

Using virtual inductive loops to adapt the signal plans of junctions

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Abstract. Trafficking is a growing problem in cities around the world. Congestions occurring at peak hours have become common problems that all the major cities of the world are facing. Some metropolises, however, have found solutions to reduce traffic jams, especially in peak hours. Problem solutions are given by road traffic management by reducing waiting times and queues, in the same way as traffic safety increases. The first step in achieving coherent management is to achieve a method of collecting traffic data. Under the current infrastructure development conditions, one of the few solutions is given by virtual inductive loops. Inductive loop detectors have become the most utilized sensors in traffic management systems. The gathered traffic data is used to improve traffic efficiency (i.e., warning users about congested areas or planning new infrastructures). This paper aims to develop virtual intersection models by using primary data from virtual inductive loop video analyzers.

1. Introduction

The concept of an intelligent system to monitor and control traffic does not require integration to an existing system, but the combination of several equipments combined in a specific area studied and integrated with existing and prevailing in the area to form an intelligent system [1]. Thus, the current situation does not require identification of existing intelligent but identification of components that can be integrated into the requirements of Craiova, so use in combination lead to the creation of an intelligent system. At most intersections, to ensure effective crossing without significant safety delays, eliminating potential conflicts that may [2], [3] be caused by intersections of vehicle flows, traffic management is achieved through traffic lights.

The traffic light of an intersection must provide safety and efficiency for cars and pedestrians, and in designing a traffic light, several aspects need to be taken into account:

- Repeated traffic jamming on intersection access roads;
- Repeated vehicle routing with more than two minutes of waiting on secondary streets, the traffic density on the main street being too large to allow cross traffic or cross-filtering;
- Accidents due to non-observance of intersection priority rules.

You can see the following advantages of using a signal plan, assuming it was done according to the intersection characteristics [4]:

- Ensures the orderly movement of vehicles at the intersection;
- Increase the intersection capacity to serve the crossing requests;
- Reduce the frequency and severity of collisions between vehicles;
- Tries to maintain a decongested traffic, as fluent as possible;
- Are used to limit the waiting time to enter the intersection of vehicles;
- Improve safety on crossing the intersection.

2. Inductive loop data

For the collection of traffic data, "SmartLoop" video sensors were used to monitor traffic using presence sensors called virtual inductive loops as seen in figure 1.



Figure 1. "SmartLoop" equipment

This equipment can be used for:

- Presence: detecting the presence of the vehicle;
- Queue: queue detection in the studied area;
- Speed: Approximate circulation speed of vehicles.

2.1. Area of influence

Thus, the data gathering from the study area was carried out in three stages, namely:

- Metering of vehicles at the intersection of Calea București - Carol I Boulevard - underground passage;
- Metering of vehicles at the intersection Alexandru Ioan Cuza Street - Carol I Boulevard - Arieș Street;

The measurements were made in the course of a day, thereby identifying four time zone intervals referred to in the literature as hourly zones, important for traffic by the intersection: Zone I (Early morning - in the first part of the day - for example: transit from residential to service - often in metropolitan areas); Zone II (mid-peak time - transit to central areas where there are administrative, banking, etc.); Zone III (Top time in the second part of the day - for example: transit from service to residential areas); Zone IV (Evening - Transit to the commercial and cultural areas of the city).

2.2. Metering of Vehicles in the intersection

A video sensor positioned in Figure 2 at the Calea București intersection - Carol I Boulevard - the underground passage was used for vehicle counting. Following the assessment of the entry and exit zones and the intersection conflict points [6], [7], it was concluded that to best measure the vehicles crossing the intersection, there were 18 virtual inductive loops needed, as can be seen in Figure 3.



