The spatial structures and transportation infrastructure development in Banda Aceh City with TOD

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Abstract. The spatial structure and construction of transport infrastructure in the city of Banda Aceh, in accordance with the strategy for developing the Banda Aceh City Spatial Plan (RTRW) 2009-2029 which combines the development of "multi-canter" and "linear-growth". This has an impact on the inefficient development of transportation infrastructure with an increase in the number of vehicles 6% per year. The concept of TOD can eliminate urban sprawl, which turns urban sprawl into a compact city area. The method used is path analysis with, travel distance (X1), the purpose of the trip (X2), travel cost (X3) so that the equation can be obtained: Spatial Structure = 0.520 + 0.206X1 + 0.264X2 + 0.100X1, the relationship with infrastructure development transportation consists from variables, diversity of public/social facilities (X1), travel frequency (X2), the purpose of the trip(X3), travel costs (X4) and travel time (X5), so that the equation is obtained, Transportation Infrastructure Development = -1.457 + 0.652X1 + 0.388X2 + 0.235X3 + 0.222X4 + 0.327X5, from the model obtained, it can be concluded that the development of transportation infrastructure with the concept of TOD is strongly influenced by the spatial structure.

1. Introduction
The spatial structure of the city of Banda Aceh after the Tsunami in 2004, experienced a very significant change caused by urban sprawl to the south and east of the city of Banda Aceh, this had an impact on inadequate facilities and infrastructure in the region, especially in the construction of transportation infrastructure. The result of this problem caused a shift in the role of urban service centers and was followed by an increase in the growth of activity centers in the southern and eastern regions of Banda Aceh, namely 33% and 44% of the total population of Banda Aceh, which was 249,282. This has resulted in the inefficient development of transportation infrastructure with an increase in the number of private vehicles 6% per year due to the integration of inter-city space so as to create a new city that caused congestion on arterial road segments in the city of Banda Aceh [1].

Increasing economic growth in the city of Banda Aceh is 6.12% in 2018, which has an increasing number of living standards and population mobility needs in the city of Banda Aceh. Transportation problems are due to unfavourable contractions in the development of transportation infrastructure and spatial structures, causing problems in various factors including the uneven road network in the city of Banda Aceh, trade facilities, public and social facilities that are still concentrated in Banda Aceh, and the shift of society to private transportation [2].

The concept of Transit Oriented Development (TOD), can synergize the spatial structure with the development of transportation infrastructure so that it can eliminate urban sprawl, which transforms into
a compact city by paying attention to several factors such as business zones, offices, public facilities, and social facilities, so that TOD can reduce dependency against private vehicles [2].

2. Literature review

2.1. Spatial structure of city
The phenomenon of urban space development is basically aimed at 2 basic rankings, namely the structure of "compact" and "sprawl" spaces, this is very much based on the shape of the space structure with these attributes that will affect the shape of the activity pattern or the orientation of movements that occur [3].

Regional development instruments contain a system and public resources that are arranged comprehensively, taking into account economic, social and environmental aspects, which can be arranged in the following hierarchy (Figure 1).

![Figure 1. Selection of regional planning.](image)

2.2. Spatial structure of Banda Aceh City
The development of the city of Banda Aceh can be categorized in the growing pattern of "Multi Nuclei Model" or which has several growing points. The growth pattern of these growth points turns out to have a tendency for linear and developing patterns to follow the road network so that it shows the pattern of space development with the Linear Growth Model [4].

From the existing spatial structure, it can be seen that the direction of urban development trends (Banda Aceh City) leads to the south (directly adjacent to Aceh Besar), trade and services, sports center is located between Aceh Besar Regency areas. Thus, the tendency of the Banda Aceh urban center to come is expected to lead to the South and even to the Greater Aceh District [5].

2.3. Transportation infrastructure development
Facilities that must be built in advance that will be used for activities to transport and move cargo (goods and people) from origin to destination, geographically between the layout and the capacity and location of transportation facilities combined together to obtain the volume and pattern of traffic flow that can be said reciprocity between layout and transportation [6].

