Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Identification of Effective Intersection Control Strategies During Peak Hours

A Vajeeran[a] , GLDI De Silva[b]*

[a] *Graduate Research Assistant, University of Moratuwa, Moratuwa 40000, Sri Lanka*
[b] *Senior Lecturer, University of Moratuwa, Moratuwa, 40000, Sri Lanka*

Abstract

Traffic congestion during peak hours is one of the major issues in developing countries like Sri Lanka. Drivers undergo a considerable delay during the peak hours especially in the city centres. There are several identified reasons for the congestion. Among them ineffective intersection control strategy used is one of the major cause. There are several levels of intersection controls available. In case of Sri Lanka during the peak hours most of the intersections in city centres are controlled by traffic police in major intersections and in some extreme traffic conditions grade separated intersections also provided. When the traffic police officers control the intersection they mostly use the queue clearing approach. In such case their preference will be on the major road movements and lesser preference will be given to the minor road movements. This study tried to find out the effectiveness of the manual control by traffic police officers compare to traffic signals. Four Junctions which are controlled by Traffic police officers during the peak hours selected for the analysis. Traffic micro simulation software VISSIM has been used for the analysis and it has been calibrated and validated to local conditions before using it for the analysis. Junctions were modelled for the traffic police phase arrangement and cycle time, and for a designed traffic signal time. When the junction is undersaturated traffic signals gives lesser delay than traffic police officers control. When the junction is oversaturated traffic police officers become effective because they allow risky merging movements to reduce the critical flows.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: *Cycle time; Phase; Delay; Queue Length;*

* Corresponding author. Tel.: +94 779722025; fax: +0-000-000-0000 .
E-mail address: 168036J@uom.lk

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

1. Background information

1.1. Introduction

Traffic congestion and delays during peak hours has become a serious issue in developing countries like Sri Lanka. Many of the intersections in the city centers are congested during peak hours. Therefore, many road networks especially within the city centers have been subject to congestion. Heavy traffic congestion is experienced during school opening hours especially between 7.15a.m. - 7:45a.m and then followed by office traffic between 8.00a.m and 9.00a.m. In the afternoons and evenings, the same traffic congestion occurs between 1.30p.m-2.30p.m and 5.00p.m-8.00p.m.

There are several reasons for the congestion such as excessive traffic flow, insufficient road capacities, pavement conditions, road network, driving behaviors of the drivers, Shortage of parking areas, poor infrastructure for pedestrians, parking of heavy vehicles on main roads, poor intersection control strategies, and etc. Among the reasons for the traffic problem poor intersection control strategy is one of the main reason for the traffic problem. Traffic management at intersections during peak hours when the maximum flows are experienced is becoming a challenge.

In case of Sri Lanka during the peak hours most of the intersections in city centres are controlled by traffic police in major intersections and in some extreme traffic conditions grade separated intersections also provided. When the traffic police officers control the intersection they mostly use the queue clearing approach. In such case their preference is on the major road movements and lesser preference is given to the minor road movements. Therefore, it is essential to find the overall performance of manual control compare to the traffic signals.

In this research traffic simulation software VISSIM has been used as the analyzing tool. The benefit of using this computer software is that it is fast and cost effective. Rather than implementing and checking the changes in the actual condition to see the suitability, this software model itself gives the required output to analyze the suitability of the proposed new plans. The software needs to be calibrated to local conditions before using it for the analysis.

1.2. Objectives

The objective of the study is to find the effectiveness of the manual intersection control strategy compare to Traffic signals.

2. Literature Review

To achieve the research objectives literature review regarding different intersection control strategies and micro simulation has been done. The review covers the areas under, categories of intersections, different intersection control strategies, traffic signal design concepts, delay models and micro simulation using VISSIM software.

