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Evaluating the Efficiency of a Traffic Signal Light over a Traffic Policeman

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Abstract: The overall effect of traffic is considered to be high, at most of the intersections when they are controlled by traffic signal lights during peak hours

. This causes lengthy queues and user inconveniences at intersections. Traffic police officers also control some of the intersections during peak hours in order to reduce this queue length and waiting time. The objectives of this research were to determine the relationship between the queue length formed and vehicular delay at peak hours, when the intersection is controlled by traffic signal lights and traffic policemen. Data was collected in two four-way intersections at Kanatta road / Dudley Senanayake Mawatha and Golumadama intersection. When the queue length was considered by 5-minute time intervals, the number of vehicles in the queue were higher with traffic signal control, compared to police controlled intersection. Further, per signal cycle queues were also counted in the said two scenarios. The observed values were furthers tested using Contingency Table analysis (Chi-square test) to assess whether the effect is statistically significance. Results showed that, queue lengths and the number of waiting hours were higher when the intersection was controlled by traffic signal lights compared to a traffic policeman. However, per cycle waiting time was significantly higher when controlled by policemen. Therefore, when a single-user point of view, the intersection delay may seem higher when controlled by a traffic policeman. However, the overall delay at the intersection is lesser with the police control.

Keywords: Traffic Signal Lights, Traffic Policeman, Intersection delay

Introduction

The invention of motor vehicle had a great impact on human lives. This lead to the development and improvement of road conditions, with increased speeds and capacities which resulted vulnerability for the road users. So the necessity of properly controlling and channelization of traffic is a significant factor for road user safety.

In the early days, human resources were used to control traffic. In 1722, the Lord Mayor had appointed three men to control traffic on the London bridge, whom considered as the world's first traffic police. The first traffic signal had been installed in 1868 in London. It has used a semaphore 'arms' together with green and red gas lamps. In 1925, first three colored traffic signal light has been installed in New York. The first ever traffic signal light in Sri Lanka has been installed at Naval and Maritime Academy in Trincomalee. Traffic signal lights are used throughout the world to reduce conflicts by time-sharing right of way (Allsop, 1971; Gerlough and Wagner, 1964; Ndoke, 2006).

Traffic lights show the correct way to the road users by illuminating lamps or Light-Emitting Diods (LEDs) of standard colours: red, amber, and green, following the universal colour codes in the typical sequence of colour phases as mentioned (Reilly, 1997).

1) The green light allows traffic to proceed in the direction denoted, if it is safe to do so, and there is room on the other side of the intersection.
2) The amber light warns that the signal is about to change to red.
3) A flashing amber indication is a warning signal.
4) The red signal prohibits any traffic from proceeding.
5) A flashing red indication is treated as a stop sign.

Presently, road users face complications at intersections due to longer queue lengths and waiting times when the intersection is controlled by traffic signal lights. In order to reduce this complication, traffic policemen are used to control traffic at intersections during peak hours. The reason was believed as the signal cycle timings could not be optimized to a better scenario to cater for the high traffic flow rates. This research has evaluated how efficient the replacement of traffic signal lights could get by traffic policemen.

A study in the similar field was carried out by Parr et.al (2016) with the objective of quantifying the effect of manual traffic control at an intersection operation and to develop a quantitative model to describe the decision-making of police officers giving way for special events and emergencies (Parr et al., 2016). Apart from the main objective, the study has had three more objectives of conducting a quantitative analysis of the stimulus-response relationship between the traffic stream and officers' right-of-way decisions while directing traffic, simulating manual traffic control for the intersections in the study and evaluating the cost-benefit relationship between manual traffic control and automated traffic control. Results from that study has suggested that manual traffic control increased the intersection throughput by 16 percent because of a decrease in lost-time associated with longer phase lengths.

Methodology

This research was initially conducted focusing two factors;

1) The total number of vehicles at the queue formed in red traffic signal light
2) The total waiting time of vehicles at red traffic signal light

A. Site Selection

The Galle Road and Baseline Road have a number of intersections that are highly congested most of the time. This is due to the high volumes of vehicles that are approaching and leaving Colombo and a variety of trip attractionsare located around this area. Further, most of the intersections are highly congested during the school and office starting and ending times as well.

Various types of intersections around the area were identified as, T-intersections, Y-intersections, four-way intersections, five-way intersections, roundabouts, intersections with separate right turns, intersections without separate right turns, intersections with and without count down timers etc. Accordingly, this research focussed on two four-way intersections (Kanatta RD/ Dudley Senanayake Mw and Golumadama junction) which were controlled by both traffic police and traffic signal lights time to time. These intersections are shown in Figure 1.

