Effect Of Increased Commercial & Industrial Area For Travel Time Between Cities Surabaya-Sidoarjo

Budi Sugianto Waloejo, Karina Indra Sari

Abstract: Since the Government of Surabaya City imposed a policy of limiting the development of industrial estates in the city of Surabaya by shifting their development outside of Surabaya, the land use in areas around the city of Surabaya, namely the Gerbangkertosusila region, including Sidoarjo Regency, has become impacted. This eventually results in traffic on the arterial road that crosses around the land use becomes affected due to the activities carried out in the land use area. The purpose of this study is to discover the land use interaction model, road network performance, and factors affecting the travel time on the Waru Surabaya-Sidoarjo road. Descriptive approach was employed to explicate the road characteristics, while several quantitative analyses such as correlation and multiple linear regression analyses were employed to evaluate and formulate the model and its impact on the level of service and travel time calculation. The research showed that along the Surabaya-Sidoarjo road segment, the land use was currently dominated by industrial and commercial activities with the respective percentages of 66.2% and 14.8%, with \( F_{\text{PCU/day}} = 69,029 \) PCU/day (internal) + 57,326 PCU/day (external) = 126,354 PCU/day. The trip was higher than the road capacity rate, which was 6,820 PCU/hour. The level of service was poor at certain hours (08:00 to 19:00), which was indicated with F. The impact of the trip attraction of movement volume from the industrial zone outside the industrial estates was 9,452 PCU/day or 13.69% of the total land use, while the impact of the commercial area was 48,388 PCU/day or 53.42% of the total lands use. Thus, the travel time from Sidoarjo-Surabaya with the road length of 23.2 km was an hour and 17 minutes.

Keywords: Keywords: Commercial Area, Industrial Area, Land Use, Travel Time.

1. INTRODUCTION

Transportation is crucial for the development and growth of a country, especially in facilitating commerce, trade, and social interaction, yet it requires time and resources. The movement of people and goods is the basis of transportation carried out to achieve basic goals or duties that require moving from one location to another [1]. In the 1990’s, The Surabaya City Government encouraged the development of industrial estates out of the Surabaya urban area due to the immoderate density. The policy affected the development of industrial zones outside the industrial estates spread in the Gerbangkertosusila region [3]. The Waru Surabaya-Sidoarjo road is an arterial road which is a transition of the industrial zones from Surabaya that causes the increase in movement on the road section [10]. The level of service is significantly impacted by the change or growth of land use on certain roads [2]. Industrial estates cause several impacts related to transportation. One of the impacts is the loading and unloading of raw materials by the industrial fleets in and out of the industrial area which can cause congestion on the local roads [9]. The rapid growth of land use on primary arterial road corridor affects the increase in the continuous and local flows movement from the land use growth on the road section [4]. The accumulation of continuous flow movement between Surabaya-Sidoarjo and the increase in the flow of movement from trip generation and trip attraction of land use on the primary arterial road corridor cause the total flow of movement exceeds the road capacity [15]. In accordance with its function, that a primary arterial road is a connector of traffic flow between first-order cities or first- to second-order cities, Surabaya and Sidoarjo is connected with an internal flow movement from the movement of land use traffic along the road corridor [15]. The incorporation of land use modelling and transportation is used to depict the land use interaction and urban road network system over time in a combined interaction modelling. The advantage of this approach is that the need for exogenous data input, such as land use modeling, can be calculated directly on local land use (internal volume) added by continuous flow (external volume) [5]. Speed, travel time, and delay are commonly used as traffic performance indicators [11]. The relationship between the flow of movement and travel time can be shown by an increase in the flow of movement, in which the travel time will also increase [13]. The travel time of a road section is one of the references that can be used to plan a trip. Information about estimated travel time is useful for road users to choose travel routes that can make them easier to get to their destination [7]. Travel time is the time required to travel on an observed road [12]. This study attempts to identify the characteristics of land use growth along the Waru Surabaya-Sidoarjo road section by obtaining the land use interaction model, measuring the level of service on the corridor, and discovering the impact of traffic flow due to the industrial land use on the level of service toward travel time.