Intersections can be classified into four according to their functional. They are, priority intersection, space sharing intersection, time sharing intersection and uncontrolled intersection. The intersection control strategies can be categorized in different levels. They are, passive control, semi control and active control. In passive control, there is no external control on the driver. In semi control, some amount of control on the driver is there externally. In active control the movement of the traffic is fully controlled and the drivers cannot act according to his choice. To go from one level of control to the next level there are several warrants to be satisfied.

The parameter 'delay' is complex to determined due to the non-deterministic nature of arrival and departure process of the vehicles at the intersection. There are several researches done on this area to find delay by number of analytical delay models, including queuing, steady state stochastic and time dependent stochastic model. They made many assumptions also to reduce the complexity of flow to a quantifiable model.

A new signal time should be designed for the analysis to compare Manual control vs Traffic signal control. Signal cycle time has been designed using Webster & Cobbe (1966) model.

$$C = \frac{1.5L+5}{1-\frac{\sum_{i=1}^{n} q_i}{S}} \tag{1}$$

VISSIM is a microscopic time step and behaviour-based traffic simulation software which has been widely used assessing traffic conditions. It is especially useful to evaluate different traffic management scenarios to choose the best and optimization measures before implementation. The software itself have some default driving behavioural parameters. As Sri Lanka has a heterogeneous traffic conditions and aggressive driving behaviours the model has to be calibrated to suit the Sri Lankan conditions.

3. Methodology

The research methodology includes the following tasks to achieve the research objectives.

- Review of literature regarding different intersection control strategies and micro simulation.
- Selection of multiple intersections which are controlled by traffic police during peak hours
- Data Collection
  - Geometrical Details
  - Traffic flow, Vehicle classified count, turning movements, queue length
  - Timing and phasing arrangement of traffic police
- Calibrate the Vissim Software Driving behavioral parameters to suit the Sri Lankan conditions and validate those parameters.
- Modelling the selected junctions with,
  - Manual control by traffic police
  - Traffic signal control.
- Analyze the delay and queue results and find the effective control strategy during peak hours

4. Data Collection

For the analysis 5 intersections which are controlled manually during the peak hours has been selected. The selected intersections are,

- Kesbewa Junction – Cross Junction (For calibration of the vissim model)
- Maliban Junction – T Junction
- Golumadama Junction – Cross Junction
- Katubedda Junction – T Junction
- Kohuwala Junction – Cross Junction

Among the 5 intersection the Kesbewa Junction has been selected for the Calibration of the vissim model and other four junctions for the analysis. The Katubedda, Maliban, and Golumadama Junction consist Galle – Colombo main road which is heavily congested during the peak hours. The Geometric data, Traffic flow, turning movements, Vehicle Classified count, Queue Lengths, timing and phasing arrangement of traffic signals and traffic police were collected in all the junctions.

4.1. Geometric Data

The geometric arrangement of the intersection is essential for the vissim modelling to ensure the results. The important geometric parameters like number of lanes, lane widths, length of the turning lanes, pedestrian crossings were collected in the junctions.

Figure 1 Kohuwala Junction

4.2. Traffic data

The turning movements and vehicle classified count has been taken through traffic video survey at the junction and the traffic flow at the junction counted manually at the field and verified with the Video count. The camera positions were selected during the reconnaissance survey by considering the safety and coverage of the junction area. With the previous studies it is identified that the evening peak at these junctions occurs from 5:00 p.m. to 7:00 p.m. Vehicle classified count has been taken in all junctions for 8 different vehicle categories (Motor Bike, Three-wheeler, Car, Van, Medium good Vehicle, Medium Good Vehicle, Large Good Vehicle and Bus).

At the kesbewa junction the maximum queue length per each signal cycle for all 4 directions has been gathered for the calibration process. The survey there had conducted from 7:00 a.m. to 9:00 a.m. where the first hour data for the calibration process and second hour data for the validation of the calibrated parameters. Data collected at Kohuwala Junction is given below as the sample in Table 1, Table 2, Table 3 and Table 4.

