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A SUGGESTED MODEL TO SIMULATE STORAGE LANE FOR VEHICLE QUEUE ON URBAN ROAD U-TURN

Muhammad Hadid[1], Hera Widyastuti[2] and Wahju Herijanto[2]
[1]Departement of Civil Engineering, Institut Teknologi Kalimantan, Indonesia
[2]Departement of Civil Engineering, Institut Teknologi Sepuluh Nopember, Indonesia
E-Mail: hadid@itk.ac.id

ABSTRACT

U-turn with high arrival rate and high traffic on urban road can decrease the Level of Service (LOS) of road itself. To revitalize the current condition, storage lane for vehicle queue must be provide. To set length of storage lane, we should know the queue length. Based on current condition, queue occurs because service time or turning movement is too long. The other factor of queue is high traffic on the opposite lane. Poisson distribution for arrival rate of vehicle on U-turn and model of service time of U-turn is used for this research. Model of service time is gained from cumulative frequency distribution of service time data from each U-turn. The result of simulation is queue length and the minimum length of storage lane On Pndugo U-turn, Nirwana U-turn, Galaxy U-turn which are 150 meter (correction factor:0.96s), 102 meter (correction factor: 0.85s), and 114 meter (correction factor: 0.95s), respectively. Simulation model is accepted when correction factor is close to 0s. Based on the result, the Simulation model of queue is accepted.

Keywords: simulation, service time, U-turn.

INTRODUCTION

A U-turn in driving refers to performing a 180° rotation to reverse the direction of travel (Wikipedia). Median openings, however, may also become points of increased congestion of accident exposure (Potts. *et al*, 2004). Therefore, if traffic safety on multilane highways is to be preserved, the location of median openings must be given careful consideration (Potts, *et al*, 2004). Some factors that influence median opening location include the following (Potts, *et al.*, 2004):

- Spacing between median openings,
- Stopping sight distance,
- Intersection sight distance,
- Operating speeds,
- Length of turn lanes,
- Right-turn conflict overlap, and,
- Size and type of traffic generator.

To design U-turn is consider aspects of geometric design of road, as following (Bina Marga, 2005):

- Function of road,
- Classification of road,
- Width of median
- Width of lane
- Traffic volume each lane
- U-turn movement data

Design of U-turn can be conducted if it fulfills some requirements and has special study. The aim of special study is to anticipate traffic impact that will occur.

To anticipate the impact of U-turn traffic, this research will discuss simulation method of queue on U-turn to set the length of storage lane. Queue that occur on U-turn can decrease performance of road itself. For example, a segment of road has 2 lanes and the queue length of vehicle is 1 lane, automatically the effective width of road that can function is only 1 lane. That's why this simulation model is needed.

The Middle East Ring Road (MERR), Surabaya has some problematic U-turn. This research determines 3 (three) problematic U-turns. The main problem is the queue length that has impact to road performance. This occur because the storage lane cannot accommodate vehicle queue. The problematic U-turns are:

- Pandugo U-turn (Figure-1 and Figure-2),
- Nirwana U-turn (Figure-3 and Figure-4),
- Galaxy U-turn (Figure-5 and Figure-5).

Figure-1. Satellite view of Pndugo U-turn (Source: Google earth).

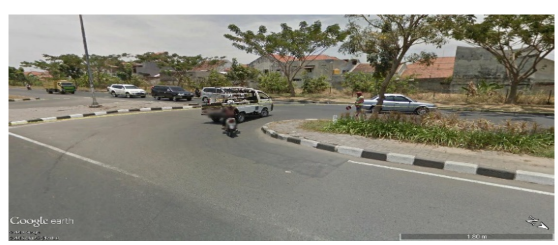

Figure-2. Street view of Pndugo U-turn (Source: Google earth).

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Figure-3. Satellite view of Nirwana U-turn (Source: Google earth).

Figure-4. Street view of Nirwana U-turn (Source: Google earth).

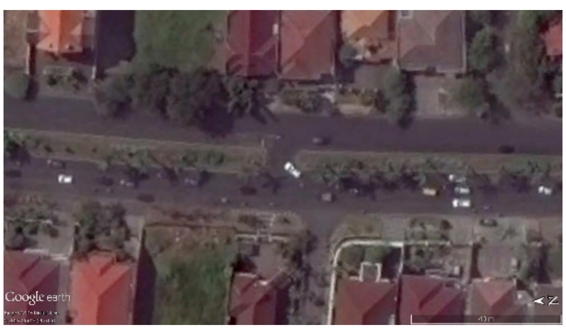

Figure-5. Satellite view of galaxy U-turn (Source: Google earth).

