RESEARCH ARTICLE OPEN ACCESS

Urbain Traffic Congestion Estimating Using Simplified CRONOS Model: Algorithm and Implementation

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Abstract:

In this paper, we present a method to calculate, the road urban traffic congestion using CRONOS model. For the model simulation we propose adapted algorithm. We compare our adaptive system results to others given by urban traffic system based on fixe pattern lights. The system is designed to make equilibrium between the length queue and the states of lights to search optimal strategy guarantying the fluidity of traffic and minimizing the total delay. The real-time urban traffic control model CRONOS has been applied on a simple intersection presenting two roads. We have choosing a simple intersection to validate our method which will apply after for a complicate intersection. We use traffic evaluation criteria to testing the accuracy the model. The results show benefits of the proposed model on the total delay compared to that of the fixe pattern lights system. All traffic situations, peak or low are concerned by these results.

Keywords — **CRONOS Model, Urban traffic congestion, intersections, traffic flow**

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I. INTRODUCTION

The road traffic congestion of urban transport can be defined as the ratio of volume to the capacity of the road [19]. The volume and capacity (or demand) of the road cannot directly measured so the calculate value of congestion becomes subjective in nature. In this paper we propose a simple method based on a simplified CRONOS model and adapted algorithm to define optimal strategy to overcome the traffic congestion witch depends on the density and speed of the vehicles, are used for the estimation of road traffic congestion [18]. These two traffic parameters are considered by keeping in mind that general perception about the congestion on the roads increases when the number of traffic (traffic density) increases and also increases when the speed of the traffic decreases [20].The density is the main input of our model and is defined as the number of vehicles entered in the intersection by second.

The output of the model is level of congestion represented by the length of waiting line or queue line. The road traffic congestion is one of the most confusing tasks, because there is no standard way of measuring congestion level on the roads and intersections [20]. It results in serious environmental, time wastage, health hazards, and economic problems. So that determining the congestion period and measuring traffic parameters which affects it are very important. In our study we use only one traffic parameters, the density, which affect mostly the congestion.

In section 2 we present a rapid overview of some approach used to estimate the urban traffic congestion and the main adaptive urban traffic control system. CRONOS model is presented in section 3. The proposal methodology to estimate the urban traffic congestion is given in section 4. In Section 5 we describe in detail the model simulation with variables and constraints of the urban traffic problem. The implementation of the model are described in section 6. The results and discussion are presented in section 7. Finally, the conclusions of the present study are summarized in section 8.

II. LITERATURE REVIEW

A. Different approach to estimate the congestion

The modeling of traffic flows is an expensive and difficult task given the variability of flows and the amount of data to process. Several models have been developed to simulate and control the flow of traffic. We distinguish two main types of

models: macroscopic models and microscopic models. Macroscopic models describe globally the traffic flow, they are used in general in strategic study aims to giving planning or tactical solutions for the problems [8]. Although these models are fast, easy to calibrate and they do not require significant computer resources to simulate them, they are not well adapted to simulate realistic traffic flow, because the level of detail with which they deal the flow is very low. In contrast, microscopic models treat interactions between individual vehicles, they take into account many parameters related to vehicles, making the treatment of a large number of very delicate vehicles and calibrating a difficult task [21]. We cite as exemple: Krause and Altrock uses fuzzy logic to determine six discrete levels of congestion [13]. Porikli and Li determine five level of congestion from traffic flow information and video images using a Hidden Markov Model [17]. Jia and Li use different factors which affect the road traffic congestion [12]. Atikom and Pongpaibool estimates the road traffic congestion by using vehicle velocity [16].

B. Adaptive urban traffic control system (UTC)

To overcome the urban traffic congestion, urban traffic control system (UTC) using traffic signals is a major element of safety for vehicles and pedestrians when crossing an intersection. Traffic signals share the time between the different flows, that are considered to be antagonistic, and eliminate the most serious conflicts. This was the first reason for installing signals on intersections in the early 1900s [7]. Growing amount of traffic in urban areas made UTC by signals a significant traffic management tool in order to reduce the consequences of this increase: congestion, delay, stop, pollution, fuel consumption, noise, stress, discomfort. In the point view of methodology, the main problem of controlling signalized intersections is concedering different conflictual objectives. In fact; looking for the best fluidity is generally incompatible with the best safety in the sense that controlling the traffic from a safety point of view implies constraints on the traffic signal color durations and this implies limitations on traffic fluidity management. Competing interests in crossing an intersection of the different types of user (vehicle, pedestrian, emergency vehicle, bus, bicycle, etc.) made the task very difficult. Another problem of urban traffic management is to reach the optimum and search to carry out the objectives for the best. A number of constraints appear: flexibility in the control method, the size of the controlled network, the CPU time required, the reliability of sensors, modeling and forecasting, etc. Many UTC systems exist, all over the world, from the simplest fixed-time plan to the new generations which lead to greater flexibility of control. In our study we present the UTC model „„control of networks by optimization of switchovers"" (CRONOS)[12],[5]. The authors of this model/algorithm have fixed as objectives on the one hand using advanced sensors for real-time traffic measurements and secondly focusing on its speed and flexibility.

The adaptive time plans are certainly the most widely used control systems in the world. When the plan is well adjusted to the recurrent traffic situations and the sensors are working correctly, these methods show good performances in a wide range of situations [7].

The first adaptive system that was applied is the English system SCOOT. This system produces a time plan incrementally. The Australian system SCATS builds a time plan piece by piece. These systems are very close to a classical time plan, but they lead to a new type of flexibility, which follows changes in traffic not only throughout the day but also over a period of months [15].

