 | .322 |
| The dominant landuse | 17.203 | 5.111 | .717 | 3.366 | .044 |
| (Constant) | 34.463 | 39.923 | .863 | .437 |
| Building Density (No.Build/Ha) | 2.877 | 1.249 | .538 | 2.303 | .083 |
| 3 | Road Performance (V/C) | 51.209 | 22.164 | .363 | 2.311 | .082 |
| Average Travel Costs (Rp) | -.009 | .005 | -.394 | -1.948 | .123 |
| Landuse yang Dominan | 13.045 | 3.892 | .544 | 3.352 | .029 |
| (Constant) | -37.861 | 18.359 | -2.062 | .094 |
| Building Density (No.Build/Ha) | 1.262 | 1.167 | .236 | 1.081 | .329 |
| 4 | Road Performance (V/C) | 43.974 | 27.285 | .312 | 1.612 | .168 |
| The dominant landuse | 15.622 | 4.571 | .651 | 3.417 | .019 |
| (Constant) | -37.126 | 18.603 | -1.996 | .093 |
| Road Performance (V/C) | 58.723 | 23.961 | .417 | 2.451 | .050 |
| The dominant landuse | 17.968 | 4.079 | .749 | 4.405 | .005 |

The trip generation equation is:

\[ O_1 = -37.126 + 58.723X_3 + 17.968X_6 \]

Where:

- \( O_1 \) = Trip Generation
- \( X_3 \) = Road Performance (V/C)
- \( X_6 \) = dominant Landuse

a. Dependent Variable: Generation (Oi)
4.2. **Trip distribution model existing**

The trip distribution phase will produce a relationship model that links land use parameters with the number of trip distributions, which go to a zone or the number of movements that go to a zone. From the processing of trip distribution coefficients obtained results:

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|------------------------------|---------------------------|---|------|
| (Constant) | -15.263 | 108.929 | -.140 | .901 |
| Population | -1.660 | 4.749 | -.885 | .350 |
| Building Density | 6.601 | 1.174 | .863 | .385 |
| Road Performance (V/C) | 115.712 | 143.352 | .574 | .807 |
| Average Travel Costs (Rp) | -.013 | .019 | -.370 | -.667 |
| Average Travel Distance Per Day | 6.990 | 39.545 | .107 | .175 |
| The dominant landuse | 31.950 | 13.355 | .930 | 2.392 |
| Population Density(Jiwa/Ha) | -2.003 | 3.559 | -1.067 | .563 |
| Building Density (Bang/Ha) | 8.035 | 12.389 | 1.050 | .649 |
| Road Performance (V/C) | 116.816 | 117.825 | .579 | .991 |
| Average Travel Costs (Rp) | -.010 | .011 | -.301 | -.935 |
| The dominant landuse | 30.759 | 9.455 | .896 | 3.253 |

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|------------------------------|---------------------------|---|------|
| (Constant) | 3.338 | 72.354 | .046 | .965 |
| Building Density (Bang/Ha) | 1.203 | 2.264 | .157 | .531 |
| Road Performance (V/C) | 55.309 | 40.168 | .274 | 1.377 |
| Average Travel Costs (Rp) | -.007 | .009 | -.313 | -.831 |
| The dominant landuse | 27.707 | 7.054 | .807 | 3.928 |

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|------------------------------|---------------------------|---|------|
| (Constant) | -19.971 | 53.234 | -.375 | .723 |
| Road Performance (V/C) | 60.806 | 35.917 | .301 | 1.693 |
| Average Travel Costs (Rp) | -.004 | .006 | -.122 | -.691 |
| The dominant landuse | 29.803 | 5.410 | .868 | 5.508 |
| Population Density(Jiwa/Ha) | -52.594 | 23.544 | -2.234 | .067 |
| Average Travel Costs (Rp) | 49.181 | 30.326 | .244 | 1.622 |
| The dominant landuse | 29.614 | 5.163 | .862 | 5.736 |

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|------------------------------|---------------------------|---|------|
| (Constant) | -20.351 | 14.003 | -1.453 | .189 |
| The dominant landuse | 30.903 | 5.664 | .900 | 5.456 |

The fifth model has a direct influence on the dominant land use variable. The trip distribution equation is:

\[ Dd = -20.351 + 30.903X6 \]

Where: \( Dd = \text{Trip Distribution} \); \( X6 = \text{dominant land use} \)
4.3. *Trip generation model with TOD*

Using the same method, the projection for a trip generation of 10 years from the research year obtained a relationship model that links the land use parameters with the number of generations from a zone.

