THE COMPARISON OF A ROUNDABOUT TRAFFIC DELAY ESTIMATION BETWEEN SUMO AND IHCM 1997 ON ROUNDABOUT

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ABSTRACT

Transportation is an important sector to support the development of countries in terms of highway design, road systems and traffic management. As users of transport infrastructure, human has close relationship to the field of transportation. Their driving behavior affects vehicle movements and may cause conflicts. In order to investigate the conflicts such as traffic delay, there are two different calculation methods using SUMO software and IHCM 1997 manually. The objective of this research is to compare the calculation methods of traffic delay using IHCM 1997 and SUMO which more appropriately with the actual condition.

The research location is in Idröttparken roundabout, Norrköping, Sweden which has four arms. The data collection is conducted during three days in the morning and afternoon. Types of data collection in this research were traffic flow and its turning, travel time and queue length. The queue length data is converted into traffic delay data for observation data. In SUMO, the traffic delay value is the mean halting duration. In IHCM 1997, the calculation of traffic delay needs several data i.e. roundabout geometric, capacity, and degree of saturation. To analyze data, the statistical method is used i.e. normality test, parametric and non-parametric test and also linear regression method.

The result showed the traffic delay in observation data is higher than delay in SUMO result and IHCM 1997 calculation. The statistical results showed that the traffic delay of SUMO, and IHCM 1997 have no similarities to the observation. Furthermore, from the linear regression result, only SUMO result has the highest value for determination coefficient (R2) compared to IHCM 1997 as shown in the West and South arms for SUMO result in the morning measurement. It means SUMO more representatives the observation compared to IHCM 1997. It is occurred because SUMO is developed in Europe and also the location for this research is in Sweden, Europe which has very different traffic condition from Indonesia.

Keywords: Roundabout, traffic delay, SUMO, IHCM 1997.

1 INTRODUCTION

1.1 Background

As users of transportation infrastructures, people have close relationship to the field of transportation. For example, in urban and intercity roads especially in non-signalized roundabouts, the driving behavior affects vehicle movements and may cause conflicts. The longer queue of the vehicles, the worse the sight obstruction is caused by vehicles on front line for those vehicles which turn to left.

There are several methods to calculate traffic delay at roundabout either manually or using program computer. Therefore, it will be valuable to find the differences in delay calculation using Indonesian Highway Capacity Manual (IHCM) 1997 and software SUMO (Simulation of Urban Mobility).

This research was carried out in Idröttparken roundabout in Norrköping, Sweden. It has four arms and located in the intersection of the Södra promenaden, Kungsgatan and Albrektsvägen.

1.2 Research Objectives and Scope of Works

The objective of this investigation is to compare the calculation methods of traffic delay using IHCM 1997 manually and traffic simulation software SUMO with the actual conditions in the field.

The scopes of this research are as follows:

a) The data collection is conducted on Tuesday, Wednesday and Thursday in the morning (07.15-08.15), and afternoon (16.30-17.30).

b) The research area is limited at the Idröttparken roundabout and the analysis is focused only in the roundabout.

c) SUMO is not applicable for pedestrian and two-wheeled vehicles based on Maciejewski research, 2010. To simplify the model, the pedestrian and cyclists are ignored.

d) The data to be compared are delay in each arm in the morning and afternoon.
2 ROUNDABOUT AND TRAFFIC SIMULATION

2.1 Roundabout
A roundabout can be described as a type of intersection where road traffic flows in one direction around a central island and it also gives more benefits in terms of traffic safety, operational efficiency, and other benefits (FHWA, 2010).

Roundabout can be separated into three basic categories according to size and number of lanes based on the performance or design issues, i.e. mini-roundabouts, single-lane roundabouts, and multilane roundabouts.

2.2 Traffic Simulation
Traffic simulation is defined as a method which used to assess and evaluate the traffic and transportation system and the results from simulation can be used as a traffic management decisions for infrastructure improvements (Lansdowne, 2006). There are three classifications for traffic flow models based on the level of detail simulation, namely macroscopic, mesoscopic and microscopic model.

2.3 Calibration and Validation
In calibration process, there are several strategies that can be implemented in order to find the parameters which have more influence to the model. Those strategies are to calibrate parameters, route choice parameters and to calibrate overall model performance (Dowling et al., 2004). This research uses RMSE (Root Mean Square Error) for changing the MSE unit from the square to single unit. Based on Holmes (2000), the equation for RMSE can be seen in the equation 1.

\[
RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (M - F)^2}
\]

where \( F \) is field measurement, \( M \) is model output, and \( N \) is number of data points.