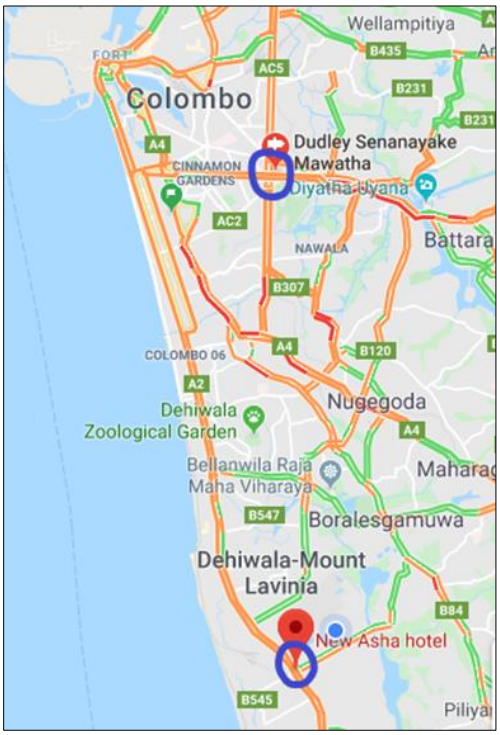

Figure 10. Selected Intersections
Source: Retrived from Google Maps (2019)

B. *Data Collection Duration*

Data was collected on two weekdays; Monday and Thursday. The peak hours differed with the day and Monday morning peak was not considered when taking the counts to capture the commuting traffic. This was because, it differed from a normal day, since higher number of vehicles travelled through selected intersections on Monday morning peak hours as returning pupoulation who were away during the weekends. Google maps were used to find the peak hour details of the selected intersections which is deliberated in Table 1. The traffic overlays in Google Maps were used on street maps. By the color indications of it, traffic congestions and mild traffic so forth were identified. By adjusting the day of the week and time of the day, behavior of a typical traffic flow on the selected intersections were realized. By adjusting the time periods, the time period which has the most congested condition for a given intersection was recognized as the peak period.

Table 15. Peak Hours Selection

Intersection	**Morning peak hour**	**Evening peak hour**
Golumadama	0730hrs-0830hrs	1550hrs-1650hrs
Kanatta RD/ Dudley Senanayake Mw	0840hrs-0940hrs	1635hrs-1735hrs

C. *Queue length determination*

The data collection was conducted in three types of approaches which are mentioned as follow;

1) Field Surveys
2) Manual Data Collection
3) Video Surveys

After the data collection process, the data analysing was carried out to evaluate how efficient was the replacement of traffic signal lights by traffic policemen could be.

According to the traffic control techniques, the types of traffic controls that were selected for this research was the controlling by the traffic police officer and the control of traffic by the traffic signal lights. Initially, signal light phases were observed in order to identify the phase at which the intersection was controlled by traffic signal lights and the phase of which it was controlled by traffic policeman. During the field survey, parameters such as queue lengths and the vehicular delays were observed and subsequently, the data was used for the evaluations.

Traffic counts were obtained with the use of tally counters and a mobile software called “Counter”, which made the collection and recording of data convinient with limited

human resources available. The manual counts were taken with the assist of sixteen observers. Five observers for each main road and three observers for each by road was considered.

Subsequently, five observers were allocated for the main road such that large busses/trucks/SUVs, threewheels/cars, van/minitrucks/motorcycles were counted by each individual respectively and one individual counting the right turnings and others taking the left turnings. Three members in the byroads, took the counts as number of left turns and right turns with the use of the mentioned mobile application.

During the data analysis stage, Passenger Car Unit (PCU) values were taken into consideration which were from a previous study conducted by the University of Moratuwa in 2016 (Jayaratne et al., 2016). The values considered for the analysis could be mentioned as;

1)	Car	1.0	
2)	Three-wheeler	0.6	
3)	Van/mini truck		1.2
4)	Motor cycle	0.2	
5)	Large bus	4.1	
6)	SUV	1.4	
7)	Truck	3.2	

D. Video Surveys

During this study, the traffic counts at Kanatta road/ Dudley Senanayake Mw (Borella junction) were taken using video recordings. The necessary permissions were taken from the Borella police station for the video recording since it was conducted at a public place. Two wide-angle cameras were fixed on either side of the road such that, it covered all four roads at the intersection at the same time. Moreover, four other cameras were fixed to take the queue lengths of each approach.

