Methodology for determining optimized traffic light cycles based on simulation

G Rivera[1], L Velasquez[1], A Bravo[2] and P Miñano[2]

1 Research Student. Faculty of Civil Engineering, UPC, Lima, Peru
2 Full Professor. Faculty of Civil Engineering, UPC, Lima, Peru
E-mail: aldo.bravo@upc.pe

Abstract. In large urbanized cities, a major problem that affects the economy and health of all citizens is vehicular congestion. This is because the traffic light cycles are not adequate. In the present study, we seek to optimize traffic light cycles based on simulation, in order to improve vehicle flow. For this, the PTV Vissim 9.0 software was used as a simulator and the Synchro 10.0 software to determine the initial optimal traffic light cycle. Through several runs and having as variables the length of queues, delay times and the average speed, the optimal traffic light cycle could be found for the study area. The results obtained reflect a 14% reduction in delay times and 10% in queue lengths. On the other hand, the average vehicle speed increased by 10.56%. All this represents an improvement in the service level of the study intersections.

1. Introduction

The growth of the motor park in the major cities of the world brings with it the increase in vehicular congestion, which has an impact on the economy and health of all citizens. This is due to a delay in the management of urban circulation systems that causes various problems that affect traffic [1]. Currently finding a solution to these problems requires that the investment of significant resources is aimed at improving existing infrastructure.

With the rise of the motor park in modern cities, the problem remains unresolved and even worse is compounded every year. There are several solution proposals to reduce this problem. The first is to modify the existing road infrastructure (rails, bridges, roundabouts or underground passages). This solution can be implemented in non-metropolitan areas, but it is very expensive. Another concerns the restriction of mobilization of private vehicles in high-density flow times. The most promising approach is the smart traffic light system that can adapt to real-time traffic conditions. This proposal is the most cost-effective because it only requires the integration and updating of existing systems, without imposing restrictions on the movement of the vehicle [2].

Programs used for the investigation of traffic control systems are divided into two types. The first concerns Adaptive Traffic Control Systems (ATCS), which consist of changing the duration of the traffic light cycle based on sensors located on the tracks which detect queued vehicles in real time. However, managing this system requires a high operating cost and qualified personnel. This real-time traffic information allows drivers to plot an optimal route to reach their destination [3]. The second approach is to use highly modern simulators [4], to simulate real-world scenarios cost-effectively and test them by iteration parameters (queue lengths or speeds) microscopic or macroscopic traffic views [5].

Within this context, the work done consists specifically of the topic of optimizing simulation-based traffic light cycles.

2. Case study

For this study, two intersections located in the city of Lima will be evaluated. According to the Dutch GPS company "TomTom" [6], it is ranked third in the world ranking of congested cities. Javier Prado Avenue is one of the main roads used so it is necessary to have an optimal vehicular flow. That is why the assessment of the intersections of the Av. Javier Prado – Ca. Las Flores y la Av. Javier Prado – Ca. Las Palmeras.

3. Methodology

The methodology used in this study is to generate an initial optimal cycle with Synchro 10.0 software. To do this, information (vehicle count, traffic light cycles, geometry and signaling) will need to be collected from the evaluated intersection. From this, through the simulation with the PTV Vissim 9.0 software will modify the traffic light cycles, taking into account variables such as tail lengths and average speeds (vehicles). This process is iterative so you can determine that the traffic light cycle is optimized when the tail length, decrease; and average speed; increase; in the best possible expression.

3.1 Data collection and analysis

To optimize traffic light cycles based on simulation, information was required from high vehicle density intersections in which the following were performed:

  i.   A vehicular count of the intersections was carried out for three days.
  ii.   Information was acquired on the geometry and signage of the study area.
  iii. The "peak hour" (period where there is higher vehicular density) at intersections was determined.

3.2 Modeling and calibration

A.   PTV Vissim 9.0

The Vissim 9.0 program is a microscopic traffic simulation model: each vehicle is explicitly modeled, has its own route and moves individually, through a route including vehicle tracking logic and lane change [7].

B.   Synchro 10.0

Synchro 10.0 is a program for modeling, optimizing, managing and simulating traffic systems. The generation of optimal time plans consists of optimizing the cycle duration, partial times, compensation and phase sequence to minimize driver stops and vehicle delay [8].