Table 1 Golumadama Junction Traffic Flow

Start time	Time	Vehicle approaching from				Junction Flow	Hourly flow
		Nugegoda	Pepiliyana	Kalubowila Hospital	Colombo		
5:00 pm	0-15	338	301	228	504	1371	
5:15pm	15-30	348	304	252	629	1533	
5:30pm	30-45	445	283	219	491	1438	
5:45pm	45-60	402	331	156	532	1421	5763
6:00pm	60-75	443	276	197	531	1447	**5839**
6:15pm	75-90	363	315	210	402	1290	5596
6:30pm	90-105	317	321	210	445	1293	5451
6:45pm	105-120	312	306	201	421	1240	5270
Peak Hour Flow		**1638**	**1194**	**824**	**2183**	**5839**	

Table 2 Kohuwala Junction – Peak Hour Flow

Day	Vehicle approaching from				Junction Flow	Percentage change from Day 1 flow
	Pepiliyana	Kalubowila Hospital	Nugegoda	Colombo		
1	1194	824	1638	2183	5839	0
2	1168	836	1536	2071	5611	-3.91%
3	1192	867	1372	2104	5535	-5.21%

Table 3 Kohuwala Junction - Vehicle Classified Count Day 1

Vehicles approaching from	Vehicle Categories							
	Car	Motor bike	Three-wheeler	Van / jeep	Bus	LGV	MGV	HGV
Nugegoda	31.8%	27.2%	30.5%	4.6%	2.4%	1.8%	1.8%	0.1%
Pepiliyana	34.6%	19.8%	39.3%	1.6%	2.3%	1.9%	0.4%	0.1%
Kalubowila	33.5%	20.4%	37.6%	3.6%	2.7%	1.4%	0.9%	0.0%
Colombo	33.7%	37.6%	16.8%	5.2%	3.0%	2.6%	1.1%	0.1%

Table 4 Kohuwala Junction - Turning Movements Day 1

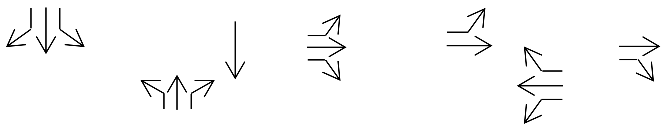
Turning Movements at Kohuwala Junction Day 1							
From Nugegoda				From Pepiliyana			
Time	Through	Right	Left	Time	Through	Right	Left
0-15	134	38	176	0-15	177	78	49
15-30	197	32	216	15-30	167	83	33
30-45	157	34	211	30-45	199	101	31
45-60	188	38	217	45-60	175	75	26
60-75	183	34	146	60-75	196	92	27
75-90	148	16	153	75-90	220	75	26
From Kalubowila Hospital				From Colombo			
Time	Through	Right	Left	Time	Through	Right	Left
0-15	181	56	15	0-15	553	5	71
15-30	181	28	10	15-30	406	15	70
30-45	122	26	8	30-45	458	7	67
45-60	152	37	8	45-60	450	6	75
60-75	154	47	9	60-75	356	6	40
75-90	158	45	7	75-90	401	4	40

4.3. Intersection Control Data

All the junctions other than Kesbewa junction are controlled manually during the evening peak hour which is essential for our analysis. Simulating the manual control in vissim software is highly impossible so a nearly equal strategy has been used to model the manual control in the software. The cycle time, phase time and phase arrangement used by the manual controller had been taken for each cycle and the average of them has been used for modelling. That timing and phase arrangement can be modelled as a traffic signal + Restrained conflicting movements in the vissim software so that it will simulate what we do manually on the field. Manual control phase and time used by traffic police officers at Kohuwala junction is given in Table 5.

Gathering the existing signal timing on the intersection makes no use as the currently posted one could be outdated. So, for the analysis posted signal timing cannot be used to check the efficiency of the traffic signals. A new signal time should be designed for the analysis.