To determine the validation of simulation results, the following equation can be used in this process.

\[
H_0 : \mu_x = \mu_y
\]
\[
H_A : \mu_x \neq \mu_y
\]

where \( \mu_x \) is field measurement and \( \mu_y \) is model output. In hypothesis test, the \( H_0 \) will be rejected if:

a) \( T_{\text{statistic}} < -T_{\text{table}} \) the average of the proposed scenarios decreased or

b) \( T_{\text{statistic}} > T_{\text{table}} \) the average of the proposed scenarios increased

2.4 SUMO (Simulation of Urban Mobility)
SUMO is open source software for micro-simulation. Its development is started in 2001 and became open source software in 2002. It uses car following theory as philosophy for building model. According to the SUMO-User documentation, there are four steps that should have been performed to make simulation run (Krajzewicz & Behrisch, n.d.), i.e.: build the network, build the demand, compute the dynamic user assignment (optional), run simulation.

2.5 Indonesian Highway Capacity Manual (IHCM) 1997

Indonesian Highway Capacity Manual (IHCM) 1997 uses empirical method which is obtained from conducting surveys in various cities Indonesia. For example, delays of a road could be analyzed empirically by using IHCM 1997. The method used is to calculate the volume of traffic entering the road segment according to survey conducted on the actual condition. Another necessary data is geometric conditions of road. The procedural of calculation could be seen in Figure 1.

\[
\text{Capacity (C)} = 135xW_1^{1.3}(1+W_2/W_0)^{1.5}(1-p_2W_2/L_1)^{1.3}xF_{CS}xF_{RSU}
\]

\[
\text{Degree of Saturation (DS)} = Q/C
\]

\[
\text{Delay of Traffic for Roundabout (D_{RS}) = D_{TR} + DG}
\]

Figure 1. Flowchart of non-signalized roundabout analysis.

Indonesian Highway Capacity Manual (IHCM) 1997 uses empirical method which is obtained from conducting surveys in various cities Indonesia. For example, delays of a road could be analyzed empirically by using IHCM 1997. The method used is to calculate the volume of traffic entering the road segment according to survey conducted on the actual condition. Another necessary data is geometric conditions of road. The procedural of calculation could be seen in Figure 1.

3 RESEARCH METHODS

3.1 General Flowchart
The flowchart of this research can be seen in Figure 2.
3.2 Data Collection and Preparation

There are several data to be used to develop the simulation model by using SUMO software. It can be seen in the following description.

a) Road geometry in Idrottparken roundabout which consists of four sections i.e. Kungsgatan, Albrektsvagen, West, and East Sodra Promenaden sections.

b) Traffic flow and turning movement of the vehicle passing the roundabout.

c) Queue length of each section in certain time of period. The average of queue length data is used to traffic delay calculation for observation data.

d) According to Widyagama Malang University, 2008, in order to obtain delay at an intersection, the traffic volume data and the queue length are needed for the calculation. So, based on the explanation and the data, the equation to calculate the delay (in second/vehicle) is written as follow.

\[
DT = \frac{\text{Average Queue} \times 5 \text{ minutes}}{\text{Flow}} \times 60 \text{ seconds}
\]

e) Travel time data is used for calibration.

4 RESULTS AND DISCUSSIONS

4.1 SUMO

The development of base model can be seen in the flowchart below at Figure 3.
Based on trial and error, there are two important parameters which are giving significant changes to the simulation which are driver imperfection (sigma) and driver’s reaction time (tau). In order to adjust those parameters, RMSE (Root Mean Square Error) will be used to get optimal parameter value. As result, there are three conditions for getting minimum RMSE either in the morning or in the afternoon i.e. queue length, travel time, and combination between queue length and travel time. Before it can be concluded that the model represents the field measurement, the validation process has to be done. As a result, the third condition RMSE is chosen as best value and parameters.

![Figure 4. Output delay from SUMO.](image)

Based on the simulation result by using SUMO software related to output generated from E2-d Detectors, the delay/halting is determined either in the morning or in the afternoon by using value of mean halting duration. The output of delay can be seen in Figure 4.

4.2 Indonesian Highway Capacity Manual (IHCM) 1997

By using Ms. Excel as the program tools, calculation analysis for finding the traffic delay value in this research is done manually using IHCM 1997. There are several steps in terms of traffic delay calculation i.e. geometric of roundabout from secondary data, capacity of roundabout (C), and degree saturation (DS). The demand contains three kinds of data i.e. vehicle flow data, turning proportions, and heavy vehicle percentages. They are also converted into passenger car unit (PCU).

As result, the calculation of traffic delay using IHCM 1997 can be seen in Figure 5.

4.3 Comparison of Traffic Delay

Based on data analysis, the delay value is compared among observation data, SUMO result, and IHCM 1997 calculation (see Figure 6 and Figure 7). While, comparison of queue length between observation and SUMO result can be seen in Figure 8.

![Figure 5. Output delay from IHCM 1997.](image)

4.4 Discussion

Normality test is basically comparison between the provided with normal distributed data with mean and standard deviation similar to data provided. In order to determine the normality of data distribution, descriptive analysis using SPSS is required. If the distribution is normal, data is tested using parametric test. If not, they are tested using non-parametric test.

The Independent Sample T-test and Two Independent Kolmogorov-Smirnov (K-S) test are used for parametric and non-parametric distribution, respectively.