Figure 2. Catch with inductive loop positioning at the first intersection

Thus, to cover all the bands and the points of conflict, the virtual inductive loops were used in the following way:

- Calea București direction west-east were used 5 virtual inductive loops (numbers 5, 6, 7, 8 and 12 in Figure 2)
- Calea București direction east-west were used 4 virtual inductive loops (numbers 15, 16, 17 and 18 in figure 2)

- Carol I Boulevard in the north-south direction were used 4 virtual inductive loops (numbers 1, 2, 3 and 4 in figure 2)
- Carol I Boulevard in the south-north direction were used 5 virtual inductive loops (numbers 9, 10, 11, 13 and 14 in Figure 2)

After the introduction of the virtual inductive loops, the length of time for which the reports for each loop were to be made was introduced. As can be seen from Figure 4 and 5, for each virtual inductive loop, the reports are generated every hour.

View summaries on disk

Detector Id	From	To	Total
15	2016-08-30 15:54	2016-09-02 23:00	42
14	2016-08-30 15:54	2016-09-02 23:00	42
13	2016-08-30 15:54	2016-09-02 23:00	42
12	2016-08-30 15:54	2016-09-02 23:00	42
11	2016-08-30 15:54	2016-09-02 23:00	42
10	2016-08-30 15:54	2016-09-02 23:00	42
9	2016-08-30 15:54	2016-09-02 23:00	42
8	2016-08-30 14:55	2016-09-02 23:00	43
7	2016-08-30 14:55	2016-09-02 23:00	43
6	2016-08-30 14:55	2016-09-02 23:00	43
5	2016-08-30 14:55	2016-09-02 23:00	43

Figure 3. Report Verification Window

3. Signal plan adaptation

To be able to adapt the inductive signal plan based on the inductive loop and the mathematical algorithm as accurately as possible [8], the semaphore cycle was measured so that it was possible to identify and create the signal plans for the intersection.

For the intersection of Figure 3, the greening times for each of the four phases and all four arms of the intersection were identified. Thus, the measurements made in the field are as follows:

- North arm traffic: Two movement phases F1 and F2 were identified for this movement arm, namely the F1 movement before the Carol I Boulevard and F2 the left movement on the Carol I Boulevard. The right-hand movement on Carol I Boulevard is made on the bracelet separated from the islet and does not enter the traffic light cycle. Following the F1 measurements, it has 17 seconds of green and F2 has 20 seconds of green.



Figure 7. Selection of traffic phases on North arm of the intersection

- South arm traffic: Two movement phases F1 and F2 have been identified for this movement arm, which coincides with the phases of traffic lights on the north arm, namely F1 the forward movement both in the passage of the University and on Blvd. Carol I and F2 the left movement both from the passage of the University as well as from Carol I Boulevard. The right-hand movement in the passage is forbidden, and the right-hand movement on Carol I Boulevard is realized on a separate branch of the island. Following the F1 measurements, it has 17 seconds of green and F2 has 20 seconds of green.



Figure 8. Selection of traffic phases on the South arm of the intersection

- West arm traffic: Two movement phases F3 and F4 were identified for this movement arm, namely F3 the left movement on Calea București and F4 the forward and right movement in the passage of the University on Calea București. The right-hand movement on Bucharest Avenue

to Carol I Boulevard is realized on a separate island from the island and does not enter the traffic light cycle. Following the measurements, F3 has 17 seconds of green, and F4 has 42 seconds of green.

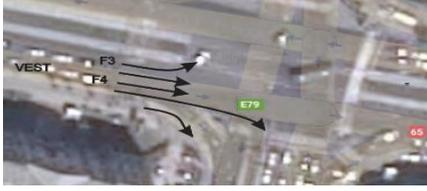


Figure 9. Selection of traffic phases on West arm of the intersection

- East arm traffic: Two movement phases F3 and F4 were identified for this movement arm, circulation phases coinciding with the west arm, namely F3 the left movement on Calea București and F4 the movement before Bucharest. The right-hand movement on Bucharest Avenue to Carol I Boulevard is realized on a separate island from the island and does not enter the traffic light cycle. Following the measurements, F3 has 17 seconds of green, and F4 has 42 seconds of green.