2.4. Transit Oriented Development (TOD)
TOD is the allotment of mixed land in the form of housing or trade that is planned to maximize public transport access and often other activities are added to encourage users of public transport modes, the development of TOD is influenced by the physical social dimension to synergize 4 factors: mixed-use high density, non-motorized vehicle access and close to MRT / BRT stations [7].

The relationship between land use and transportation systems to accommodate these movements is designed to produce efficient spatial forms which will further form "spatial imprint" in the form of
spatial structures, and the determinants of successful TOD implementation include land use and transportation systems where both are elements forming space structures [8,9].

3. Methodology
The type of research used is quantitative using path analysis. Data used to model the development of transportation infrastructure and spatial structure with the TOD concept [10]. Spatial structure variable \((X_1)\) is a diversity of public/social facilities in sub-districts in Banda Aceh, and which is a variable in the development of transportation infrastructure \((X_2)\) is the type of land use and spatial structure becomes intervening variables, while other variables are travel distance, travel intent, and travel costs, and travel frequency.

3.1. Research hypothesis
The spatial of the city of Banda Aceh has an irregular and non-geometric pattern, giving rise to concentration in an area, with the TOD concept so that the construction of transportation infrastructure can follow the structure of space so that it affects the trip generation and attraction and can overcome congestion problems due to urban sprawl.

3.2. Data analysis model
The methodology developed will link the variables of Transportation Infrastructure Development and Space Structure with the TOD concept in the form of a model. The model used is a four-stage transportation planning model. Model calibration is carried out using data on transportation network conditions with the concept of TOD, socio-economic and population, and the structure pattern of existing space in Banda Aceh City. From the calibration results, several models are needed to predict future travel demand and transportation infrastructure performance.

4. Research result

4.1. Space structure regression analysis

| Model | R  | R Square | Adjusted R Square | Std. The error of the Estimate | Change Statistics |
|-------|----|----------|-------------------|--------------------------------|------------------|
|       |    |          |                   |                                |                  |
| 1     | .789a | .623     | .617              | .37950                        | .623 110,159 6 400 .000 |
| 2     | .789b | .623     | .618              | .37912                        | .000 190 1 400 .663 |
| 3     | .788c | .621     | .617              | .37978                        | -.002 2,400 1 401 .122 |
| 4     | .787d | .619     | .616              | .38027                        | -.002 2,043 1 402 .154 |

Source: Processed data 2019

The variability of spatial structure that can be explained by using the independent variable is 61.9% due to other variables outside of this model and so the error model 4, \(\varepsilon = 1 - R^4 = 1 - 0.619 = 0.381\).

The path coefficient after trimming can be seen in model 4 in the Table Coefficients.
Table 2. Space structure coefficients.