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|-----------------------------|---------------------------|---|-----|
|       | B   | Std. Error | Beta |   |    |
| **1** |     |           |      |   |    |
| (Constant) | 33.419 | 28.887 | 1.157 | .367 |
| Population Density (Jiwa/Ha) | -.184 | .991 | -.182 | -.186 | .870 |
| Building Density (Bang/Ha) | .418 | 3.608 | .099 | .116 | .918 |
| Road Performance (V/C) | 7.329 | 45.539 | .047 | .161 | .887 |
| Average Travel Costs (Rp) | .002 | .001 | 1.111 | 3.226 | .084 |
| Average Travel Distance Per Day | -.7464 | 6.788 | -.145 | -1.100 | .386 |
| The dominant landuse | -.2047 | 6.137 | -.085 | -.334 | .770 |
| **2** |     |           |      |   |    |
| (Constant) | 34.561 | 22.241 | 1.554 | .218 |
| Population Density (Jiwa/Ha) | -.073 | .190 | -.072 | -.384 | .727 |
| Road Performance (V/C) | 2.726 | 18.170 | .017 | .150 | .890 |
| Average Travel Costs (Rp) | .002 | .000 | 1.124 | 4.192 | .025 |
| Average Travel Distance Per Day | -.7008 | 4.528 | -.136 | -1.548 | .219 |
| The dominant landuse | -2.399 | 4.368 | -.100 | -.549 | .621 |
| **3** |     |           |      |   |    |
| (Constant) | 36.477 | 15.827 | 2.305 | .083 |
| Population Density (Jiwa/Ha) | -.064 | .157 | -.063 | -.409 | .703 |
| Average Travel Costs (Rp) | .002 | .000 | 1.137 | 5.177 | .007 |
| Average Travel Distance Per Day | -7.142 | 3.858 | -.139 | -1.851 | .138 |
| The dominant landuse | -2.712 | 3.334 | -.113 | -.813 | .462 |
| **4** |     |           |      |   |    |
| (Constant) | 36.881 | 14.421 | 2.558 | .051 |
| Average Travel Costs (Rp) | .002 | .000 | 1.062 | 9.590 | .000 |
| Average Travel Distance Per Day | -7.792 | 3.210 | -.151 | -2.427 | .060 |
| The dominant landuse | -2.057 | 2.670 | -.086 | -.770 | .476 |
| **5** |     |           |      |   |    |
| (Constant) | 32.180 | 12.616 | 2.551 | .043 |
| Average Travel Costs (Rp) | .002 | .000 | .990 | 17.322 | .000 |
| Average Travel Distance Per Day | -7.017 | 2.944 | -.136 | -2.384 | .054 |

*a. Dependent Variable: Generation (Oi)*
The fifth model has a direct influence on trip generation with a dominant land use variable. The trip generation equation is:

\[ O_{i10} = 32.180 + 0.002X_4 - 7.017X_5 \]

Where:

- \( O_i \) = Trip Awakening
- \( X_4 \) = Travel Costs
- \( X_5 \) = Travel Distance

### 4.4. Trip distribution model with TOD

Using the same method, the projection for a 10-year trip distribution from the research year of 2029 shows an equation model:

#### Table 5. Coefficients of trip distribution using the TOD concept.

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|-----------------------------|---------------------------|---|------|
|       | B                           | Std. Error                | Beta |     |     |
| (Constant) | 38.547 | 19.914 | 1.936 | .193 |
| Population Density (Jiwa/ha) | -642 | .683 | -442 | -.940 | .446 |
| Building Density (Bang/ha) | .103 | 2.488 | -.017 | .041 | .971 |
| Road Performance (V/C) | 7.273 | 31.394 | .032 | .232 | .838 |
| Average Travel Costs (Rp) | .003 | .000 | 1.188 | 7.161 | .019 |
| Average Travel Distance Per Day | -8.907 | 4.680 | -.121 | -1.903 | .197 |
| The dominant landuse  | 4.091 | 4.230 | .119 | .967 | .436 |
| (Constant) | 38.829 | 15.288 | 2.540 | .085 |
| Population Density (Jiwa/ha) | -615 | .130 | -423 | -4.720 | .018 |
| Road Performance (V/C) | 6.136 | 12.490 | .027 | .491 | .657 |
| Average Travel Costs (Rp) | .003 | .000 | 1.190 | 9.247 | .003 |
| Average Travel Distance Per Day | -8.795 | 3.113 | -.119 | -2.825 | .066 |
| The dominant landuse  | 4.004 | 3.002 | .117 | 1.334 | .275 |
| (Constant) | 43.143 | 11.266 | 3.829 | .019 |
| Population Density (Jiwa/ha) | -596 | .112 | -410 | -5.317 | .006 |
| Average Travel Costs (Rp) | .003 | .000 | 1.211 | 11.090 | .000 |
| Average Travel Distance Per Day | -9.097 | 2.746 | -.123 | -3.312 | .030 |
| The dominant landuse  | 3.299 | 2.373 | .096 | 1.390 | .237 |
| (Constant) | 48.474 | 11.538 | 4.201 | .008 |
| Population Density (Jiwa/ha) | -671 | .107 | -462 | -6.263 | .002 |
| Average Travel Costs (Rp) | .003 | .000 | 1.334 | 19.113 | .000 |
| Average Travel Distance Per Day | -9.299 | 2.987 | -.126 | -3.113 | .026 |

a. Dependent Variable: Distribution (Dd)
The fourth model has a direct effect on trip distribution with the dominant land use variable. The trip distribution equation is:

$$Dd_{10} = 48.474 - 0.671X_1 + 0.003X_4 - 9.299X_5$$

Where:

- $Dd$ = Trip Distribution
- $X_1$ = Population Density
- $X_4$ = Travel Costs
- $X_5$ = Travel Distance

5. Conclusions

From the model obtained by the City of Banda Aceh it is a homogeneous region type characterized by a relative similarity in the region and is not characterized by the layout with the TOD concept; so that coefficient of determination of 83.1% trip generation obtained, for trip distribution coefficient of determination of 81% trip distribution can be explained by the dominant land use. Transportation generation and attraction related to the development of transportation infrastructure to the spatial structure with the TOD concept obtained 98% trip generation and trip distribution of 99.4% in interzone. It can be concluded that the application of the TOD concept in a given area gives a reduction in trip distribution and results in trip generation in the region or sub-district itself so that it does not affect other areas of sub-districts in the City of Banda Aceh.

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