The Use of KREISIG Computer Simulation Program to Optimize Signalized Roundabout

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Abstract— KREISIG is a computer simulation program, firstly developed by Munawar (1994) in Germany to optimize signalized roundabout. The traffic movement is based on the car following theory. Turbine method has been implemented for signal setting. The program has then been further developed in Indonesia to meet the traffic characteristics in Indonesia by adjusting the sensitivity of the drivers. Trial and error method has been implemented to adjust the saturation flow. The saturation flow output has also been compared to the calculation method according to 1997 Indonesian Highway Capacity Manual. It has then been implemented to optimize signalized roundabout at Kleringan roundabout in Malioboro area, Yogyakarta, Indonesia. It is found that this method can optimize the signal setting of this roundabout. Therefore, it is recommended to use this program to optimize signalized roundabout.

Keywords: KREISIG, signalized roundabout, traffic

I. INTRODUCTION

Prediction of capacities, queues and delays at signalized roundabouts may be made by the use of empirical, mathematical and simulation approaches. Empirical models attempt to predict highway capacity on the basis of pas observations, whereas in the mathematical approach, vehicular delay is calculated, and capacity or level of service defined in terms of the flow occuring when delays reach a certain value. In contrast, a simulation model requires the formation of a model system which represents the real situation at the site being studied. Simulation models can be flexible enough to cover a wide range of highway traffic conditions.This model has, therefore, been developed by many researchers in thee recent years, such as Hewage and Ruwanpura [1].

KREISIG computer program (Kreisverkehrsplaetze mit Lichtsignalanlage = signalized roundabout) was firstly developed by Munawar [2] in Germany, to calculate queues and delays at signalized roundabout. It has been implemented to optimize signal timing at signalized roundabouts in Hagen, Berlin, Hidelsheim and Frankfurt.

II. METHODOLOGY

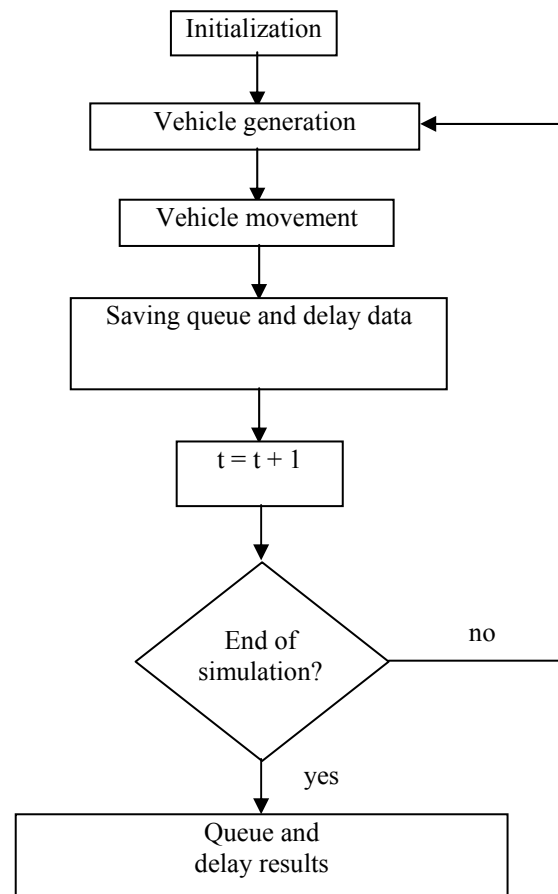Flow chart of the simulation program is shown below.

Figure 1. Simulation Flow Chart

The program contains:
1. Data inputting system
    a. Geometry data (see figure 2): diameter (D), entry width (e), entry radius (r), *entry angle* (ϕ) and normal width (v)
    b. Traffic data: traffic counting data for each type of vehicle.
    c. Traffic signal calculation method. Turbine method (anti clock wise green time phasing) has been employed to optimize the signal setting. This turbine method can minimize the lost time during intergreen period.
2. Random generator: to generate random numbers to be used for simulation, i.e.: time headway, vehicle type, vehicle direction, desirable speed, driver sensitivity, acceleration, distance at stop line, overtaking decision, and driver decision at yellow time.
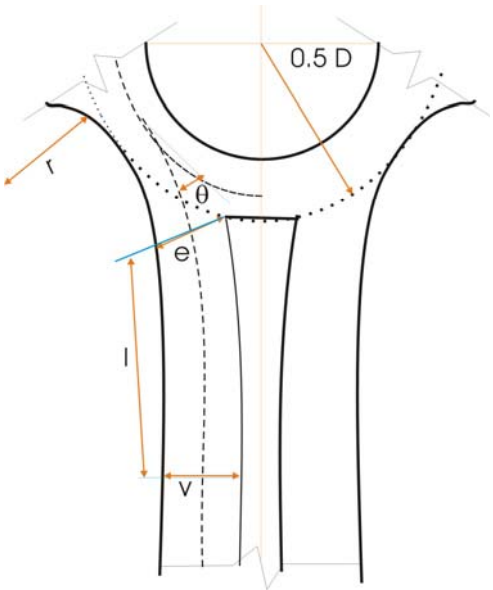
3. Traffic movement for every second.

