The Study Degree of Saturation on Toll Road Access Based on Changes in Urban Settlement Land

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Abstract: Changes in land use that are not in harmony with the growth in the number of vehicles cause congestion and decrease in the speed of travel. Toll road access is one of the important ways to decrease traffic jams in cities that require smooth traffic flow. The purpose of this study is to analyze the level of service degree of toll road access to land use changes from residential environments to commercial areas. The analytical method was used to use multiple regression analysis to estimate traffic generation from changes in commercial land use. The degree of saturation of road toll access before land use change shows DS values of 0.56 to 0.65 which were analyzed at peak morning hours. This was an indication of the smooth flow of traffic. After there was a change in land use shown from the trip generation from the commercial area with the equation $Y = 2.554 + 1.143 X_3 + 1.041 X_4 + 1.011 X_5 + 1.256 X_6 + 1.2045 X_7$ with the significance of the model $R^2 = 0.91$. So that due to changes in land use, the toll access point was higher with changes in the degree of saturation 0.6 to 1.2.

Keywords: degree of saturation, toll road access, changes in land use, urban settlement

1. Introduction
The high urban population growth has led to greater housing needs. Urban residential areas with large populations need infrastructure and facilities that are in accordance with the needs of the population in urban areas. The use of residential land with a large population change causes changes in the use of residential land to become commercial areas. Changes in commercial areas in general have a high level of movement in terms of mobility of residential residents. The system of urban road networks with residential areas that are densely packed with changes in commercial areas causes a decrease in the speed of urban road traffic. Urban toll roads are one of the urban traffic infrastructure to increase greater accessibility in urban areas. The toll road access that is integrated with residential areas is a city governance system that encourages the accessibility of urban land. Changes in urban settlement areas into commercial areas make toll road access hampered because of changes in land use which causes high volumes of traffic on toll road access. The blocked toll road access causes the distribution system of urban residential traffic in general based on zones to cause higher congestion. Analyzing congestion of toll access roads is a goal to find out changes in land use from urban residential areas to commercial areas. Estimated generation of movements from changes in land use to urban settlements to commercial causes decreases the smooth flow of traffic towards the toll road [2][3][4].

This study aims to determine the effect of toll road access performance on land use changes, with special purpose: (a) identification of changes in residential land use variables in the toll access road corridor, (b) analyzing trip generation in the toll road access corridor zone, (c) analysis of toll road access service performance based on trip generation from residential zones.
2. Trip generation and urban land use changes

2.1. Type of land use.
The land use type has the characteristics of different movement generations, namely:
a. Different types of land use result in different movements
b. Different types of land use result in different types of movement
c. Different types of land use produce movement at different times.

2.2. Trip generation for urban land use travel determined by:
a. Population income in a region and GDP of the area,
b. Number of vehicle ownership as one of transportation services,
c. Structure and size of households within a population of communities in residential areas that determine density,
d. The value of land within the area determining the residential or commercial location,
e. The accessibility of movement will encourage the rate of rise of movement [1-5][13].

3. Road degree of saturation
The level of road service is the relationship between traffic volume and road capacity. Based on the Road Capacity Manual (MKJI), the level of road service is indicated by the degree of saturation (DS) as the main factor in determining the level of performance of intersections and road segments. DS is defined as the ratio of current to capacity [13].

\[ DS = \frac{Q}{C} \]  

with:
\( DS \) = degree of saturation, the main factor in determining road performance,
\( Q \) = vehicles volume (smp/hour),
\( C \) = capacity (smp/hour).

3.1. Capacity
Capacity is defined as the maximum current through a point on the road that can be maintained in units of hours under certain conditions. The capacity value has also been estimated from the analysis of traffic accompaniment conditions, and theoretically by assuming mathematical relationships between density, speed, and current. Capacity is expressed in passenger car units (pcu) as you can see below[13]:

\[ C = C_0 \times F_{CW} \times F_{CSP} \times F_{CSF} \times F_{CCS} \]  

with:
\( C_0 \) = basic capacity (smp/hour),
\( F_{CW} \) = road width adjustment factor,
\( F_{CSP} \) = factor of direction separation adjustment (only for undivided roads),
\( F_{CSF} \) = factor for adjusting side barriers,
\( F_{CCS} \) = city size adjustment factor.

The ideal DS value is <0.75, nothing that the DS does not exceed 0.75 at peak hours. If the DS value exceeds 1, there will be a serious problem since at peak hours the existing traffic flow will exceed the value of the road capacity that accommodates traffic flow [5][7][8][9].