Figure-6. Street view of galaxy U-turn (Source: Google earth).

These U-turns are cause of the decreasing of road performance. The storage lane provided is not enough to accommodate the queue. Based on survey, the queue length that occur are:

- Pndugo U-turn : 150 meter
- Nirwana U-turn : 102 meter
- Galaxy U-turn : 114 meter

All U-turn in this study are a part of single weaving system. Queue that occur decrease length and width of weaving. The impact is decreasing of single weaving and road performance. On Nirwana U-turn, the depreciation of single weaving performance, which is represented by Degree of Saturation or V/C ratio, is from 0.60 become 0.88 (Hadid *et al.*, 2014).

The aim of this research is to obtain queue length that can be used to obtain minimum requirement of length of storage lane. To decrease the influences of queue length on road performance, providing storage lane which accommodate queue vehicle is needed. Minimal length of storage lane is same as maximum queue length that occur on U-turn.

The reason for using simulation is because characteristics of traffic each location different. From this research, the differences is the service time. Service time depends on opposite traffic volume. High opposite traffic volume effects the maximum service time on U-turn. Usually, determining minimum length of storage lane is based on right turn vehicle (vehicle/minute) and head distance (meter). The value that is used is the mean value, both right turn vehicle and head distance. Using the simulation, we can generate various service time each vehicle based on model of service time in each location. Using simulation is more accurate to obtain length of queue than using simpler method. The length of queue from simulation is useful to determine length of storage lane.

LITERATURE REVIEW

U-turn or median opening is designed to accommodate vehicle to undertake maneuver turning to opposite direction, crossing maneuver and right turn maneuver. Illustration of U-turn is shown by Figure-7 below:

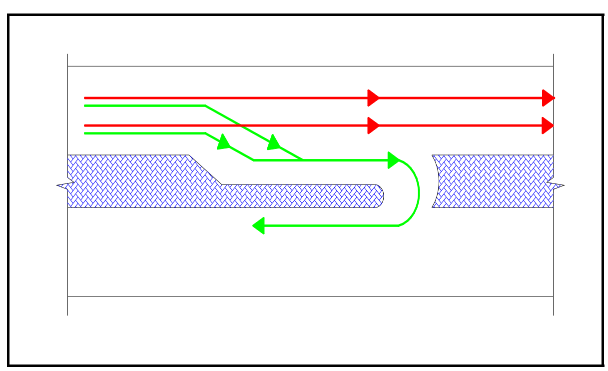

Figure-7. U-turn and the movement.

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Decelaration lane

Deceleration Lane is a provided lane that has function to decelerate vehicle to exit from continuous traffic (Bina Marga, 1992). To design deceleration lane, we can use equation 1 below:

$$ls = 2 \times M \times s \quad (1)$$

Where:
Ls : length of storage section (meter)
M : mean of right turn vehicle (vehicle/minutes)
s : mean of head distance (meter)

Based on Bina Marga (1988) the minimum deceleration lane is shown by Table-1 below.

Table-1. Minimum deceleration lane length.

Speed Design (km/h)	Minimum Length (meter)
80	45
60	30
50	20
40	15
30	10
20	10

Source: Bina Marga (1992)

Decelaration lane

The algorithm for generating Poisson (λ) random varieties is based essentially on the relationship between the Poisson (λ) dan expo (1/λ) distributions (Law&Kelton, 1991). The algorithm is as follows:

1. Let $a = e^{-\lambda}$, b=1, and i = 0
2. Generate $U_{i+1} \sim U(0,1)$ and replace b by bU_{i+1}. If b<a, return x=i. Otherwise, go to step 3.
3. Replace I by i+1 and go back to step 2.

The algorithm is justified by nothing that x=i if and only if

$$\sum_{j=1}^{i} Y_j \leq 1 < \sum_{j=1}^{i+1} Y_j \quad (2)$$

The (stationary) Poisson process with rate λ>0 has Where $Y_j = (-1/\lambda)\ln U_j \sim \exp(1/\lambda)$ and the Yj's are independent property that the interarrival times $A_i = t_i - t_{i-1}$ (where *i=1,2,…n*) are IID exponential random variables with common mean (1/λ). Thus, we can generate the ti's recursively, as follows (Law&Kelton, 1991):

1. Generate U~U(0,1) independent of any previous random variates
2. Return $t_i = t_{i-1} - (1/\lambda) \cdot \ln U$

The recursion starts by computing t_1 (recall that $t_0=0$).