| Model       | Unstandardized Coefficients B | Std. Error | Standardized Coefficients Beta | t      | Sig. | 95.0% Confidence Interval for B Lower Bound | Upper Bound |
|-------------|-------------------------------|------------|-------------------------------|--------|------|-----------------------------------------------|-------------|
| (Constant)  |                               |            |                               |        |      |                                               |             |
| Travel Distance | ,514                           | ,071       |                               | 7,266  | .000 | ,375                                          | ,653        |
| Transp network connect | -,012                           | ,027       | -.022                         | -,436  | .663 | -,-065                                        | ,041        |
| 1 Travel Frequency | -,100                           | ,053       | -.090                         | -1,875 | .062 | -,-204                                        | ,005        |
| The purpose of the trip | ,276                           | ,030       | ,462                          | 9,200  | .000 | ,217                                          | ,335        |
| Travel cost | ,106                           | ,033       | ,176                          | 3,250  | .001 | ,042                                          | ,171        |
| Travel time | ,073                           | ,050       | ,063                          | 1,463  | ,144 | -,-025                                        | ,171        |
| (Constant) |                               |            |                               |        |      |                                               |             |
| Travel Distance | ,504                           | ,067       |                               | 7,544  | .000 | ,373                                          | ,636        |
| Travel Frequency | -.101                          | ,053       | -.091                         | -1,910 | .057 | -,-206                                        | ,003        |
| The purpose of the trip | ,271                           | ,028       | ,454                          | 9,832  | ,000 | ,217                                          | ,325        |
| Travel cost | ,101                           | ,030       | ,167                          | 3,336  | ,001 | ,041                                          | ,160        |
| Travel time | ,076                           | ,049       | ,066                          | 1,549  | ,122 | -,-021                                        | ,173        |
| 2 Travel Frequency | -,101                          | ,053       | -.091                         | -1,910 | ,057 | -,-206                                        | ,003        |
| The purpose of the trip | ,271                           | ,028       | ,454                          | 9,832  | ,000 | ,217                                          | ,325        |
| Travel cost | ,101                           | ,030       | ,167                          | 3,336  | ,001 | ,041                                          | ,160        |
| Travel time | ,076                           | ,049       | ,066                          | 1,549  | ,122 | -,-021                                        | ,173        |
| (Constant) |                               |            |                               |        |      |                                               |             |
| Travel Distance | ,521                           | ,066       |                               | 7,881  | ,000 | ,391                                          | ,651        |
| Travel Frequency | -.070                          | ,049       | -.063                         | -1,429 | ,154 | -,-167                                        | ,026        |
| The purpose of the trip | ,272                           | ,028       | ,456                          | 9,870  | ,000 | ,218                                          | ,326        |
| Travel cost | ,105                           | ,030       | ,173                          | 3,462  | ,001 | ,045                                          | ,164        |
| 3 Travel Frequency | -.070                          | ,049       | -.063                         | -1,429 | ,154 | -,-167                                        | ,026        |
| The purpose of the trip | ,272                           | ,028       | ,456                          | 9,870  | ,000 | ,218                                          | ,326        |
| Travel cost | ,105                           | ,030       | ,173                          | 3,462  | ,001 | ,045                                          | ,164        |
| (Constant) |                               |            |                               |        |      |                                               |             |
| Travel Distance | ,520                           | ,066       |                               | 7,855  | ,000 | ,390                                          | ,650        |
| Travel Frequency | -.070                          | ,049       | -.063                         | -1,429 | ,154 | -,-167                                        | ,026        |
| The purpose of the trip | ,272                           | ,028       | ,456                          | 9,870  | ,000 | ,218                                          | ,326        |
| Travel cost | ,105                           | ,030       | ,173                          | 3,462  | ,001 | ,045                                          | ,164        |
| 4 Travel Frequency | -.070                          | ,049       | -.063                         | -1,429 | ,154 | -,-167                                        | ,026        |
| The purpose of the trip | ,272                           | ,028       | ,456                          | 9,870  | ,000 | ,218                                          | ,326        |
| Travel cost | ,105                           | ,030       | ,173                          | 3,462  | ,001 | ,045                                          | ,164        |

Source: Processed data 2019

So that the equation of spatial structure is:

\[ \text{Space Structure} = 0.520 + 0.206X_1 + 0.264X_2 + 0.100X_3 \]

\( X_1 = \) Travel distance
\( X_2 = \) The purpose of the trip
\( X_3 = \) Travel cost

Table 3. Summary of transportation infrastructure development models.

| Model | R | R Square | Adjusted R Square | Std. The error of the Estimate | R Square Change | Change Statistics | F | df1 | df2 | Sig. F Change |
|-------|---|----------|------------------|-------------------------------|----------------|------------------|---|-----|-----|-------------|
| 1     | .790 | .624     | .618             | .81925                        | .624           | 94,639           | 7 | 399 | .000 | .000        |
| 2     | .790 | .624     | .618             | .81823                        | .000           | .001             | 1 | 399 | .971 | .001        |
| 3     | .789 | .623     | .618             | .81887                        | -.002          | 1,634            | 1 | 400 | .202 | .001        |

Source: Processed data 2019

4.2 Regression analysis of transportation infrastructure development

At this stage, it will analyze the regression by looking at the effects in a combination and partially, by adding variable spatial structure to the development of transportation infrastructure, which is a variable of transportation infrastructure is land used.
The variability of transportation infrastructure development that can be explained by using independent variables is 62.3%, while the influence of 37.7% is caused by other variables outside of this model.

It appears that the coefficient of determination for models 1 and 2 ($R^2$) is 0.624 and model 3 ($R^2$) is 0.623. so that the error model, $\varepsilon = 1 - R^2 = 1 - 0.623 = 0.377$.

