Implementation of Transit Oriented Development in Handling Congestion Effect on Urban Sprawl Phenomenon and Traffic Growth in Banda Aceh

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Abstract. The occurrence of spatial and road network changes, increased traffic volume approaching road capacity, causing congestion due to urban sprawl phenomena as well as lack of public facilities and social facilities. From this background problem considered to be solved by a concept that is Transit Oriented Development (TOD), concept of transportation development in co-operation with spatial. The TOD concept can eliminate urban sprawl, which transforms urban sprawl into a compact city area. Pull model are obtained from the results of the analysis is, \( O_i = -37,126 + 58,723 \times X9 + 17,968X2 \), where road performance, land use, the coefficient indicates the number of additional trip generation. Trips pull obtained by model \( D_d = -20,351 + 30,903X2 \) where only one significant variable causing attraction of land use that is dominant. With concept of TOD, the model obtained is \( O_i = 32.180 + 0.002X7 - 7.017X3 \) where travel and distance travel costs indicate the number of additional trips generation, the generation will decrease over the base year. Objects obtained with the model \( D_d = 48.474 - 0.671X11 + 0,003X7 - 9,299X3 \), meaning travel attraction in the absence of population density, travel expenses, and travel distance, then travel appeal that occurs on 48 journeys influenced by variable population density and distance travel will decrease, it can be interpreted this independent variables can influence the drag on the concept of Banda Aceh City and TOD can be applied in the city of Banda Aceh.

1. Introduction
Banda Aceh after an earthquake and tsunami in 2004, causing the change of spatial and road network, coupled with better economic community which can be seen from the high vehicle growth of 6% per year. The increase in the number of motor vehicles and spatial changes causes traffic to increase traffic volume that continues to approach road capacity. It also caused increased traffic to emerge in new areas, causing congestion in some arterial roads, urban sprawl, and the availability of public facilities and incomplete social facilities in the sub-districts of Banda Aceh City [1].

Development of transportation infrastructure in Banda Aceh City, namely subdistrict Jaya Baru, Lueng Bata and Kuta Alam. The subdistricts and rural roads have the shortest percentage of 8%, and 9% of the total city roads 552,789 km, and 9% of the village road length 56.65 km, the district that has the longest city street percentage is Kuta Alam 17% and 14% rural road, Meuraxa sub-districts 16% of urban roads and 14% of village roads, Syiah Kuala subdistrict 13.55% of urban roads and 1.62% of
village roads, and Ulee Kareng sub-district 14% of urban roads and 1.09% of village roads [2]. This resulted is not being integrated between existing sub-districts and between centers of activity, resulting in the performance of down road networks causing congestion in some sub-districts during rush hour, at Kuta Alam sub-district with level of service (LOS) E-F (V / C ratio = 0.98) with the meaning of current not stable and dominant stop, and the current started unstable until unstable at Banda Raya, Jaya Baru, Baiturrahman, Lueng Bata with LOS D (V/C ratio = 0.8 - 0.9) [3].

The increasing number of populations and activities in Banda Aceh City and unstoppable urban sprawl in the south by 33% and East of Banda Aceh City by 44% of the total population of Banda Aceh City in 2013 which is 249,282 inhabitants [4], there will be inter-city spatial integration and create new city. This can be seen from the amount of realization of building permit (IMB) in the south area that is 45.35% IMB and 40% IMB eastern and 42.44% IMB occupancy and 47.11% IMB business [5]. The growth of Banda Aceh City following the 2004 earthquake and tsunami caused urban sprawl which affected the congestion problem in City of Banda Aceh, urban sprawl had an impact on the inefficiency of urban transportation system arrangement with 6% vehicle increase per year [3], due to unregulated settlements due to lack of control of spatial use as well as the occurrence of groupings or differences in socio-economic strata that will impact the more complex problems of population mobility, can be proved by the level of welfare in each region in Banda Aceh City, in the West there are 14.40% prosperous families, 4.23% prosperous and 4.3% prosperous and South East of Banda Aceh city 34.20% and 47.16% from total family prosperous 39747 family [4].

This study uses the concept of Transit Oriented Development to overcome traffic problems above with the concept of transportation development synergize with spatial to accelerate new growth by strengthening residential environment and expansion of choice or benefit, through optimization of mass public transportation network, making it easier for city residents to access city resources. With the concept of TOD can eliminate urban sprawl, which transforms urban sprawl into a compact city area, taking into account several factors: business zones, offices, public facilities and social facilities so that people can carry out activities and meet their needs in the area without having to go downtown [1].

2. Literature review

2.1. Development of transport infrastructure
The volume and pattern of traffic flows on the transport network will have feedback effects on the new spatial and the need for improved transportation facilities [6]. Infrastructure is defined as a means to be built or provided in advance, which will then be used to serve the means [7]. Transportation is defined as the activity of transporting cargo (goods and people/people). The journey carrying the cargo from the origin to the destination is called Origin - Destination Travel.