Cumulative frequency distribution

For obtain the data, we need to get the number of data that has value below or above from certain value that be compared that different on certain interval. So we used cumulative frequency distribution and used Ogive graph Figure-8 to present the data (Harinaldi, 2005).

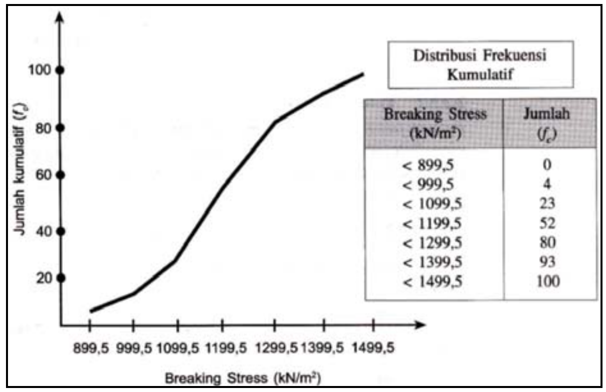

Figure-8. Cumulative frequency dist. diagram (Source: Harinaldi, 2005).

METHODS

The method that using on this study is shown on Figure-9 below:

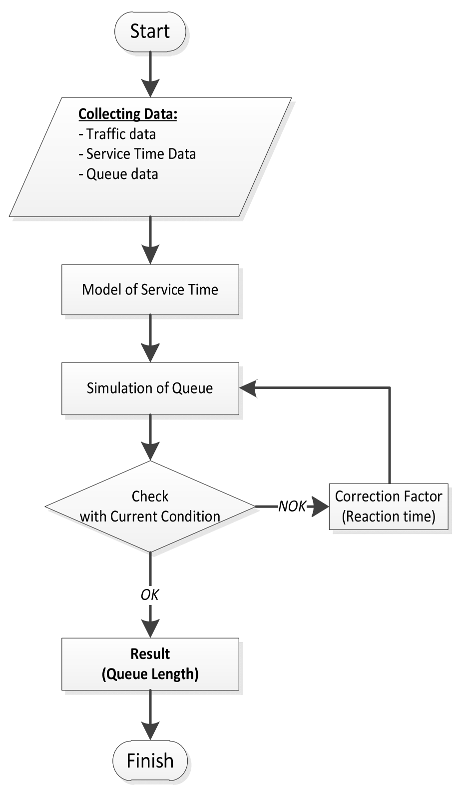

Figure-9. Flowchart.

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Collecting data

The Data needed in this study is primary data, such as:

1. Traffic Data
2. Service Time Data
3. Queue Data

From field observation, the data that obtained is shown by Table-2 below:

Table-2. Observed data.

U-turn	arrival rate (veh/h)	Service Time (sec)		QL (meter)
		min	max	
Pandugo	509	2	18	150
Nirwana	711	3	21	102
Galaxy	725	2	26	114

Source: Hadid (2014)

The observed data above is obtained from field observation on each location on MERR Surabaya. Table-2 shows the maximum value each data. Arrival rate is taken from peak hour volume of U-turn traffic. Based on table 2, peak hour volume on Pndugo U-turn is 509 vehicle/hour, 711 vehicle/hour on Nirwana U-turn, and 725 vehicle/hour on Galaxy U-turn. Service time data is a time when the vehicle start to turn until finish. Each location has minimum and maximum service time. On Pndugo U-turn, the minimum service time is 2 seconds, and 18 seconds for maximum value. Service time value on Nirwana U-turn is 3 seconds for minimum value and 21 for maximum one. For Galaxy U-turn, service time is 2 seconds for minimum value and 26 seconds for maximum one. The queue length is obtained from maximum queue during observation. The locations of the observed U-turns are shown in Figure-1 trough Figure-6.

Model of service time

Model of Service time is obtained by cumulative frequency distribution from data of service time. Each U-turn has one model of service time. Model of service time is an exponential equation with y as service time (sec) and x as generating random number (0,1).

The model of service time is used for simulation of service time. By generating random number, we will get service time based on equation model of each U-turn.

From data of service time on Pndugo U-turn, we plot the cumulative frequency diagram to get model of service time on Pndugo U-turn. The diagram of cumulative frequency is shown in Figure-10.