Video surveys were conducted at morning and evening peak hours when the intersection was controlled both by, traffic signal lights and by traffic police officers. The respective queue lengths were recorded separately for the calculation of the existing signal phasing arrangement at the intersection. Video recording was done at peak hours for a total time duration of one hour. Also separate queues that were generated when the approach was stopped by the traffic controls were recorded at the same time in order to compare the queues generated when intersection was controlled by the traffic police officer and when controlled by traffic signal lights.

Data extraction and analysis was done by counting the vehicles from the videos taken and accordingly, data was tabulated considering the two approaches. This data analysis was useful in order to find the queue length formed when the approached vehicle was stopped by traffic signal lights or policemen. The number of vehicles in the queues which were at the start of red signal light were tabulated with five-minute intervals.

E. Data Analysis

Contingency table analysis or the Chi-square test was done to analyze statistical significance of any effect between the two traffic control types.

H_0: Null hypothese: Two queue lengths are independents of the traffic control type

H1: Alternative hypothesis: H_0 is not true,

If the Chi-square $(\chi^2)_{\text{critical}} < \chi^2_{\text{estimated}}$; H_0 is rejected

If the Chi-square $(\chi^2)_{\text{critical}} > \chi^2_{\text{estimated}}$: No sufficient evidence to reject H_0

Using this statistical test, it was tested whether the observed increase in queue length or decrease, is actually a statistically significant difference. Confident interval was taken as 95% for all analyses.

Also Signal timing calculations were done in order to see whether the traffic signal lights were operating at correct phasing arrangement. Webster's method was used in that.

Results and Discussion

A. Que Lengths formed at Borella Junction

The results presented in Figure 2 shows a clear difference between the queue lengths formed with the two control methods. However, this was not found statistically significant.

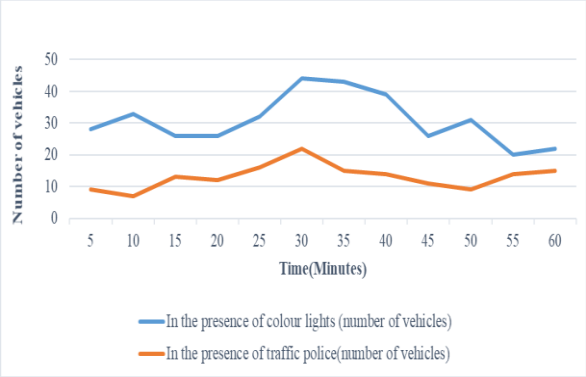

Figure 11. Queue lengths towards Baseline

Results showed that a higher volume of vehicles waited at the approach towards baseline, when the intersection was controlled by traffic signal lights. Accordingly, similar behaviour of higher volume of vehicles controlled by traffic signal lights were observed from the results towards Kollupitiya, towards Dudley Senanayake Mawatha and towards Dehiwala at the Borella junction.

B. Vehicle Waiting Times at Borella Intersection

As shown in Table 2, a comparison between the delay at each approach and the total delay caused at the intersection when the intersection was controlled by traffic signal lights and traffic policemen was carried out. Same as previous, the approach the taken as towards Baseline as shown in table 3, and the other three approaches; approach towards Dudley Senanayake Mawatha, Borella and Kollupitiya. The results further proved that, all four approaches showed a higher queue length when the intersection was controlled by traffic signal lights.

Table 2. Results of Queue Length Towards Baseline at Borella Junction

Type of control	Vehicle hours				
	Towards Kollupitiya	Towards Baseline	Towards Dudley Senanayake Mawatha	Towards Borella	Total Delay
Traffic Police	12.62	4.30	3.53	3.61	24.06
Traffic Signal Lights	21.07	10.59	12.41	12.81	56.88

C. Contingency table analysis

When the five-minute interval queue lengths (converted to PCU) were considered, the Table 3 was obtained.

Table 3. Comparison of queue length: 5 min intervals

	Approach_1	Approach_2	Approach_3	Approach_4
SL	85.67	30.83	35.58	36.67
PM	27.17	13.08	7.58	11.83

Where,

SL: With traffic signal light
PM: with traffic policeman
Approach_1: towards Kollupitiya
Approach_2: towards Baseline
Approach_3: towards Dudley Senayake Mawatha
Approach_4: towards Borella

$\chi^2_{critical}$ = 7.815 (for Confidence Interval of 95%)

$\chi^2_{estimated}$ = 1.5656 (Decimal placed were removed by rounding up for discrete variable definition)

7.815 > 1.5656

Therefore, no clear conclusion can be reached, and the null hypothesis is sustained. Moreover, the p-value is estimated .667225. Hence, the result is not significant at p < .05.