2.2. Accessibility and activity
Accessibility can be measured by calculating the number of available (opportunity-opportunity) locations from a certain distance from the origin and factoring the number by the distance between them, so accessibility can be expressed in terms of distance, time or cost [8].

Movements in the form of human movement (population) and/or goods, clearly require the mode of transportation (medium) and media (infrastructure) where the mode of transportation is moving [9]. The necessary transportation infrastructure, a second micro-system, commonly known as the transport network system, the interaction between system of activities and network system (infrastructure) generates movement, activity system or space structure is influenced by network system factors, system of movement and purpose of the mutually influential movements.

2.3. Trip generation and distribution
Trip generation is a process that links land use parameters to the number of moves leading to a zone or the number of moves leaving a zone [10], resulting in a model, motion stages predict the number of
moves a person will perform in each home zone using detailed data on the rate of movement increase, socio-economic attributes, land management and will illustrate realistic patterns of movement [11].

Trip distribution is an analytical step to find out the number of trips and trips that each zone has [12].

2.4. Transit oriented development
The determinants of the successful implementation of TOD among others are land use, and transportation system where they are the building blocks of spatial structure [13].

TOD development is influenced by the ideal social and physical dimension to synergize, there are four factors to be considered [14]:
- Mixed-use;
- High Density;
- Unauthorized Vehicle Access;
- Close to MRT / BRT Station.

TOD can be defined with the following characteristics [15]:
- Land use density;
- Pedestrian and eco-friendly cycle;
- Public facilities close to the station;
- Stations as community liaison.

3. Research methodology
The conceptual framework in this study stems from the spatial structure planning in Banda Aceh City with the concept of Transit Oriented Development (TOD) associated with the development of transport infrastructure, to prevent congestion and urban sprawl. These two indicators of space structure and construction of transport infrastructure have related interactions such as travel distance, transportation network, mobility of movement, travel intent, travel costs, diversity of social facilities/public facilities available in a region, and land use types in a region. It was then associated with the development of the conceptual area of TOD. The conceptual framework in this research can be seen in Figure 1. Below this.

3.1. Research hypothesis
The development of transport infrastructure follows the structure of the space so as to influence the rise and pull of travel.

The development of transportation infrastructure using TOD concepts can overcome the problem of the rise and pull that causes congestion in other areas, outside the administrative area.

3.2. Data analysis model
In the distribution of 10 data for the population, the population growth rate is 2.4% per year for Banda Aceh City [5] statistics, and the building density is 2.4%, the number of social / public facilities using the TOD method is that the sub-district has a number of social / public facilities, as well as the availability of social / public facilities, this study assumes between 3-5 km, is decreased by 10% in the first so the road performance will be 10% in the first While land use type, network connectivity, the frequency of travel, time and travel intention set by applying the concept of TOD.
4. Research results

4.1. Trip generation and distribution data

Stages of the trip generation and trip distribution will result in a relationship model that links land use parameters to the number of moves, leading to a zone or the number of movements that dies a zone. For more details can be seen in the Draw lines of Desire in the City of Banda Aceh.

The stages of the trip generation will result in a model of the relationships that links land use parameters to the amount of generation of a zone. Models are obtained that have a direct influence on trip generation with road performance variables (V/C) and dominant land use.

So that the equation of the existing condition of travel is obtained:

$$O_i = -37,126 + 58,723 X_9 + 17,968 X_2$$  \hspace{1cm} (1)

Where:
- $O_i =$ Trip Generation
- $X_9 =$ Road Performance (V/C)
- $X_2 =$ Land use is dominant

The model for the trip distribution is obtained:

So that the existing travel attraction equation is:
Dd = -20,351 + 30,903X2  
(2)

Where:
Dd = Trip Distribution  
X2 = Landuse is dominant

By using the concept of TOD, obtained the model:
So the equation of trip generation is:
Oi10 = 32,180 + 0.002 X7 - 7.017 X3  
(3)

Where:
Oi = Trip Generation  
X7 = Travel Fees  
X3 = Travel Distance

So the traction equation is:
Dd10 = 48,474 -0.671X11 + 0.003X7  - 9.299X3  
(4)

Where:
Dd = Trip Distribution  
X11 = Population Density  
X7 = Travel Fees  
X3 = Travel Distance

4.2. Development of transport infrastructure

At this stage of regression analysis is done by looking at the effect of combined and partial, by adding space structure variable to the development of transportation infrastructure, which becomes the transportation infrastructure variable is the type of land used, this condition is considered the existing conditions. Where the role of TOD concept has not been applied.