The path coefficient after trimming can be seen in model 3 in the Table Coefficients.

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B |
|-------|-----------------------------|---------------------------|---|------|--------------------------------|
|       | B   | Std. Error | Beta |      | Lower Bound | Upper Bound |
| (Constant) | -1.527 | .163 | -9.394 | .000 | -1.847 | -1.207 |
| Public/social facilities | .650 | .108 | .301 | 6.021 | .000 | .438 | .862 |
| Travel distance | .004 | .099 | .002 | .037 | .971 | -1.911 | 1.985 |
| Transp network connect | .074 | .058 | .065 | 1.263 | .207 | -0.041 | .188 |
| Travel Frequency | .373 | .115 | .155 | 3.229 | .001 | .146 | .600 |
| The purpose of the trip | .200 | .071 | .156 | 2.813 | .005 | .060 | .341 |
| Travel cost | .183 | .072 | .140 | 2.563 | .011 | .043 | .324 |
| Travel time | .345 | .108 | .137 | 3.195 | .002 | .133 | .558 |
| (Constant) | -1.526 | .161 | -9.492 | .000 | -1.842 | -1.210 |
| Public/social facilities | .651 | .105 | .301 | 6.218 | .000 | .445 | .857 |
| Transp network connect | .074 | .058 | .065 | 1.278 | .202 | -0.040 | .188 |
| Travel Frequency | .374 | .111 | .156 | 3.365 | .001 | .155 | .592 |
| The purpose of the trip | .201 | .071 | .156 | 2.831 | .005 | .061 | .340 |
| Travel cost | .184 | .068 | .141 | 2.721 | .007 | .051 | .317 |
| Travel time | .346 | .107 | .137 | 3.242 | .001 | .136 | .556 |
| (Constant) | -1.457 | .152 | -9.615 | .000 | -1.755 | -1.159 |
| Public/social facilities | .652 | .105 | .302 | 6.222 | .000 | .446 | .858 |
| Travel Frequency | .388 | .111 | .162 | 3.509 | .001 | .171 | .606 |
| The purpose of the trip | .235 | .066 | .183 | 3.588 | .000 | .106 | .364 |
| Travel cost | .222 | .061 | .170 | 3.657 | .000 | .103 | .342 |
| Travel time | .327 | .106 | .130 | 3.096 | .002 | .120 | .535 |

| Model | Coefficients$^a$ | 95.0% Confidence Interval for B |
|-------|-------------------|--------------------------------|
|       | B   | Std. Error | Beta | Lower Bound | Upper Bound |
| (Constant) | -1.457 | .152 | -9.615 | .000 | -1.755 | -1.159 |
| Public/social facilities | .652 | .105 | .302 | 6.222 | .000 | .446 | .858 |
| Travel Frequency | .388 | .111 | .162 | 3.509 | .001 | .171 | .606 |
| The purpose of the trip | .235 | .066 | .183 | 3.588 | .000 | .106 | .364 |
| Travel cost | .222 | .061 | .170 | 3.657 | .000 | .103 | .342 |
| Travel time | .327 | .106 | .130 | 3.096 | .002 | .120 | .535 |

a. Dependent Variable: Land use type

Source: Processed data 2019

Transportation Infrastructure Development = -1.457 + 0.652X₁ + 0.388X₂ + 0.235X₃ + 0.222X₄ + 0.327X₅
X₁ = Public / social facilities
X₂ = Travel frequency
X₃ = The purpose of the trip
X₄ = Travel cost
X₅ = Travel time

4.3. Spatial structures and infrastructure development with the TOD concept

The results of the processing of path analysis methods obtained influence variables that have lower value if the direct effect is with the development of transportation infrastructure, but if the indirect effect through space structure has a greater influence, it can be seen from the spatial structure scheme - the construction of transportation infrastructure interpreted the concept of TOD has an influence on transportation infrastructure development through land use type.
5. Conclusions

The construction of a TOD transportation infrastructure is strongly influenced by the structure of space, this can be seen from the variables of influence, travel distance, transportation network connectivity, travel frequency, the purpose of the trip, travel costs, and travel time, which have a lower value direct influence with the construction of transportation infrastructure, but if the indirect influence through the structure of space has a greater influence.

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