By observing the values, it seems that the queue length is longer when the intersection is controlled by a traffic signal light. However, that is statisticaly proven to be significant.

When the cycle-wise queue length is considered, the Table 4 can be developed

Table 4. Comparison of queue length: per cycle

	Approach_1	Approach_2	Approach_3	Approach_4
SL	73	103	104	105
PM	188	94	1391	95

$\chi^2_{critical}$ = 38.3877 (for Confidence Interval of 95%)

$\chi^2_{estimated}$ = 7.815 (Decimal placed were removed by rounding up for discrete variable definition)

38.7777>> 7.815

Therefore, the Null hypothesis is rejected. Hence, the visible increase in queue length can be considered statistically significant. Furthermore, the p-value is < 0.00001. The result is significant at p < .05.

D. Evaluating the Appropriateness of Current Phase at Golumadama Intersection

Currently, the Golumadama intersection is controlled with a five-phase signal light scheme. With the phase calculations done according to the 'Webster method', it was identified that the allocated phase scheme was not suitable to control the current traffic during peak hours at Golumadama Intersection. The results from the Webster's method showed that none of the phases satisfied the required condition. Due to lengthier calculations, it was not mentioned in this paper. So, as a result of the current allocated phase scheme, the vehicles had to face a greater delay at the intersection. However, as a soulution for this issue, a signal timing optimization could be implemented inorder to increase the intersection delay at that the intersection. Authors cannot comment on that without a traffic simulation software.

Conclusion

Use of a traffic policeman for traffic control at intersections of arterial vs collector or arterial vs arterial is frequently observed during peak periods. In Sri Lanka, this is observed at certain intersections where the right turns are high. However, as it is not observed in many other countries, traffic policemen are used in Sri Lankaa at signalized intersections with

amber light on for all movements. The reason for this is that the signal timing in the cycle does not help at high traffic flows in the peak hour (Alexander et al., 2014). As adaptive traffic signals are not availbe in Sri Lanka at the moment, traffic policemen are used in peak times to eliminate this issue. However, it is a social opinion that the delay at an intersection increases when it is controlled by a traffic policeman. This study attempted to study this scenario and conclude upon the suitability of the use of policemen at intersections. Contingency analyses were carried out for difference scenarios. Only some scnearios of this study are reported in this paper.

From the results obtained, it was observed that the queue lengths and waiting time for all approaches were high when the traffic was controlled by traffic signal lights compared with the control of traffic policemen. However, when the intersection was controlled by traffic police, the individual delay was greater, so a rider has to spend more time before clearing the intersection, if the queue in the clearing approach is greater.

The intersection delay showed that the delay observed while policemen controlled intersections were 32 vehicle hours lesser when compared with traffic signal lights. During this study, it was identified that a police officer would be good at allocating time properly, at any given situation, where he could give priority to emergency vehicles and he is able to use the common sense judgments on situations where necessary. Also, in overly saturated conditions, traffic policemen tend to run very long phases (longer time duration for one phase) in order to clear the whole queue resulting in unbalanced delays on other approaches. During the study, it was clear that the communication between the traffic policemen at neighboring intersections helped them for a better understanding of the queue situation of different approaches and giving them the priority as needed.

When the intersection was controlled by traffic policemen, the clearing shall be done in one approach at a time. One of the negative issues identified during this research was when the traffic police officer clear the approach, subsequently the sequence they use to clear the approach adversely affects the other approaches, resulting of a gradual vehicle block.

When considering the calculations done regarding the Golumadama intersection it was understood that the current phasing scheme was not suitable for that particular intersection during peak hours. With this phasing scheme all the vehicles which approached towards the intersection were not able to pass the intersection during green time causing long queue lengths. So, it is recommended that the traffic planners should consider alternative options to reduce the traffic at this intersection either by changing the phasing scheme or replacing a traffic policeman. Since this intersection is already controlled with a five-phase traffic scheme during peak hours, increasing of phases will rise the intersection delay. So that option would not be suitable to control the traffic, instead it is recommended to replace of signal lights with a traffic policeman during peak hours to control the traffic without causing long queues or traffic congestion at the intersection.

Therefore, when a single-user point of view, the intersection delay may seems higher when controlled by a traffic policeman. However, the overall delay at the intersection is lesser under that condition.

Therefore, with the results of this study, it can be seen that the first option to minimize the delay at intersections may not be to replace by

a traffic policeman at all the times. It can be checked whether a signal time optimization can be introduced. As a social study, it has to studied whether a road user prefers the individual waiting time to be lesser over minimizing the intersection delay.

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