Figure 2. Roundabout Geometry

Time headway or headway is the time interval between the passage of successive vehicles past a point on the highway (see figure 3). Minimum headway should gave the safety for the vehicle to avoid an accident.
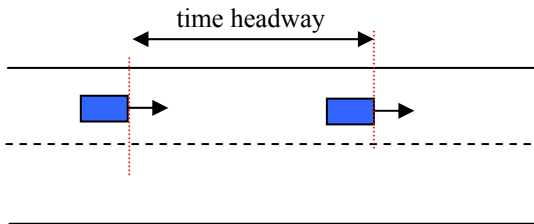

Figure 3. Time headway

According to Salter and Hounsell [3], headway distribution could be negative exponential. When this distribution represents the cumulative headway distribution then arrivals occur at random and the counting distribution may be represented by the Poisson distribution. This type of flow may be found where there are ample opportunities for overtaking, at low volume/capacity ratios. For congested traffic, double exponential or Erlang distribution is more suitable than negative exponential distribution. Erlang distribution has, therefore, been employed for this simulation.

When approaching the stop line, simulation of vehicle movement is based on car following theory [4]. Basic equation is as follows:

Reaction (t+Δt) = sensitivity x stimulant   (1)

Two vehicle movement, i.e. vehicle (n) and vehicle (n+1), approaching the stop line, can be explained in Figure 3 below.
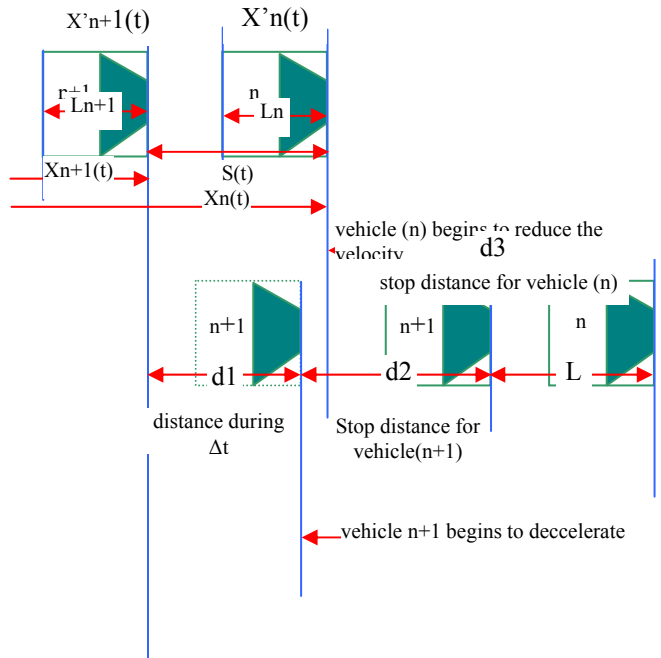

Figure 3. Vehicle position approaching stop line

with :
$X'_n(t)$ = velocity of vehicle n at time t (m/s)
$X_n(t)$ = position of vehicle n at time t (meter)
$X'_{n+1}(t)$ = velocity of vehicle n+1 at time t (m/s)
$X_{n+1}(t)$ = position of vehicle n+1 at time t (meter)
Ln = length of vehicle n (meter)
Ln+1 = length of vehicle n+1 (meter)
S(t) = distance between vehicle n and n+1 at time t =
    $X_n(t) - X_{n+1}(t)$ (meter)
d1 = distance of vehicle (n+1) after moving during Δt
    = $U_{n+1}(t)$
d2 = distance of vehicle (n+1) after moving =
    $[U_{n+1}(t+ \Delta t)]2/2a_{n+1}(t+ \Delta t)$
L = distance between vehicle (meter)
$U_i(t)$ = velocity vehicle i at time t (m/sec)
$a_i(t)$ = acceleration of vehicle i at time t (m/sec^2)
Δt = reaction time (sec)

Acceleration of vehicle is shown in formula below:

$$X''_{n+1}(t+\Delta t) = \frac{\alpha o[X'_{n+1}(t + \Delta t)]^m}{[X_n(t) - X_{n+1}(t)]^l} [X'_n(t) - X'_{n+1}(t)] \quad (2)$$

with

$X''_{n+1}(t+\Delta t)$ = acceleration of vehicle n+1 at time (t+Δt) (m/sec^2)
$X'_{n+1}(t+\Delta t)]^m$ = velocity of vehicle n+1 at time (t+Δt) (m/s)
$X_{n+1}(t)$ = position of vehicle n+1 At time t (meter)
Δt = reaction time (sec)
α_o = sensitivity

l   = distance component of sensitivity
m   = velocity component of sensitivity

According to Hoefs [5] and Koehler [6]: $\alpha_o = 17$, $m = 0,2$ dan $l = 0,5$

According to the field survey, it is found that:
   a. Indonesian driver begins to deccelerate the speed when approaching the stop line during the red signal at a distance of 75 meters from the stop line. It can be compared to the existing KREISIG program, which is based on the German driver behavior, i.e. German driver begins to deccelerate the speed at a distance of 250 meters from the stop line. It is shown that Indonesian driver takes more risks than German driver.
   b. Most Indonesian drivers still pass the stop line during the yellow time, whether most German drivers decide to stop during the yellow time.