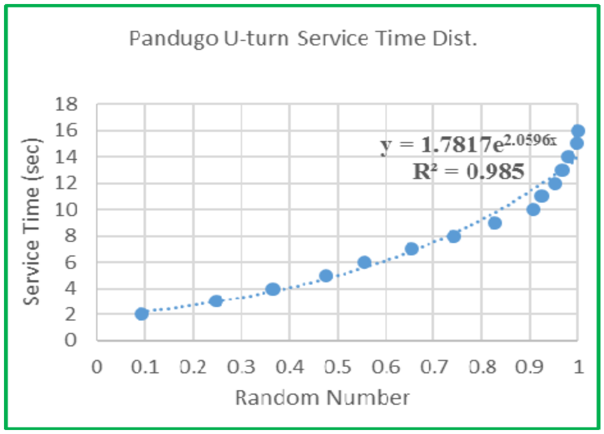

Figure-10. Cumulative frequency distribution of service time on Pndugo U-turn (Hadid, 2014).

From diagram of cumulative frequency distribution, we get the equation of service time model which shown by Equation 3 below:

$$y = 1.7817 \cdot e^{2.0596X} \tag{3}$$

Based on Figure-10 determinant factor (R^2) is above 0.985 or above 0.5. So that, the model of service time on Pandugo U-turn is accepted.

Same as model of service time on Pndugo U-turn. Diagram of cummulative frequency distribution of service time on Nirwana U-turn is shown by Figure-11 below:

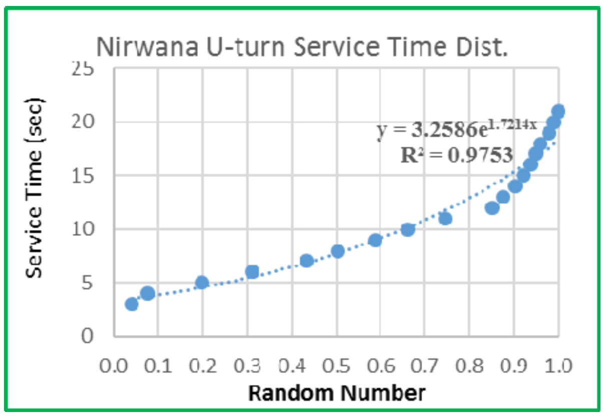

Figure-11. Cumulative frequency distribution of service time on Nirwana U-turn (Hadid,2014).

From diagram of cumulative frequency distribution we get the equation of service time model Figure-11 which shown by Equation 4 below:

$$y = 3.2586 \cdot e^{1.7214X} \tag{4}$$

Based on Figure 11 determinant factor (R^2) is above 0.9753 or above 0.5. So that, the model of service time on Nirwana U-turn is accepted.

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And for Galaxy U-turn, model of service time is shown by Figure-12 below:

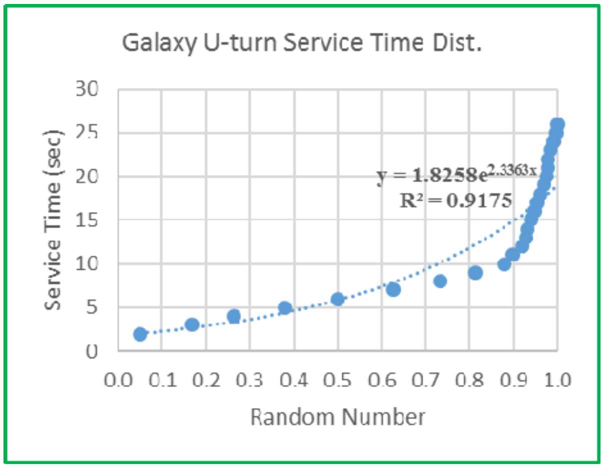

Figure-12. Cumulative frequency distribution of service time on galaxy U-turn (Hadid, 2014).

From diagram of cumulative frequency distribution we get the equation of service time model which shown by [Equation 5] below:

$$y = 1.8258 \cdot e^{2.3363X} \quad (5)$$

Based on [Figure-12] determinant factor (R^2) is above 0.9175 or above 0.5. So that, the model of service time on Galaxy U-turn is accepted.