For modeling and calibration, the sketchup and Vissim 9.0 programs were used, which was performed as follows:

  i.   The Sketchup program included geometry, signaling, and all users involved in intersections.
  ii.   This file was exported to the Vissim 9.0 software in (skp) format.
  iii. The vehicle composition (cars, buses, trucks and motorbikes) and pedestrian composition were defined. In addition, the assignment of vehicle and pedestrian routes with priority rules, and control signals. The current traffic light cycles of the intersections studied can be seen in Table 1.
  iv.   The parameters of the model worked in the Vissim 9.0 program (speeds, times and queue lengths) were compared with the results obtained in the field. To do this, calibration was performed with the travel times of vehicles and pedestrians collected in the field.

Table 1: Current traffic light cycles present at intersections

Time (s)	Av. Javier Prado & Ca. Las Flores			Av. Javier Prado & Ca. Las Palmeras		
	Green	Amber	Red	Green	Amber	Red
W-E/E-W	169	3	150	248	3	177
Exclusive Turn	15	3	135	20	3	157
S-N	75	3	244	85	3	340
N-S	63	3	254	75	3	350

3.3 Validation and Simulation

Another dataset (aphores collected during a different day than the evaluated one) was used for model validation. On the other hand, the simulation was performed in time intervals of 15 min.

i.   The validation process consisted of analyzing the model with another dataset (vehicular and pedestrian capacity). The analysis was carried out on vehicles and pedestrians in the stretch with the highest demand.

ii.   15 runs were performed in each 15-minute time interval with the current traffic light cycle present at both intersections to assess traffic indicators (speeds, delay times and queue lengths); it was observed that the speed of vehicles at each access varies depending on the time set in each traffic light cycle, so at each interval, the time it takes to cross vehicles was measured by a distance of 235 m and then calculated the average speed per access. The above mentioned, can be seen in Table 2.

iii.   The proposal was to simulate the model with the optimized cycles obtained from the Synchro 10.0 program and as the parameters of tail lengths and vehicle speeds vary at each access, more optimized traffic light times were obtained, which are in Table 3.

iv.   In Table 4, it is noted that through changes in traffic light cycles higher average speeds were obtained, for each time interval, which will optimize the vehicular flow.

Table 2: Simulation of current parameters

Access	Av. Javier Prado & Ca. Las Flores			Av. Javier Prado & Ca. Las Palmeras		
	Time (s)	**Distance (m)**	**Speed (km/h)**	**Time (s)**	**Distance (m)**	**Speed (km/h)**
W-E/E-W	58	235	14.58	70	235	12.09
S-N	40	235	21.13	46	235	18.39
N-S	45	235	18.79	50	235	16.92

Table 3: Optimized traffic light cycles every 15 minutes

Time (s)	7:15 - 7:30 a.m.			7:30 - 7:45 a.m.			7:45 – 8:00 a.m.			8:00 - 8:15 a.m.		
	Green	**Amber**	**Red**	**Green**	**Amber**	**Red**	**Green**	**Amber**	**Red**	**Green**	**Amber**	**Red**
W-E/E-W	155	3	122	158	3	137	160	3	128	155	3	130
Exclusive Turn	25	3	97	30	3	107	25	3	103	25	3	105
S-N	45	3	232	50	3	245	48	3	240	50	3	235
N-S	55	3	222	60	3	235	58	3	230	58	3	227

Time (s)	8:45 - 9:00 a.m.			9:00 - 9:15 a.m.			9:15 – 9:30 a.m.			9:30 - 9:45 a.m.		
	Green	**Ámber**	**Red**	**Green**	**Ámber**	**Red**	**Green**	**Ámber**	**Red**	**Green**	**Ámber**	**Red**
W-E/E-W	235	3	142	240	3	142	238	3	147	240	3	147
Exclusive Turn	20	3	122	15	3	127	20	3	127	20	3	127
S-N	70	3	307	70	3	312	75	3	310	70	3	317
N-S	55	3	322	60	3	322	55	3	330	60	3	327

Table 4: Simulation of optimized parameters

Access	Av. Javier Prado & Ca. Las Flores			Av. Javier Prado & Ca. Las Palmeras		
	Time (s)	Distance (m)	Speed (km/h)	Time (s)	Distance (m)	Speed (km/h)
W-E/E-W	50	235	16.92	57	235	14.84
S-N	36	235	23.50	42	235	20.14
N-S	40	235	21.15	46	235	18.39