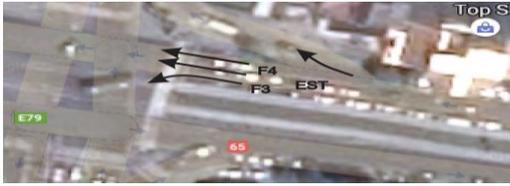


Figure 10. Selection of traffic phases on East arm of the intersection

3.1. Calculation of the new signal plan

According to the literature, the saturation flow for each group of bands is the flow of vehicles that can be taken over by the band group assuming that the phase with right of access for the particular group (green color) lasts 100% of the time. So, it will be calculated using the following formula:

$$s = s_0 \cdot N \cdot f_W \cdot f_{HV} \cdot f_g \cdot f_p \cdot f_{bb} \cdot f_a \cdot f_{LU} \cdot f_{LT} \cdot f_{RT} \cdot f_{LTP} \cdot f_{RTP} \quad (1)$$

Were:

- s - flow lane saturation; s_0 - the basic saturation flow; N - the number of bands in the group of movements; f - the adjustment factor for the following conditions (w - bandwidth; HV - heavy vehicles; g - declivity; p - parking; bb - buses blocking; a - the type of the studied area; LU - the use of bands; RT - right turn; LT - left turn; Rpb - Interference of cyclists or pedestrians at the right turn, and Lpb - Interference of cyclists or pedestrians at the left turn).

The role of intermediate time (interchange and traffic phase protection) is to eliminate the potential conflict between vehicles that evacuate the intersection at the end of a traffic phase (after the end of the green phase of that phase) and the vehicles entering the intersection at the start of the greenback of the next phase. The mean time can be calculated with the formula:

$$L = C_g + C_r = t + \frac{V}{2 \cdot a + g \cdot G} + \frac{l+w}{V} \quad (2)$$

Were:

- L is the length of the exchange interval (or lost time) corresponding to a semaphore phase; C_g - is the time for yellow, (s); C_r is the time for full red, (s); T is the reaction time (can be considered 1 s); V - is the traffic speed at the intersection access points (m / s), $1 \text{ km / h} = 0.27 \text{ m / s}$; A - is the deceleration of vehicles (can be considered 3 m / s^2); G - is the gravitational acceleration (9.81 m / s^2); G - is the land gradient (%), positive on climb, negative at the descent; L is the length of the vehicle (m); W is the width of the intersection to be crossed (m).

The next step is to calculate the saturation flow based on the flow ratios and the total traffic light cycle.

$$Y = \sum_{i,\text{critic}} Y_i = \sum_{i,\text{critic}} \left(\frac{v}{s}\right)_i \quad (3)$$

$$C = \frac{1.50 \cdot L + 5}{1 - \sum_{i,\text{critic}} Y_i} \quad (4)$$

The final step is to calculate the length of the green light for each phase.

$$g_i = \left(\frac{v}{s}\right)_i \left(\frac{c_{ef}}{Y}\right) \quad (4)$$

Based on the formulas above and the calculation algorithm the new traffic light cycle is as follows: Phase 1 (F1) – 15s; Phase 2 (F2) – 18s; Phase 3 (F3) – 22s; Phase 4 (F4) – 20s.

4. Conclusion

Road traffic, in general, is divided into two areas: the peak area and the general traffic area. However, it can be seen from the data collected using virtual inductive loops that the traffic in the studied area has 4 intensive traffic areas: Zone I (Early morning - in the first part of the day), Zone II (mid-peak time), Zone III (Top time in the second part of the day), Zone IV (Evening).

Using the virtual inductive loops to adapt the signal plans of junctions is essential to high-level junction because it can account for every situation.

Another important aspect is that at the calculation of the traffic light cycle is based on how many measurements are in an hour. Based on this, the virtual inductive loop can generate reports based 5-minute increment so that the calculation of the traffic light cycle can be very accurate.

In the same time, the virtual inductive loop can be used in creating a traffic signal plan for every zone identified as a peak hour.

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