2 METHODS

The location of this study is the Surabaya-Sidoarjo road corridor through several main roads along the corridor with the land use characteristics. This study was a descriptive study which attempted to explain the existing condition of land use that is correlated to Core Urbanism. Descriptive approach is used to explain the outputs related to the general explication of traffic condition, land use, road network characteristics, and land use growth on the Waru Surabaya-Sidoarjo corridor (Figure 1). The steps of this study were systematic, corresponding to the facts, and accurate based on the existing conditions and phenomena at the location. The steps of this study began with literature study, previous studies, data

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collection, data processing, data analysis, and conclusion. Several quantitative methods were employed in this study, including degree of saturation analysis, trip generation and trip attraction analysis (multiple linear regression analysis), and land use interaction modelling. The level of service can be observed from the interaction model [14]. The data collection method employed primary survey which included field observation, interview/questionnaire, traffic enumeration, vehicle plate recording, and road measurement. Then, the secondary survey included literature survey, field survey, and similar research.

Road Capacity

\[ C = CO \times FCW \times FCSP \times FCSF \times FCCS \]  
(1)

in which:
- \( C \) = Road Capacity (PCU/hour)
- \( CO \) = Base Capacity (PCU/hour)
- \( FCW \) = Road Width Factor
- \( FCSP \) = Factor of Separator for Capacity (does not apply to one-way streets)
- \( FCSF \) = Factor of Side Friction for Capacity
- \( FCCS \) = Factor of City Size for Capacity

\[ VCR = V / C \]  
(2)

Interaction Model of Road Network-Land Use

\[ VCR = ( \sum V_{\text{Internal}} + \sum V_{\text{External}} ) / C \]  
(3)

in which:
- \( VCR \) = Level of Service
- \( V \) = Traffic Volume (PCU/hour)
- \( V_{\text{Internal}} \) = Total Volume of Vehicles from Trip Generation/Attraction of Land Use
- \( V_{\text{External}} \) = Total Volume of Continuous Vehicle Flow on the Main Road Section

\[ V_{\text{Internal}} = V_{\text{Ex-1}} + V_{\text{Ex-2}} + \ldots + V_{\text{Ex-n}} + V_{\text{Ex-5}} + V_{\text{Ex-6}} \]  
(4)

in which:
- \( V_{\text{Internal}} \) = Total volume of vehicle movement/hour on the main road corridor
- \( V_{\text{External}} \) = Total volume of vehicle movement/hour on the main road corridor

\[ V_{\text{Ex-1}} = V_{\text{Ex-1}} + V_{\text{Ex-2}} + \ldots + V_{\text{Ex-n}} + V_{\text{Ex-5}} + V_{\text{Ex-6}} \]  
(5)

Total volume of vehicle movement/hour on the main road:

\[ Vi = e_1 Y_1 + e_2 Y_2 + e_3 Y_3 + \ldots + e_n Y_n \]  
(6)

while:

- \( V_{\text{Ex-1}} \) = Volume of vehicle movement/hour from alleys
- \( V_{\text{Ex-2}} \) = Volume of vehicle movement/hour from alleys
- \( V_{\text{Ex-5}} \) = Volume of continuous vehicle movement/hour on the main road
The population of this study was the arterial road in East Java (Surabaya-Sidoarjo). An arterial road connects a first-order city to another first-order city or to second- or third-order cities. The sampling technique used was simple random sampling technique. The sample determination was assumed that all the population members had the opportunity to be chosen. The variable approached employed in this study was road network and land-based modelling approach.