Development of Transport Infrastructure = -1.457 + 0.652X1 + 0.388X5 + 0.235X6 + 0.222X7 + 0.327X8  
(5)

Where:
X1 = Diversity of Social Facilities/Public Facilities  
X5 = Frequency of Travel/Mobility of Movement  
X6 = Purpose of Travel  
X7 = Travel Fees  
X8 = Travel Time

The model fit test is performed using the equation below.

\[ R = \frac{1-R_m^2}{1-R_e^2} \]  
(6)

So obtained: R2m = 1- (1-0.623) * (1-0.624) = 0.858 Furthermore the coefficient of determination for model 2 each on structural 1 and 2 (after trimming):

Re^2 = 1- (1-0.616) * (1-0.623) = 0.855, so the value Q = 1- 0.858 / 1- 0.855 = 0.979.

With the sample size (n) = 407, and the number of path coefficients is not significant (d) = 4, the chi-square with W = - (nd) ln Q = - (407-4) ln (0.979) = 8.55 From chi-square table with db = d = 4 at significance level \( \alpha = 0.05 \) at X2tab = X2 (0.05; 2) = 9.48, because W = 8.55 <= 9.48 or HO rejected. Thus, the model obtained is appropriate or fit (fit model) with the data.

By using the concept of TOD the results obtained: Construction of Transport Infrastructure = -1.372 + 0.220X4 + 0.663X6 + 0.275X7
Where:
X4 = Network Connectivity
X6 = Purpose of Travel
X7 = Travel Fee

The model fit tests is done using equation 6. So obtained: $R^2_m = 1 - (1-0.847) \times (1-0.539) = 0.929$
Furthermore the coefficient of determination for model 2 each on structural 1 and 2 (after trimming): $R^2_e = 1 - (1-0.847) \times (1-0.535) = 0.928$, so the value of $Q = 1 - 0.929 / 1 - 0.0928 = 0.986$. With the sample size ($n$) = 407, and the number of insignificant path coefficients ($d$) = 5, the chi-square with $W = - (nd)$ $ln Q = - (407-5) \times ln (0.986) = 5.67$ From chi-square table with $db = d = 5$ at significance level $\alpha = 0.05$ at $X^2_{tab} = X^2 (0,05; 2) = 11.07$, because $W = 5.67 \leq 11.07$ or HO rejected.

4.3. Analysis
From the trip generation and trip distribution model, $O_i = -37,126 + 58,723 X_9 + 17,968X_2$, where $X_9$ = Road Performance (V/C), $X_2$ = Landuse dominant, regression coefficient 58,723 and 17,968 indicate the amount of trip increase. The generated model obtained as a basis for predicting the rise of the journey. For the journey pull obtained model $D_d = -20,351 + 30,903X_2$ where only one very significant variable that cause the traction of the land use that is dominant from a district in Banda Aceh City.

By applying the concept of TOD in the 10th year, the model obtained is $O_i = 32,180 + 0.002 X_7 - 7.017 X_3$ where the travel expense ($X_7$), and travel distance ($X_3$) indicate the amount of trip generation increase, in this equation the rise will decrease compared to the year basic. For the travel distance, the model $D_d = 48,474 -0.671X_{11} + 0.003X_7 - 9.299X_3$, meaning travel attraction in the absence of population density ($X_{11}$), travel expense ($X_7$) and travel distance ($X_3$), but if influenced by population density variables ($X_{11}$), travel costs ($X_7$) and travel distance ($X_3$) then the pull of the journey will decrease, it can be interpreted that this independent variable can influence the pull on the city of Banda Aceh.

The result of processing by path analysis method for existing condition, the influence variable, node ratio, network connectivity, travel frequency, travel intent, travel cost, and travel time, have lower value if direct influence with transportation infrastructure development, but if indirect effect through space structure has a greater influence, it can be seen from the scheme of space structure path - the development of transport infrastructure. This can be interpreted as the urban sprawl effect on traffic congestion gives significant results.

When using the concept of TOD in eliminating urban sprawl in donating feeding congestion obtained:
Figure 4. Spatial structure - transportation infrastructure development (TOD concept).

The variable of influence depends heavily on the structure of the space, this is in accordance with the concept of TOD so that the value of the development of transportation infrastructure is greater than if the six variables do not pass through the space structure.

5. Conclusions

- It can be concluded that the application of the concept of TOD in a region gives Trip Generation a decrease, and generates a trip distribution to the area or the sub-district itself, so that it does not affect other areas or districts in the city of Banda Aceh.
- Trip generation and trip distribution occurring in the city of Banda Aceh, is the second model of the planning model that is, the optimization model, which emphasizes the optimum achievement of a journey due to resource constraints or limitations, from the model obtained by the city of Banda Aceh is a region of type homogeneous region characterized by a relatively similarity in the region and not yet characterized by layout with the concept of TOD.
- The development of transportation infrastructure TOD concept is influenced by the structure of the space it can be seen if the existing conditions obtained influence variables, node ratio, network connectivity, travel frequency, travel intent, travel cost, and travel time, has a lower value when direct effect with the development of transportation infrastructure, but if the effect of indirect effect through space structure has a greater influence so as to reduce traffic congestion due to traffic growth and urban sprawl.

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