Table 5 Traffic Police Intersection Control Phase and Time

Cycle No	Phase					Cycle time (s)
	1	2	3	4	5	
Direction						
1	28	74	30	118	10	260
2	30	81	21	122	21	275
4	60	85	35	95	20	295
5	20	65	25	90	15	215
7	20	95	45	110	15	285
8	20	80	15	95	20	230
10	22	60	25	80	10	197
11	40	80	40	70	10	240
13	35	85	25	85	10	240
Average Time	31	78	29	96	15	249

Likewise, traffic data at the other four junctions were collected.

5. Calibration of vissim software

VISSIM is a microscopic time step and behavior-based traffic simulation software which has been widely used assessing traffic conditions. It is especially useful to evaluate different traffic management scenarios to choose the best and optimization measures before implementation. The traffic analyzing key parameters like Delay, Vehicle travel time, Queue length and junction flow values can be easily generated using the VISSIM software.

To generate accurate results the model needs to be calibrated to suit the Sri Lankan conditions. Traffic in developing countries like Sri Lanka are heterogeneous in nature. Heterogeneous traffic is characterized by a wide mix of vehicles having diverse static and dynamic characteristics. “Driving Behavior” parameters are the key parameters to calibrate the model to Sri Lankan conditions. The VISSIM software itself has some default driving behavioral parameters to suit many conditions such as urban and rural areas. But none of them represents the Sri Lankan Conditions because most of the Sri Lankan drivers have aggressive mind set of Driving especially during peak hours. So a driving behavior parameter template has to be created in vissim software to match the driving behavior of the Sri Lankan drivers.

The calibration can be done in two ways, equating the junction flow and equating the propagated queue length per each direction. In this study the calibration had done in a trial and error process by changing the Driving behavioral parameters (Look ahead distance, look back distance, Minimum headway, Average standstill distance, Additive part of safety distance, Multiplicative part of safety Distance, Lateral distances) in the software model, the propagated queue length (Average of maximum queue length propagated per each signal cycle) is compared with the actual queue length observed in the field. All four directions of traffic were considered during the calibration process. This process is continued until these two set of values become nearly equal.

For the calibration the Kesbewa Junction has been selected. It is a four-leg intersection with proper lane markings and traffic signal. The traffic data at this intersection has been taken for 2 Hours (7:00 a.m. to 9:00 a.m.). The first one-hour data was used for the calibration of the junction and the second hour data used for the validation of the calibrated driving behavioral parameters.

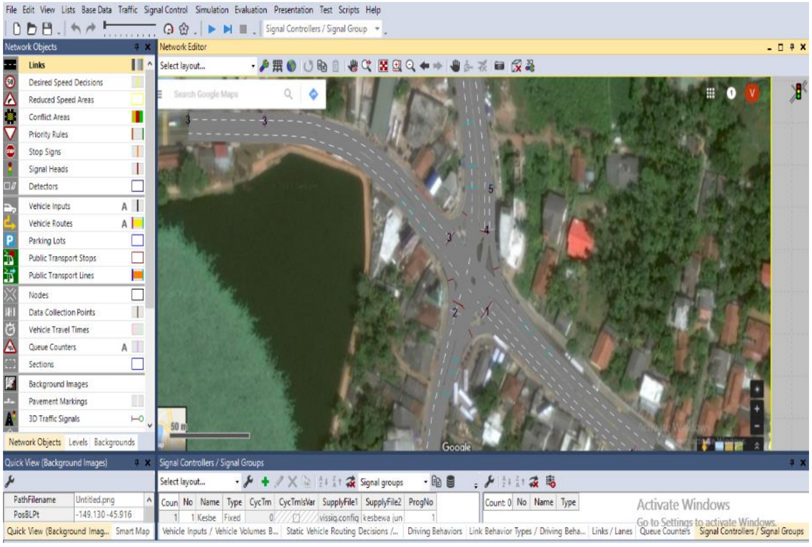


Figure 2 Kesbewa Junction – Vissim Model

Table 6 Calibration

Direction	Average of Maximum queue length per cycle		% Error from
	Actual	Model	Actual Value
1	78.34	90.32	15.30%
2	122.67	138.06	12.55%
3	65.54	73.18	11.66%
4	102.9	116.74	13.45%