In T-test and non-parametric test, there are two hypotheses as below.

a) Ho : Population is similar  
b) H1 : Population is not similar

Both of them have similar decision making to accept or reject the hypothesis.

a) If probability < 0.05 (sig. 2-tailed), then Ho is rejected  
b) If probability > 0.05 (sig. 2-tailed), then Ho is accepted
Table 1. Recapitulation of T-Test and Non-parametric test (SPSS)

<table>
<thead>
<tr>
<th>Arm</th>
<th>West</th>
<th>South</th>
<th>East</th>
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<tr>
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<td>Sig Analysis</td>
<td>Sig Analysis</td>
<td>Sig Analysis</td>
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<tr>
<td>Obs. vs SUMO</td>
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<td>0**) Ho Reject</td>
<td>0*) Ho Reject</td>
<td>0*) Ho Reject</td>
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<tr>
<td>Obs. vs IHCM 1997</td>
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<td>0**) Ho Reject</td>
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<td>SUMO vs IHCM 1997</td>
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<td>0**) Ho Reject</td>
<td>0*) Ho Reject</td>
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<tr>
<td>Afternoon</td>
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<tr>
<td>Obs. vs SUMO</td>
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<td>0*) Ho Reject</td>
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Note: *) = T-Test; **) = K-S test

Figure 6. Comparison of observation, SUMO, and IHCM 1997 (morning).

Figure 7. Comparison of observation, SUMO, and IHCM 1997 (afternoon).

Figure 8. Comparison of queue length between observation and SUMO.
4.4.1 Linear Regression

Linear regression analysis is the next step up after correlation. It is used to predict the value of a variable based on the value of another variable. In this case, the variable used to predict the other variable's value is called the independent variable (Sugiyono, 2007). The equations obtained from a simple regression is $Y = a + bX$ where $X$ is the independent variable and $Y$ is the dependent variable.

By using Ms. Excel and SPSS, the relationship of both results and the value of $R$ as correlation coefficient in this method are obtained. The more complete results can be showed in Table 2 and Table 3 either in the morning or afternoon calculation. According to Table 2 and Table 3, the value of $R^2$ in West arm 0.4248 and South arm 0.6242 for morning calculation is the closest to value 1.

In order to perform the decision making for comparison between observation, SUMO and IHCM 1997, two options are used as below:

a) If probability $< 0.05$ (sig), then variable $X$ has significant influence on variable $Y$  
b) If probability $> 0.05$ (sig), then variable $X$ has no significant influence on variable $Y$

From Table 4, the comparison of observation and SUMO in the morning calculation has the significance

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<thead>
<tr>
<th>Arm</th>
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<th>South</th>
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<td>Coefficient</td>
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<td>Obs vs SUMO</td>
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<tr>
<td>Afternoon</td>
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<td>Obs vs SUMO</td>
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<tr>
<td>Obs vs IHCM 1997</td>
<td>38.298</td>
<td>-3.8938</td>
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<td>-33.637</td>
<td>13.21</td>
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<th>Table 4. Hypothesis test</th>
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<td><strong>Weaving Section</strong></td>
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<td>Significant in Linear Regression</td>
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<td>Obs. vs SUMO</td>
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<tr>
<td>Obs. vs IHCM 1997</td>
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</tbody>
</table>
value less than 0.05. It means variable $X$ (delay of SUMO) has significant influence on variable $Y$ (observation). Otherwise, in IHCM 1997, the significance value for all arms more than 0.05 which indicates that the result of IHCM 1997 far from data observation. It can be summarized that SUMO represents the observation more than IHCM 1997 based on the analysis by using statistical methods.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions
According to the analysis and discussion, there are several conclusions obtained.

a) In order to obtain a good model which represents the field measurement, a calibration is performed. In SUMO, the parameters with more effects to calibration process are the driver imperfection (sigma) and the driver’s reaction time (tau). By using both parameters in combination between RMSE travel time and RMSE queue length, the calibrated model is obtained.

b) According to statistical methods, there is none of the arms similar neither for comparison between observation and two calculation methods nor comparison of traffic delay value between those methods SUMO and IHCM 1997.

c) While, in linear regression result, SUMO represents the observation data more than IHCM 1997 i.e. traffic delay in West and South arm for morning result with the significance value less than 0.05. It occurs due to the location of research in Sweden, Europe which has different traffic condition, and driver behavior.

5.2 Recommendations
There are several recommendations related to this study as follow.

a) SUMO is developed in Europe which in totally different traffic condition compared to condition in Indonesia which is using IHCM 1997 as manual design for highway capacity. It means that IHCM 1997 is more applicable in Indonesia due to consideration of several factors in environmental conditions such as city size/population, side friction classes. So, when SUMO is applied in Indonesia, it needs adjustment some parameters i.e. to reduce the maximum speed allowance on the road as substitute the side friction.

b) Based on the comparison between observation and SUMO either for delay and queue, the result showed that the observation is higher than SUMO. To obtain the better model than model in this research, it is recommended for trying the other parameters to calibrate besides driver reaction time and driver imperfection.

REFERENCES