Simulation and correction factor

Simulate of queue is as follow:

1. Arrival time is based from random number and Poisson equation $t_i = t_{i-1} - (1/\lambda) \cdot \ln U$. λ is arrival rate of vehicle (veh/sec)
2. Simulation of service time is based on model of service time and random number
3. Queue will occur when the arrival time of vehicle is above of arrival time of previous vehicle and below of end time of U maneuver one.
4. Generate correction factor that representative of reaction time of driver.
5. If simulation is not reach target (queue length based on data), back to step 4.
6. Simulation is stop when arrival vehicle reach number of arriving vehicle based on data.

RESULT AND DISCUSSION

Pandugo U-turn

Procedure of simulation of queue has discussed above. In this section is discuss about the result of simulation. Pndugo U-turn has 1 lane that allowed is used to perform U maneuver. The result of simulation is shown by Table-3 below.

Table-3. Result Pndugo U-turn simulation.

C	AT	NQ	QL	C	AT	NQ	QL
	0.0000						
1	11.8683	0	0	245	1678.5588	23	138
2	24.5201	0	0	246	1682.0915	23	138
3	33.0720	0	0	247	1690.6702	24	144
4	35.7112	0	0	248	1692.0692	24	144
5	54.2603	1	6	**249**	**1693.8145**	**25**	**150**
6	55.2712	1	6	250	1699.3673	24	144
7	61.5849	0	0	251	1700.0342	24	144
8	77.8798	1	6	252	1704.7454	23	138
9	84.0197	0	0	253	1711.7081	22	132
10	101.1494	1	6	254	1713.6708	22	132

Source: Simulation Result (Hadid, 2014)

Where:
C : Car
AT : Arrival Time (second)
NQ : Number of Queue (vehicles)
QL : Queue Length (meters)

And the graphic of queue on Pandugo U-turn is shown by Figure-13 below:

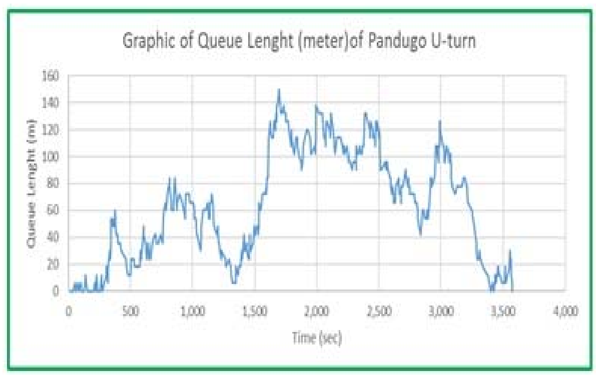

Figure-13. Queue length (meter) of Pndugo U-turn (Hadid, 2014).

Based on Table-3 and Figure-13 the simulation result is 150 meter. The correction factor or reaction time of driver is 0.96 second. From the result the minimum length of storage lane on Pndugo U-turn based on simulation is 150 meter.

Nirwana U-turn

Different from Pndugo U-turn, Nirwana U-turn is provide 2 lane that used as storage lane of U-turn. The simulation has simulate the number of lane that taken by vehicle. To get the simulation of deciding of number of lane, used random number. The random number is just 1 and 2 to represented number of lane. The simulation of queue is not different from Pndugo U-turn. The result of simulation of queue on Nirwana U-turn is shown by Table-4 below:

Table-4. Result Nirwana U-turn simulation.

C	AT	NL	NQ	QL	C	AT	NL	NQ	QL
	0.000								
1	8.496	1	0	0	**453**	2208.713	2	1	6
2	17.554	1	1	6	**454**	2212.150	1	15	90
3	23.676	2	0	0	**455**	2240.055	2	2	12
4	25.565	1	0	0	**456**	2241.576	2	1	6
5	38.845	2	2	12	**457**	**2249.259**	**1**	**17**	**102**
6	39.568	2	1	6	**458**	2249.982	1	16	96
7	44.088	2	0	0	**459**	2260.801	1	15	90
8	55.754	1	3	18	**460**	2263.292	1	16	96
9	60.149	1	1	6	**461**	2272.812	1	16	96
10	72.412	2	0	0	**462**	2276.184	1	16	96

Source: Simulation Result (Hadid, 2014)

Where:
C : Car
AT : Arrival Time (second)
NL : Number of Lane (1 or 2)
NQ : Number of Queue (vehicles)
QL : Queue Length (meters)

And the graphic of queue on Nirwana U-turn is shown by Figure-14 below:

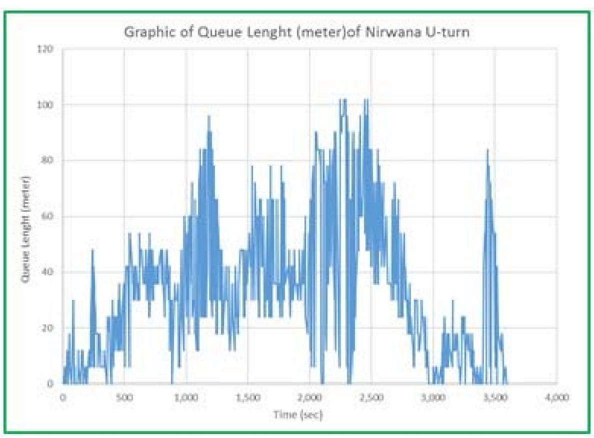

Figure-14. Queue length (meter) of Nirwana U-turn (Hadid, 2014).

Based on Table-4 and Figure-14 the simulation result is 102 meter. The correction factor or reaction time of driver is 0.85 second. From the result the minimum length of storage lane on Pndugo U-turn based on simulation is 102 meter.

Galaxy U-turn

Similar with Nirwana U-turn, this location has 2 lane that provide to turning movement. And the result of simulation is shown by Table-5 below.

Table-5. Result of galaxy U-turn simulation.

C	AT	NL	NQ	QL	C	AT	NL	NQ	QL
	0								
1	0.068	1	0	0	492	2441.657	2	16	96
2	9.303	1	2	12	493	2446.115	2	17	102
3	14.778	1	1	6	494	2446.285	1	2	12
4	16.390	1	1	6	495	2446.527	1	2	12
5	21.384	2	1	6	**496**	**2448.766**	**2**	**19**	**114**
6	22.675	2	0	0	497	2449.033	1	2	12
7	33.441	1	2	12	**498**	**2455.227**	**2**	**19**	**114**
8	36.240	1	1	6	499	2468.483	2	18	108
9	50.880	2	0	0	500	2471.961	1	5	30
10	60.083	1	0	0	501	2473.497	1	4	24

Source: Simulation Result (Hadid, 2014)

Where:
C : Car
AT : Arrival Time (second)
NL : Number of Lane (1 or 2)
NQ : Number of Queue (vehicles)
QL : Queue Length (meters)

And the graphic of queue on Galaxy U-turn is shown by Figure-14 below:

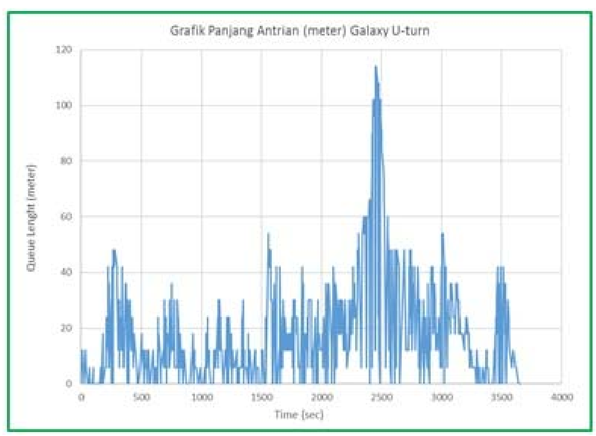

Figure-15. Queue length (meter) of galaxy U-turn (Hadid, 2014).

Based on Table-5 and Figure-15 the simulation result is 114 meter. The correction factor or reaction time of driver is 0.95 second. From the result the minimum length of storage lane on Galaxy U-turn based on simulation is 114 meter.

CONCLUSIONS

From the result above, the minimum requirement length of storage lane based on queue length simulation on Pndugo U-turn is 150 meter with correction factor 0.96s, 102 meter on Nirwana U-turn with correction factor 0.85s and 114 meter on Galaxy U-turn with correction factor 0.95s. Based on the simulation, the correction factor is close to 0s, its means the method of simulation of queue length on U-turn can be used to obtain the length of storage lane.

Correction factor represents the reaction time of driver and is added to ending time of maneuver. If the correction factor or reaction time is closer 0s, the model is closer to real condition.

This research does not consider the opposite direction traffic flow and motorcycle. Opposite direction traffic flow is represented by service time or necessary time for vehicle to maneuver. If the service time is too long, it shows that the vehicle is waiting on the opposite traffic to maneuver. The simulating queue of motorcycle is difficult because of unpredictable maneuver of motorcycle itself.

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