Table 7 Validation

Direction	Average of Maximum queue length per cycle		% Error from
	Actual	Model	Actual Value
1	62.1	71.18	14.62%
2	68.67	80.56	17.32%
3	76.3	89.00	16.64%
4	55.34	60.52	9.36%

6. Results

During the peak flows intersections are controlled manually or by traffic signals. So, for the analysis four junctions which are controlled by traffic police during the peak hours has been selected. Where two of them are T junctions and Two are Cross Junctions. The geometry of the junction, vehicle flow, turning movements, vehicle classification count and traffic and manual control time and phase details were taken by surveys. Traffic micro simulation approach has been used in the analysis. Traffic simulation software PTV VISSIM is used as the analyzing tool. The software had been calibrated and validated to suit the Sri Lankan driver's behavior before using it for the analysis.

All the junctions were modelled for the phase time used by traffic police and for a designed signal value for the peak hour flow. Signal cycle time has designed using Webster's Signal cycle time model. Vehicle travel time has been defined in the model 250m upstream and 100m downstream to cover the maximum queue length. The vehicle delay, stop delay and maximum queue lengths were obtained from the model.

6.1. Katubedda Junction

During the peak hour the junction flow is 5992veh/h and the traffic police is maintaining an average cycle time of 257s. The traffic signal cycle time has designed using Webster & Cobbe (1966) signal cycle time model. The designed signal cycle time is 191s. The average saturation headway measured at the junction is 1.9s and the saturation flow rate is 1894 pcu/h. The total Critical lane flow at the junction is 1722 pcu/h. So, with the existing geometry of the junction we can accommodate this cycle time.

Table 8 Delay results during Peak Hour – Katubedda Junction

Direction	No of vehicle	**Traffic signal**		**Traffic police**	
		veh delay (s/veh)	Tot Veh delay (vehh)	veh delay (s/veh)	Tot Veh delay (vehh)
1: Colombo to Piliyandala	615	95.83	16.37	94.79	17.01
2: Colombo to Moratuwa	1916	99.54	52.98	95.16	52.21
3: Piliyandala to Moratuwa	528	55.05	8.07	76.23	11.22
4: Piliyandala to Colombo	376	56.63	5.91	126.06	13.45
5: Moratuwa to Colombo	1441	13.16	5.27	15.23	6.11
6: Moratuwa to Piliyandala	349	63.24	6.13	100.74	9.09
Total Delay during peak hour (Vehh)			**94.74**		**109.09**

6.2. Malian Junction

During the peak hour the junction flow is 5987veh/h and the traffic police is maintaining an average cycle time of 188s. The traffic signal cycle time has designed using Webster & Cobbe (1966) signal cycle time model and the designed cycle time is 148s with three phases. The average saturation headway measured at the junction is 2.1s and the saturation flow is 1725 pcu/h. The total Critical lane flow at the junction is 1522 pcu/h. So, with the existing geometry of the junction we can accommodate this cycle time.

Table 9 Delay results during Peak Hour –Maliban Junction

Direction	No of vehicle	**Traffic signal**		**Traffic police**	
		veh delay (s/veh)	Tot Veh delay (vehh)	veh delay (s/veh)	Tot Veh delay (vehh)
1: Moratuwa to Colombo	1743	5.58	2.70	7.16	3.46
2: Moratuwa to Mirihana	540	35.50	5.32	59.74	9.36
3: Mirihana to Moratuwa	862	111.74	26.75	206.30	50.83
4: Mirihana to Colombo	95	181.07	4.78	290.27	8.47
5: Colombo to Mirihana	73	29.64	0.60	17.74	0.35
6: Colombo to Moratuwa	2035	42.00	23.74	36.90	20.41
Total Delay during peak hour (Vehh)			**63.90**		**92.87**

6.3. Golumadama Junction

During the peak hour the junction flow is 5987veh/h and the traffic police is maintaining an average cycle time of 188s. The designed cycle time is 148s. The saturation flow is 1700 pcu/h. The total Critical lane flow at the junction is 1462 pcu/h. So, with the existing geometry of the junction we can accommodate this cycle time.