3.2. Correlation analysis test

\[ r = \frac{\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N} (x_i - \bar{x})^2 (y_i - \bar{y})^2}} \]  

The correlation coefficient, \( r \), measures the strength and direction of the linear relationship between two variables. A value of \( r \) close to 1 indicates a strong positive correlation, while a value close to -1 indicates a strong negative correlation. A value close to 0 indicates no linear relationship.
3.3 Multiple regression analysis

\[ Y = b_0 + b_1X_1 + b_2X_2 + \cdots + b_kX_k \]  

(4)

To receive \( b_0 \) and \( b_1-b_k \), can be gotten by finishing this formulations:

\[
\begin{align*}
Nb0 & + b1 \sum_{i=1}^{N} X_{1i} + b2 \sum_{i=1}^{N} X_{2i} + b3 \sum_{i=1}^{N} X_{3i} = \sum_{i=1}^{N} Y_i \\
& \\
& = b0 \sum_{i=1}^{N} X_{1i} + b1 \sum_{i=1}^{N} (X_{1i})^2 + b2 \sum_{i=1}^{N} (X_{1i}.X_{2i}) + b3 \sum_{i=1}^{N} (X_{1i}.X_{3i}) = \sum_{i=1}^{N} (X_{1i}.Y_i) \\
& \\
& = b0 \sum_{i=1}^{N} X_{2i} + b1 \sum_{i=1}^{N} (X_{1i}.X_{2i}) + b2 \sum_{i=1}^{N} (X_{2i})^2 + b3 \sum_{i=1}^{N} (X_{2i}.X_{3i}) = \sum_{i=1}^{N} (X_{2i}.Y_i) \\
& \\
& = b0 \sum_{i=1}^{N} X_{3i} + b1 \sum_{i=1}^{N} (X_{1i}.X_{3i}) + b2 \sum_{i=1}^{N} (X_{2i}.X_{3i}) + b3 \sum_{i=1}^{N} (X_{3i})^2 = \sum_{i=1}^{N} (X_{3i}.Y_i) \\
\end{align*}
\]  

(5)

3.4 Determination test

\[ R^2 = \frac{\sum_{i=1}^{N} x_i y_i + b2 \sum_{i=1}^{N} x_{2i} y_i + b3 \sum_{i=1}^{N} x_{3i} y_i + b2 \sum_{i=1}^{N} x_{4i} y_i}{\sum_{i=1}^{N} y_i^2} \]  

(6)

with:

- \( N \) = number of sample,
- \( K \) = number of free variable used,
- \( k \) = free variable,
- \( \beta \) = regression coefficient = considered 0,
- \( b \) = regression constant,
- \( Sb \) = standard deviation error (standard error).

4. Methodology

4.1 Variabel and data analysis

Approach to the level of service of toll road access based on changes in urban settlement land use with the formulation of a generation model of movement from residential areas. Resettlement generation model is based on independent variables with characteristics of urban settlement conditions and variable dependent traffic volumes generated from trip generation with the following variables [1][6][7][10].

Y1 = Generating movements due to changes in urban land use

While for free variables as follows:

X1 = age (year)
X2 = education
X3 = job
X4 = family income per month
X5 = number of family members
X6 = number of working family members
X7 = number of trips made by family members per day
X8 = number of motorcycle ownership
X9 = number of car ownership

In this study the stages of analysis using descriptive quantitative research methods, the determinant variables of the trip generation model are analyzed by the multiple regression analysis method in stages. The significance of the trip generation model is determined by the correlation test and determination analysis [2-13].

4.2. Research location

The research location is the toll access road on the road corridor in the residential zone shown in the Figure 1.
4.3. Flowchart of research
The research steps are explained in the research flow chart (Figure 2).

![Flowchart of research](image)

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**Figure 1.** Location of the study.

**Figure 2.** Research flow chart.
5. Results and discussion

5.1. Analysis of trips generation models due to changes in urban residential land use.

Data from questionnaires are not all made free variables, which will be used which has the highest correlation with generation, but does not have a high correlation with each of the independent variables that will be used. To calculate the correlation coefficient using equations (3 analysis results are shown in Table 1).

| No | Variables               | Y1  | X3  | X4  | X5  | X6  | X7  | X8  | X9  |
|----|-------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | Seizure                 | 1   |     |     |     |     |     |     |     |
| 2  | Job                     |     |     |     |     |     |     |     |     |
| 3  | Salary                  |     |     |     |     |     |     |     |     |
| 4  | Members of family       |     |     |     |     |     |     |     |     |
| 5  | Number of working person|     |     |     |     |     |     |     |     |
| 6  | Movements/hr            |     |     |     |     |     |     |     |     |
| 7  | Number of Motorcycle    |     |     |     |     |     |     |     |     |
| 8  | Number of Car           |     |     |     |     |     |     |     |     |

Movement generation modeling using multiple linear regression analysis. The values of $b_0$ and $b_1$-$b_z$ can be obtained by completing several linear Equation 4, obtained by the model parameters:

$$b_0 = 6.068$$
$$b_1 = 1.239$$
$$b_2 = 1.435$$

The movement generation model due to changes in urban settlement land use is shown in Equation 7.

$$Y = 6.068 + 1.239X_4 + 1.435X_5 + 0.855X_7 + 1.166X_8$$  \(7\)

By testing the significance of the model from the press (50 is $R^2 = 0.91$)

The results of modeling analysis show that the dominant variable are: Number of working person, Number of car owner, Member of family and Number of Motorcycles.