### Table 1.
The Independent and Dependent Variables for Land Use

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Dependent Variables</th>
<th>Independent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Y&lt;sub&gt;Residential&lt;/sub&gt;</td>
<td>X&lt;sub&gt;1&lt;/sub&gt; (Number of Family Members)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;2&lt;/sub&gt; (Total Vehicle Ownership)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;3&lt;/sub&gt; (Building Area)</td>
</tr>
<tr>
<td>Elementary, Junior High, Senior High Schools</td>
<td>Y&lt;sub&gt;Educational&lt;/sub&gt;</td>
<td>X&lt;sub&gt;4&lt;/sub&gt; (Number of Students)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;5&lt;/sub&gt; (Number of Teachers)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;6&lt;/sub&gt; (Building Area)</td>
</tr>
<tr>
<td>Office</td>
<td>Y&lt;sub&gt;Office&lt;/sub&gt;</td>
<td>X&lt;sub&gt;7&lt;/sub&gt; (Number of Workers)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;8&lt;/sub&gt; (Number of Visitors)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;9&lt;/sub&gt; (Building Area)</td>
</tr>
<tr>
<td>Hospital</td>
<td>Y&lt;sub&gt;Hospital&lt;/sub&gt;</td>
<td>X&lt;sub&gt;10&lt;/sub&gt; (Number of Daily Patients)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;11&lt;/sub&gt; (Total Area of Inpatient Rooms)</td>
</tr>
<tr>
<td>Commercial</td>
<td>Y&lt;sub&gt;Commercial&lt;/sub&gt;</td>
<td>X&lt;sub&gt;12&lt;/sub&gt; (Number of Visitors)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;13&lt;/sub&gt; (Building Area)</td>
</tr>
<tr>
<td>Gas Station</td>
<td>Y&lt;sub&gt;Gas Station&lt;/sub&gt;</td>
<td>X&lt;sub&gt;14&lt;/sub&gt; (Land Area Built)</td>
</tr>
<tr>
<td>Industrial</td>
<td>Y&lt;sub&gt;Industrial&lt;/sub&gt;</td>
<td>X&lt;sub&gt;15&lt;/sub&gt; (Number of Workers)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X&lt;sub&gt;16&lt;/sub&gt; (Frequency of Delivery Cars)</td>
</tr>
</tbody>
</table>

### Table 2.
The Characteristics of Waru Surabaya-Sidoarjo Road Network

<table>
<thead>
<tr>
<th>Road Characteristics</th>
<th>Waru Surabaya-Sidoarjo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>4/2 D</td>
</tr>
<tr>
<td>Traffic Flow Direction</td>
<td>North-South and South-North</td>
</tr>
<tr>
<td>Lane</td>
<td>4</td>
</tr>
</tbody>
</table>

3.2 The Land Use Characteristics
The land use in the Surabaya-Sidoarjo corridor, with the land use area of 5,967,019 m², was dominated by industrial activity with an area of 3,952,112 m² or 66.2% of the total area, while the smallest land use is the terminal area of 12,000 m². The dominant land use was industrial area with 66.2% and commercial area with 14.8%. This would attract workers in the industrial, commercial, and service sectors, which would affect the vehicle volume passing the Surabaya-Sidoarjo road.

3.3 The Land Use Modelling
The results of land use modelling on the dependent and independent variables employing multiple linear regression analysis along the Surabaya-Sidoarjo corridor are as follows.