According to the calibration in Indonesian signalized intersections, so that the saturation flow according to the simulation result should be the same as the actual saturation flow in the field. it is found that: α_o for decceleration = 140 and for acceleration = 0,2, $m = 0,2$ and $l = 2,0$. This calibration has also been tested using Indonesian Highway Capacity Manual modified formula, developed by Munawar [7]. It has no significant different.

III. CASE STUDY

This modified KREISIG program has been implemented to set the signal time at Kleringan roundabout, in CBD area of Yogyakarta City, Indonesia. This roundabout was unsignalized, and because of the queue length during peak hour, it will be signalized. KREISIG program has been implemented to optimize signal setting. This roundabout is shown in figure 4.
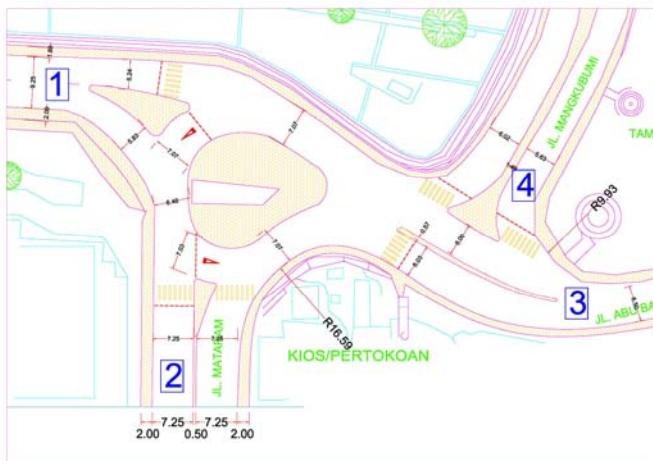

Figure 4. Kleringan roundabout

This roundabout has four arms, i.e.
Arm 1: Abu Bakar Ali Street (Malioboro)
Arm 2: Mataram Street

Arm 3: Abu Bakar Ali Street (Kotabaru)
Arm 4; Mangkubumi Street

The optimized green time, intergreen and cycle time are shown in table 1 below.

Table 1. Green time and intergreen as signalized roundabout (cycle time 87 seconds)

Arm	Green period (green time) (seconds)	Integreen (seconds)
1	11 – 21 (10)	-2
2	67 – 14 (34)	-3
3	32 – 69 (37)	-2
4	19 – 34 (15)	-2

The average queue length and average delay for each arm, if it is signalized, are shown in table 2 and 3 below.

Tabel 2. Delays, if it is signalized

Arm	to			
	1	2	3	4
1	0	0	68	0
2	77	0	0	0
3	531	0	0	439
4	380	0	384	0

Tabel 3. Average queues (meter), if it is signalized

Arm	Lane	
	left	right
1	1,8	0,0
2	100,7	84,0
3	717,8	584,0
4	250,5	154,8

The comparison of delay for signalized and unsignalized roundabouts is shown in table 4.

Tabel 4. A comparison of delay for signalized and unsignalized roundabout

	Average delay (seconds)	
Arm	Signalized	Unsignalized
1	485	1711
2	77	14
3	68	5
4	382	391

According to this calculation, this roundabout, therefore, has been signalized.

IV. CONCLUSION

This modified KREISIG program has been successfully used to set and optimize the traffic signal at Kleringan roundabout, Yogyakarta, Indonesia.

REFERENCES

[1] K.N. Hewage and J.Y. Ruwanpura, "Optimization of Traffic Signal Light Timing using Simulation", Proceeding of the 2004 Winter Simulation Conference, Monterey Canada, December 3-6, 2004

[2] A. Munawar, "Entwicklung eines Simulationsmodells fuer Kreisverkehrsplaetze mit Lichtsignalanlagen:, Schriftenreihe des Lehrstuhls fuer Verkehrswesen, Ruhr Universitaet Bochum, 1994

[3] R. J. Salter and N.B. Hounsell, "Highway Traffic Analysis and Design", London,Macmillan Pub. Ltd., 1996

[4] Adolf D. May, "Traffic Flow Fundamental", New Jersey, Prentice Hall, 1990

[5] D. H. Hoefs, "Untersuchung des Fahrverhaltens in Fahrzeugkolonnen", Bonn, Bundesminister fuer Verkher, Abt. Strassenbau, Vol. 140, 1972

[6] R. Koehler, "Verkhersablauf auf Binnenwasserstrassen – Untersuchungen zur Leistungsfaehigkeitsberechnung und Reisezeitverkuerzung, Karlsruhe, Schrifenreihe des Instituts fuer Verkehrswesen, Universiaet Karlsruhe, 1968

[7] A. Munawar, "Queue and Delay at Signalized Intersection, Indonesian Experience", Proceeding of the Symposium on Highway Capacity Manual and Quality of Service, Yokohama, July 25 – 28, 2006

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