5.2. Traffic volume analysis

Analysis of traffic volume based on primary data survey with traffic counting. The traffic volume on the toll access road is surveyed based on peak hour volume. Peak hour volume is determined based on the dominant activity in the road corridor. The traffic volume of the peak toll road access is shown in Figure 3.
Figure 3. The highest traffic volume.

The figure shows the change in traffic volume in the toll access road corridor based on the zone according to the corridor segment of the road. The volume of the segment indicated by higher volumes in the segment towards the road toll gate. Traffic volume on toll road access is the dominant variable in analyzing the degree of saturation of toll road access. Urban road traffic volume has the characteristics of a zone land use activity system[1-5][13].

5.3. Road capacity

The capacity of roads based on road space (ROW) based on formula 3 on the toll road corridor is influenced by the parameters of basic capacity, width of the road, separating direction, and the size and size of the city. The results of the road capacity analysis in the toll road corridor segment are shown in the Table 2. Capacity of road based on road typology on toll road corridor is shown in Figure 4.

Table 2. Total capacity calculation for Ciwastra Road section.

| Spot | Basic Capacity (C0) (smp/hour) | Road Width (FCw) | Separation Direction (FC3P) | Side Barriers & Shoulder Width (FC3F) | City Size (FC3) | Capacity (C) (smp/hour) |
|------|-------------------------------|----------------|---------------------------|-------------------------------------|----------------|------------------------|
| 1    | 2900                          | 0.87           | 1                         | 0.94                               | 1              | 2371.62                |
| 2    | 2900                          | 0.87           | 1                         | 0.92                               | 1              | 2321.16                |
| 3    | 2900                          | 0.87           | 1                         | 0.97                               | 1              | 2447.31                |
| 4    | 2900                          | 0.87           | 1                         | 0.94                               | 1              | 2371.62                |

Figure 4. ROW toll road access.
The determination of the road capacity factor shown in the figure above shows the effective ROW used on toll road access. The road capacity is used to determine the road capacity in the degree of saturation analysis of the access road.[8-9]

5.4. Degree of saturation analysis toll road access

The results of the analysis of the level of toll road access services based on changes in urban settlement land use are shown in Table 3. Based on the results of the analysis of the level of road service from the degree of road saturation, the road conditions have shown high congestion with DS values above 0.75 segments 1-3.

| Spot   | Time         | C (smp/hour) | Q (smp/hour) | DS existing (Q/C) |
|--------|--------------|--------------|--------------|-------------------|
| 1      | 2371.62      | 3022.65      | 1.27         |
| 2      | 2321.16      | 2465.45      | 1.06         |
| 3      | 2447.31      | 2397.3       | 0.98         |
| 4      | 2371.62      | 1542.85      | 0.65         |

The level of road service with congestion conditions at free speed which has been disturbed is shown by the comparison between traffic flow and road capacity shown in the Figure 5.

![Figure 5. Comparison of Traffic Volume and Capacity.](image)

Comparison of traffic volume with road capacity shows that road capacity is unable to accommodate traffic volumes on the toll access corridor road.[11-13]

5.5. The degree of saturation of the road based on changes in the use of urban residential land

The results of the analysis of toll access road traffic volume on changes in urban settlement land use show that the degree of saturation has shown a high degree of saturation which is above 0.75. This indicates that the toll access road has experienced traffic congestion. Changes in the use of urban settlement land lead to the degree of saturation of the road shown in Figure 6.
The degree of saturation from the results of the analysis shows that the toll access road corridor has a high degree of saturation with indicator values above 0.85, namely at the T-junction Tugu, Rancabolang and Margahayu roads. This condition is a condition of the low level of road service with the vehicle speed of movement is hampered.[1-6]

5.6. Road services improvement based on road capacity
The low level of road services from the high degree of saturation of roads requires a change in road capacity that is carried out by increasing road capacity. Additional road capacity for toll road access based on existing conditions still allows for increased road capacity shown in Figure 7.

The road capacity improvement carried out is an alternative solution to traffic congestion at an early stage. Increasing road capacity is done because land in corridor roads still allows for urban activity systems. The lane width adjustment factor and side obstacle factor are the parameters that are dominant in the development of road capacity in the urban zone. The results of increasing road capacity from Figure 7 result in an increase in road service by decreasing the degree of degree of road saturation on toll access roads. So that the smooth traffic on the toll access road is better with increased road capacity. A decrease in the degree of saturation of the toll access road is shown in Figure 8.
Figure 8. Degree of Saturation (DS) after the increase of road capacity.

The results of the increase in road capacity are obtained by the degree of saturation that is better than the road segment that experiences high congestion. With the indicator value of the degree of saturation between 0.46 to 0.65.

6. Conclusions
The results of the survey and data analysis as well as modeling can be concluded that the study of the degree of saturation of toll road access based on changes in urban settlement land use is dominated by changes in the system of urban structure activities from residential corridor zones to commercial corridor zones. The change in land use function of the activity system affects the road capacity parameters of the side resistance factor. So that the toll road access capacity decreases from the influence of side barriers and the width of the road lane. Increased toll access road by increasing the lane width factor because geometric road capacity is still possible increasing the lane width factor because geometric road capacity is still possible.

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