4. Discussion of the results

4.1 Tail lengths

Figure 1 shows the results of the simulation in the PTV Vissim 9.0 program by 15-minute intervals. The results indicate that the tail lengths decrease by 10%. This reduction is related to the optimization of traffic light cycles.
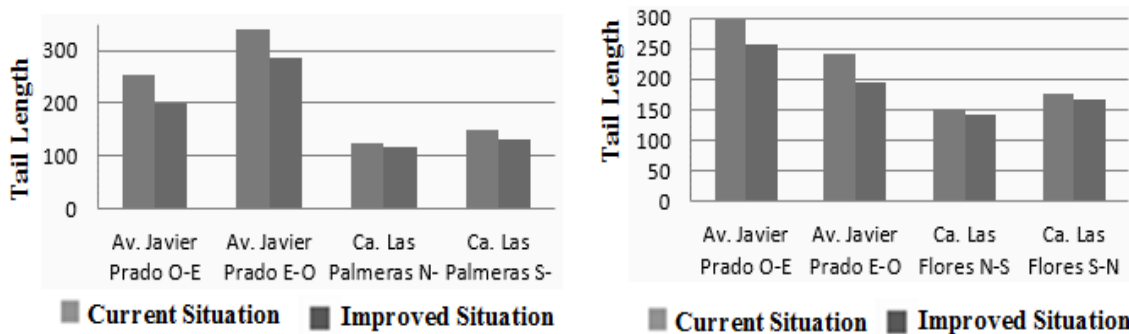

Figure 1: Comparison of queue lengths at both intersections, with current and optimized traffic light cycles.

4.2 Delay times and average speed

Table 5 shows travel delay times per vehicle. This parameter is based on the quality and operation of the intersections under study. The results obtained indicate that the delay times decrease by 14% and with respect to the average speed of vehicles per access increases by 10.56%.

Table 5: Parameter comparison in both scenarios

Access	Current traffic lights			Optimized traffic lights		
	Delay time (s)	Service level	Current average speed (km/h)	Delay time (s)	Service level	Current average speed (km/h)
O-E/E-O	89.7	F	14.58	77.1	E	16.92
S-N	98.7	F	21.13	78.6	E	23.50
N-S	95.1	F	18.79	76.6	E	21.15

	Current traffic lights			Optimized traffic lights		

Access	Delay time (s)	Service level	Current average speed (km/h)	Delay time (s)	Service level	Current average speed (km/h)
O-E/E-O	91.9	F	12.09	78.8	E	14.84
S-N	100.3	F	18.39	79.7	E	20.14
N-S	98.5	F	16.92	79.1	E	18.39

5. Conclusions

- Average vehicle speed increased by 10.56%, which represents an increase in the volume of traffic that flows through the intersection for each traffic light cycle.
- Optimized traffic light cycles every 15 minutes improve the average speed of vehicles during the first 235 meters of their journey.
- Tail length decreases by 10%, while delay times by 14%, which represents an improvement in the service level of both intersections.

6. References

[1]   Quintero J.& Prieto L (2015) "Sistemas inteligentes de transporte y nuevas tecnologías en el control y adminsitración del transporte" *Revista digital de la Facultad de Ingeniería, Universidad Pedagógica y Tecnológica de Colombia sede Tunja*, pp. 53-54.

[2]   D.Panovski and T.Zaharia, "Simulation-based vehicular traffic lights optimization" *Consumer Electronics (ICCE) 2019 IEEE International Conference on*, pp.258, 2019.

[3]   Molina Navarro. A., Zamora Castro. S., Remess Pérez. M. & Lagunes Lagunes E. (2016). Los semáforos inteligentes en la logística urbana sustentable. *Revista Aplicaciones de la Ingeniería*, 28-30

[4]   D. Zhao, S. members, Y. Dai, and Z. Zhang, "Computational Intelligence in Urban Traffic Signal Control: A Survey," *IEEE Trans. Syst. Man, Cybern*., vol. 42, no. 4, pp. 485-494, 2012.

[5]   C. Tolba, D. Lefebvre, P. Thomas, and A. The Moudni, "Continuous and Dated Petri Networks for Macroscopic and Microscopic Traffic Flow Modeling," *Simul. Model. Practy. Theory*, vol. 13, no. 5, pp. 407-436, 2005.

[6]   TomTom (2019). World ranking of congested cities. Ámsterdam, Países Bajos

[7]   PTV VISSIM (2016). Getting Started VISSIM 9. Karlsruhe.

[8]   TRAFFICWARE, Engineered by N Naztec. Synchro 8 Studio Analysis, optimization, and simulation applications. Fecha de consulta: 10 de Abril del 2015. Disponible en: http://www.trafficware.com/products.