Table 10 Delay results during Peak Hour –Golumadama Junction Junction

Direction	No of vehicle	**Traffic signal**		**Traffic police**	
		veh delay (s/veh)	Tot Veh delay (vehh)	veh delay (s/veh)	Tot Veh delay (vehh)
1: Moratuwa to Kaldemulla	125	14.94	0.52	20.39	0.71
2: Moratuwa to Colombo	1756	16.59	8.09	22.55	10.98
3: Moratuwa to Borupana	155	62.01	2.67	60.60	2.59
4: Kaldemulla to Moratuwa	88	52.81	1.29	60.05	1.50
5: Kaldemulla to Borupana	71	56.70	1.12	60.21	1.19
6: Kaldemulla to Colombo	120	53.33	1.78	53.04	1.80
7: Colombo to Kaldemulla	144	70.60	2.82	73.26	2.83
8: Colombo to Moratuwa	2948	29.03	23.78	42.90	35.32
9: Colombo to Borupana	153	25.75	1.09	39.88	1.73
10: Borupana to Colombo	133	65.45	2.42	55.16	1.98
11: Borupana to Kaldemulla	67	70.90	1.32	64.59	1.20
12: Borupana to Moratuwa	203	43.70	2.46	39.59	2.21
Total Delay during peak hour (Vehh)			**49.36**		**64.03**

6.4. Kohuwala Junction

During the peak hour the junction flow is 5839veh/h and the traffic police is maintaining an average cycle time of 249s. The saturation flow is 1860 pcu/h. The total Critical lane flow at the junction is 2209 pcu/h. the junction is over saturated. So, with the existing geometry of the junction we cannot accommodate traffic signals there as we cannot further reduce the phases. The traffic police officers control this intersection by allowing the merging traffic movements to reduce the critical lane flows. But with the aggressive nature of driving of Sri Lankan drivers it is not safe to allow merging a relatively high left turns to through movements.

7. Conclusions

The analysis had been done using micro simulation approach to achieve the objectives of the study. At the three junctions Katubedda, Maliban and Golumadama the total critical lane flows are less than the saturation flow rate. In these junctions the total delay from traffic signals gives lesser delay than the delay from manual control during the peak hour. So, when the Junctions are not oversaturated it is effective to control the intersections by traffic signals than control them manually

Table 11 Total delays During peak hours – All Junctions

Junction	Total delay during the peak hour	
	Manual	Signal
Katubedda	150.07	137.00
Maliban	92.87	47.64
Golumadama	64.03	49.36

When the Traffic police officers control the intersection, they use mostly queue clearing approach. They consider mostly the major road traffic and they give relatively less preference to the minor road movements. From the results from both Maliban junction and Katubedda junction it is evident that the total delay for Major road movements Moratuwa to Colombo and Colombo to Moratuwa have no significant change for both cases of control. But the minor road movements have a significant reduction in delay from manual control to traffic signal control.

