Measuring regional cohesion effects of new toll roads investments: an accessibility approach

Ridwan Anas\textsuperscript{1*}, Ika Puji Hastuty\textsuperscript{1}, Irwan S. Sembiring\textsuperscript{1}, and Yosi Sukmono\textsuperscript{2}

\textsuperscript{1}Department of Civil Engineering, Universitas Sumatera Utara, Medan 20155
\textsuperscript{2} Development and Planning Board of North Sumatra Province

\textsuperscript{*}Email: ridwan.anas@usu.ac.id

Abstract Accessibility is a concept that combines a geographic or location and transport system, considered as an interaction between locations, which represents an implementation of transport development. Therefore, an accessibility index may be used as a proxy to assess regional cohesiveness. This paper evaluates the accessibility impact of new toll roads investment by location indicator measurement. Comparing the results between the regions that connected to the toll road, differences in accessibility value for each region indicate the regional cohesion effects derived from the new toll road investment.

1. Introduction

Accessibility indicators measure the relative location importance, affecting the attractiveness and economic development potentials of regions [1], from a regional economic perspective, accessibility represents a competitive advantage of a location. The advantage of the region reflected such that a smaller number is preferred like distance, cost, or travel time.

Accessibility is considered an added value of locations, which represents one of the elements contributing to a region’s welfare. Therefore, the spatial distribution of accessibility may be used as a proxy to assess regional cohesion [2], then in other words accessibility is a concept that considers regional connectivity with transportation networks.

Accessibility impact of the new infrastructure is measured by means of three indicators: weighted average travel time, economic potential and daily accessibility [3]. Therefore, the purpose of new toll road investment is to increase accessibility also serves as a logistic (taking raw material; manufacture to consumer) and improve the regional economic [4]. In addition to the direct impact for direct users, saving Vehicle Operating Costs (VOC) and saving value of time (VOT) compared to without non-toll roads, the benefits of toll road construction also affect the regional economy and regional accessibility [5]. Each accessibility indicator highlights the different effects of transport infrastructure investments. Accessibility indicators are able to highlight various effects of the transportation system, depend on different points of view. This study aims to determine the effect of new toll road investment (Binjai-Medan-Tebing Tinggi) on the accessibility index of the connected region.

2. Accessibility and regional integration

There are many concepts of accessibility in recent decades, with many accessibility studies discuss how to measure accessibility. The concept of accessibility has been widely developed by researchers and the values obtained are cast into measurable indicators. This paper concerned with the performance of
transport systems and regional measures feedback effects between transport infrastructure and the spatial distribution of activities.

Toll road infrastructure investment is one of Indonesia’s main policy to achieve regional integration or regional connectivity. Besides saving vehicle operating costs and value of time, accessibility could be as an optional considered to evaluate new toll road investment, such as more accessible a region to reduce travel distances and travel time.

Baradaran and Ramjerdi [6] classify accessibility measures into five categories: travel-cost approach, gravity or opportunities approach, constraints-based approach, utility-based surplus approach, composite approach. Elena Lopez and Javier Gutierrez [7] classify accessibility by measure the regional cohesion effects of transport infrastructure investment.

3. Location and accessibility indicator measures
Accessibility measures travel impedance or resistance between origin and destination, or between nodes [8]. The separation between locations does not need to be measured by geographical distance alone; instead or additionally, other categories of travel cost or impedance can be employed. New transport infrastructure investment will increase the accessibility to resources goods and markets and the mobility of freight transportation thus improves the competitiveness of a region and result in regional agglomeration. Reductions in travel time and travel cost can also give rise to productivity growth and reinforcing agglomeration benefits [8]. The accessibility indicator calculates a weighted, by destination population, average travel time between each node and a choice of region’s centroids, according to the following formulation [9]:

\[ L_i = \frac{\sum_{j=1}^{n} I_{ij} P_j}{\sum_{j=1}^{n} P_j} \]  

(1)

Where \( L_i \) is the accessibility (location) of node \( i \), \( T_{ij} \) is the travel time by the minimal-time route, \( I_{ij} \) is the impedance: travel time by the minimal route through the network between node \( i \) and the centroid of region \( j \) (in min), and \( P_j \) is the region’s \( j \) population.

4. Result
The analysis below compares the measure of performance for the toll road project with the “no project” condition. Regional impacts using toll road, provide for more efficient movement throughout the region as compared to the “no project” condition. Individual projects such as Medan-Binjai and Medan-Tebing Tinggi Toll roads, using reduced tolls, show less congestion and higher average travel speeds regionally as compared to conditions with "no project".

Medan - Binjai Toll Road with a length of 16 km, connect to the existing Belmera Toll Road through the Tanjung Mulia toll gate and reach the outer ring road of Binjai as the endpoint. Medan-Tebing Tinggi Toll Road is planned to connect Medan – Tebing Tinggi and Kuala Namu Internasional Airport (KNIA). From Figure 1 above, the construction of the new toll road is located and provides new connectivity to the following region: Binjai, Medan and Tebing Tinggi. The accessibility is interpreted from the locational, travel time by the minimal route and the mass of each destination is used as a weight in order to value the importance of the minimal travel time routes.

The travel time between regions is measured from the centroid of each region. The travel time Medan-Binjai before the operation of the toll road is 75 minutes and after the operation of the toll road, it decreases to 51 minutes. The travel time from the Medan -Deli Serdang before the operation of the toll road is around 60 minutes and after the operation of the toll road, it becomes 50 minutes. While the travel time from Medan-Tebing Tinggi before the operation of the toll road is 90 minutes and decreases after the operation of the toll road to 60 minutes. The results of the location indicator and accessibility measures are briefly presented in Table 1.
Table 1. Regional accessibility results.

| Region       | Population | Accessibility Before Toll Operated | Accessibility After Toll Operated |
|--------------|------------|-------------------------------------|----------------------------------|
| Binjai       | 910,007    | 107.7                               | 101.5                            |
| Deli Serdang| 579,015    | 114.81                              | 101.72                           |
| Tebing Tinggi| 2,470,802  | 120.82                              | 103.81                           |
| Medan        | 3,470,393  | 152.3                               | 113.93                           |

Results show that change rates on the accessibility indicator, mean weighted average travel times are reduced from 75 min before toll road operated to 51 min after operated toll road (i.e. a 29% reduction). The comparison shows the differences in accessibility value for each region (before and after toll road operated).

5. Conclusions
This paper concludes that regional cohesion effects derived from the development of Trans Sumatera new toll road especially Binjai-Medan and Medan-Tebing Tinggi section. Toll road infrastructure investments reduce the travel time between the regions, where this will affect the accessibility value of the region connected to the toll road.

For the accessibility values, there was a reduction in accessibility values differences between the regions that connected to the toll road. Tebing Tinggi region has the greatest impact. Accessibility values also can be used by decision-makers to set priorities for several alternative transportation project proposals.
In summary, the lesson learned is that can be drawn depending on the formulation of measures of accessibility, we suggest measuring by using a set of accessibility indicators and analyzing the results as a complementary way.

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