### Table 3.
The Land Use Modelling

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Trip Generation Model</th>
<th>Coefficient of Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Y&lt;sub&gt;Residential&lt;/sub&gt; = 0.389 + 0.232 (X&lt;sub&gt;1&lt;/sub&gt;) + 0.027 (X&lt;sub&gt;2&lt;/sub&gt;) + 0.034 (X&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>1</td>
</tr>
<tr>
<td>Educational</td>
<td>Y&lt;sub&gt;Educational&lt;/sub&gt; = -0.254 + 0.141 (X&lt;sub&gt;4&lt;/sub&gt;) + 0.112 (X&lt;sub&gt;5&lt;/sub&gt;) + 0.024 (X&lt;sub&gt;6&lt;/sub&gt;)</td>
<td>1</td>
</tr>
<tr>
<td>Office</td>
<td>Y&lt;sub&gt;Office&lt;/sub&gt; = 0.108 + 0.662 (X&lt;sub&gt;7&lt;/sub&gt;) + 0.659 (X&lt;sub&gt;8&lt;/sub&gt;) + 0.00007194 (X&lt;sub&gt;9&lt;/sub&gt;)</td>
<td>1</td>
</tr>
<tr>
<td>Hospital</td>
<td>Y&lt;sub&gt;Hospital&lt;/sub&gt; = 13.715 + 0.291 (X&lt;sub&gt;10&lt;/sub&gt;) + 0.497 + 0.363 (X&lt;sub&gt;11&lt;/sub&gt;)</td>
<td>0.999</td>
</tr>
<tr>
<td>Commercial</td>
<td>Y&lt;sub&gt;Commercial&lt;/sub&gt; = -0.431 + 0.18 (X&lt;sub&gt;12&lt;/sub&gt;) + 0.075 (X&lt;sub&gt;13&lt;/sub&gt;)</td>
<td>1</td>
</tr>
<tr>
<td>Gas Station</td>
<td>Y&lt;sub&gt;Gas Station&lt;/sub&gt; = 0.447 + 142.318 (X&lt;sub&gt;14&lt;/sub&gt;)</td>
<td>1</td>
</tr>
<tr>
<td>Industrial</td>
<td>Y&lt;sub&gt;Industrial&lt;/sub&gt; = -0.497 + 0.363 (X&lt;sub&gt;15&lt;/sub&gt;) + 1.184 (X&lt;sub&gt;16&lt;/sub&gt;)</td>
<td>1</td>
</tr>
</tbody>
</table>

### 3.4 The Level Of Service
The total volume of vehicles passing in the Surabaya-Sidoarjo corridor was divided into local and continuous flows. The local flow came from the inflows and outflows along the corridor, while the continuous flow was the vehicle flow that only passed through the corridor (Figure 3).
It can be seen that the increase in total vehicle volume would affect the level of service along the corridor. Based on the analysis result, it can be observed that in the period of 08:00 to 19:00, the level of service was F. It is seen from the vehicle movements on average every hour reached 8,000-12,000 PCU/hour. If this condition is not controlled in the transport planning and land use policy, it will indeed aggravate the level of service, which will lead to potential bottlenecks.

3.5 The Travel Time Between Cities
1. The distance between Waru Surabaya-Sidoarjo was 23.3 km, in which the data was travelled in normal speed of 65 km/hour for 36 minutes.
2. The change in land use function of the Surabaya-Sidoarjo corridor, which was dominated by industrial and commercial areas, caused the travel time in rush hour between 08:00-17:00 to be an hour and 15 minutes.
3. An increase in an industrial and commercial land use unit will affect the movement to 550 PCU/day, in which the increase in the movement reaches 1,000 PCU/hour in rush hour. The vehicle speed decreased by 15 km/hour and the travel time between Surabaya-Sidoarjo increased by about seven minutes.

4 CONCLUSION
Based on the comparison results of the movement volume of trip generation/attraction of land use in the Surabaya-Sidoarjo main road (69,047 PCU/day), the movement volume of the continuous flow of the main road section was 57,326 PCU/day. This indicates that the dominating movement volume was the trip generation/attraction of land use of 69,047 PCU/day, which means that the more land used on the main road, the higher the congestion level on the main road. In the Surabaya-Sidoarjo road segment, the movement volume of trip generation/attraction is bigger than the movement volume of continuous flow on the main road section. The land use that contribute the most are the industrial and commercial areas. Based on the calculation results of the level of service on the Surabaya-Sidoarjo road corridor, the interaction model of land use and road network shows that the level of service between 06:00 and 20:00 was F. The current condition of the boundary between Surabaya and Sidoarjo is almost biased or connected to one another due to rapid land use growth. The travel time between Sidoarjo-Surabaya with the road length of 23.2 km is an hour and 17 minutes. The change of a unit of commercial land use increases the movement to 1,000 PCU/hour, the vehicle speed decreases by 15 km/hour, and the travel time increases by about seven minutes.

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REFERENCES