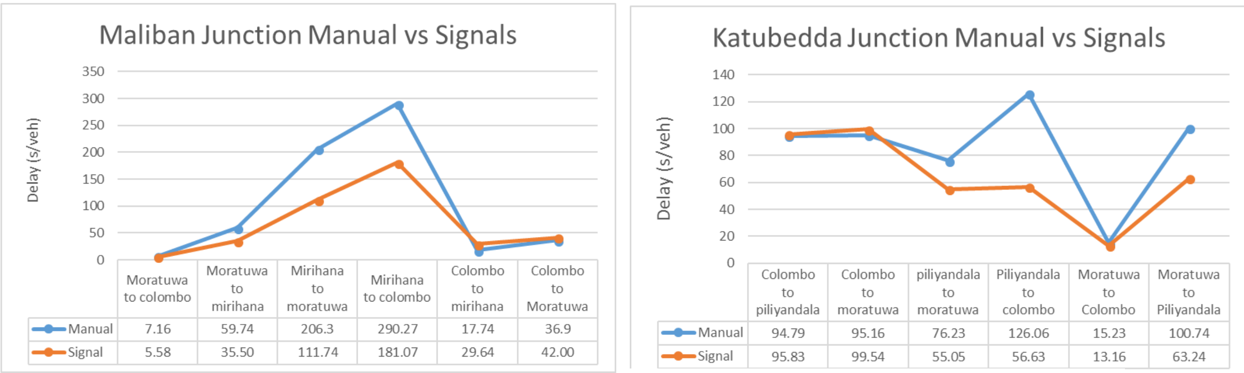


Figure 3 Vehicle delay Manual Control vs Traffic Signals

When the junction is over saturated (where the critical flows are higher than the saturation flow) traffic signal design theories fails. In such cases traffic police manage the intersections by allowing all left turn movements to merge with the through movements. Even though it looks effective it effects lesser safety to pedestrians and vehicle users.

Daily variation of traffic flow makes significant effect on delays at traffic signals. At Katubedda junction analysis has been done for different percentage of peak hour junction flow. Up to 2.5% increase of junction flow the total delay during the peak hour doesn't increase more than the total delay from the manual control by traffic police officers. The main problem of having a fixed cycle time traffic signals is the daily variation of traffic. So rather than managing this issue by controlling intersections manually, vehicle actuated traffic signals should be introduced.

Table 12 Daily variation of flow at Katubedda Junction vs Total delay

Variation from Peak hour junction flow	Junction Flow (veh/h)	Total delay (vehh)
-10%	5379	68.45
-5%	5678	80.86
0%	5977	94.74
2.5%	6126	110.73
5%	6276	137.67

References

Edirisinghe.D.U.A, "Managing traffic congestion in Colombo," Sri Lanka Institute of Development Administration, Colombo, 2014.

Woensel T.V. and Vandaele.N, "Queuing models for uninterrupted traffic flows," Faculty of Applied ecconomics, University of Antwerp., Antwerp, Belgian, 2004.

S. Gupta, "Delay at Signalized Intersection," Department of Traffic Engineering, Indian Institute of Technology, India.

Miller.A.J, "A queue model for road traffic flow.," Royal Statistical Society, vol. 23B, pp. 64-75., 1961.

Dong LIN, Xiaokuan YANG and Chao GAO, "VISSIM-based Simulation on Road Network of CBD in Beijing, China.," in 13th COTA International Conference of Transportation Professionals (CICTP 2013), Beijing, China., 2013.

Siddharth S M P and Gitakrishnan Ramadurai, "Calibration of VISSIM for Indian Heterogeneous Traffic," in 2nd Conference of Transportation Research Group of India (2nd CTRG), India, 2012.

PTV-Group, PTV vissim 8, User manual, Karlsruhe, Germany: PTV Group, 2015.

Nse S. Udoh and Emmanuel J. Ekpenyong, "Analysis of Traffic Flow at Signalized Junctions in Uyo Metropolis," Department of Mathematics and Statistics, Michael Okpara University of Agriculture., Umudike, Abia State, Nigeria., 2012.

F. Webster, "Traffic signal settings," Road research technical paper 39, London, 1958.

Chang-qiao and Xiao-ming Liu, "Estimation of saturation flow rates at signalized intersections," Lab of Transportation Engineering, Beijing University of Technology, Beijing, China, 2012.

Hellinga B and Liping F, "Delay variability at signalized intersections," in Publication of the Transport Research Board, Canada, 2001.

L. R Kadiyali. Traffic Engineering and Transportation Planning. Khanna Publishers, New Delhi, 1987.

William R McShane, Roger P Roesss, and Elena S Prassas. Traffic Engineering. PrenticeHall, Inc, Upper Saddle River, New Jesery, 1998.