Recently other systems have appeared: CARS in Spain [2] and MOTION in Germany [4]. Other systems OPAC in the USA [10], PRODYN in France [11] and UTOPIA in Italy [9] had adopted a different strategy aims to minimize a traffic criterion using an optimization method to determine the green and red stage durations by time steps of 4 or 5 s. The cycle duration is not constrained and varies from one cycle to the next. These systems initially determine the different stages of the intersection and use minimum and maximum green durations. Thanks to their small time step and the use of magnetic-loop-based sensors, these systems take into account the traffic flow variations at a scale of a few seconds and more globally (at the level of the intersection) than the vehicle actuation functions [8].

This new generation of systems does not need to re-actualize the control system after a few years as in the case of time plans. Another advantage is their greater flexibility for finding the green and red durations according to the traffic situations, especially for those which have a wide possible cycle spectrum at each cycle.

Several experimental studies have shown benefits obtained by these UTC systems on the delay and the journey time compared to actualized time plans, although this result depends on the intersection characteristics and the traffic situations.

The CRONOS algorithm was developed in the 1990s to realize two objectives: build a non-exponential and fast

optimization method providing the traffic signal states for the next second in less than one second. The stake is to react as fast as possible to the traffic variations. This method will not look at all solutions but will use a heuristic providing a good local minimum. The second objective was to use image-processing-based traffic measurements, like queue length on link and vehicle spatial occupancy inside the intersection [1].

III- THE CRONOS ALGORITHM

Consider a zone of several adjacent intersections.

The general process of the CRONOS system showed in figure 1 [7] can be summarized as follow: The one-second traffic measurements feed a forecasting and a modeling module. The forecasting module predicts, for a given time horizon, the future vehicle arrivals on each link entering the zone. This prediction is based on a rolling average of the arrivals in the past; it is used by the modeling module which calculates the value of a chosen traffic criterion for a given sequence of traffic signal states (colors) over the time horizon. These states are provided by an optimization module, which looks for the best sequence which minimizes the traffic criterion. When this sequence is found, the corresponding traffic signal states are applied on the intersection for the next time step, and the whole process is activated again one time step later [7].

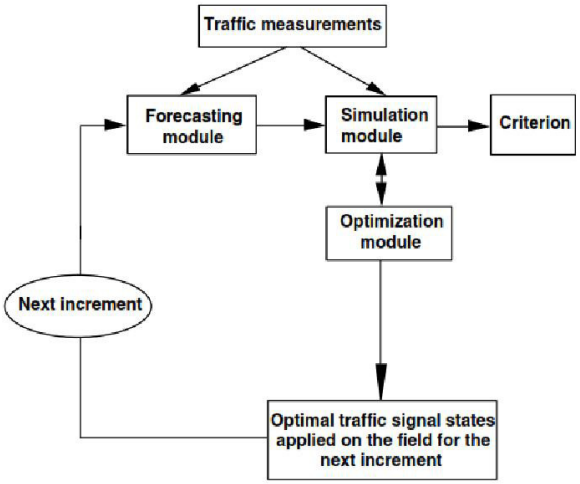

Figure 1 : General structure of CRONOS algorithm

The optimized traffic criterion is the total delay expressed on length of the waiting line the zone over the time horizon. The links entering the zone or connecting two intersections of the zone are considered in the delay. The criterion C is written as:

$$\sum(\sum \quad \sum \quad)$$

Where is the queue length at the time step s of the horizon H on the link j, is the number of stopped vehicles at the time step s in the storing inner area k of an intersection. The total number of links in the zone is N. The total number of storing areas inside the intersections is . is based on the queue evolution equation at each time step s according to the given arrivals vehicles and calculated departures during s ($a_{s,j}$ and $d_{s,j}$ respectively) for the considered link j:

A same equation is obtained for

The variables depend on the controlled variables which are the switchovers from red to green and green to amber (or red for pedestrian signals) of every traffic signal group. One group is defined as the set of traffic signals which controls the same traffic flow. At the initial time step s = 1, the queues and the storing areas inside the intersections are measured directly by the video sensors. The value of the rolling time horizon depends on the spatial extent of the zone. It is typically around one minute for one controlled intersection. The time-step value depends on the complexity of each controlled intersection and their number. It must be superior to the maximum computational time for solving the optimization process [7]. The optimization module of the CRONOS system calculate the optimized traffic criterion by a heuristic method based on a modified version of the Box algorithm [14]. The principle of the method is as follows: in the first step, the criterion value is calculated for a set of initial solutions (a solution is the set of values for the controlled variables over the time horizon). The second step is an iterative process up to convergence and consists, at each iteration, in looking for the worst solution and modifying it. Two types of modification are used: the first one tries to move the worst solution away from the centroid of the other solutions. The second one tries to bring the worst solution closer to the centroid. The effect of these successive iterations is to lead all solutions towards a region of the solution space. The convergence is reached when all solutions are very close to each other [7]. The traffic measurements are obtained by automatic image-processing of video cameras. These one-second measurements are the queue length at the stop line for each link, the traffic flow at the entries or the exits of the intersection, the spatial occupancy inside the intersection for pre-defined spatial areas. These areas represent storing zones behind a traffic signal or for left-turning vehicles.The data types concern infrastructure data (list of intersections, list of links, link length, list of traffic signal groups), traffic data (saturation flow, free flow) and traffic signal data (safety constraints).

IV- METHODOLOGY

To validate the proposal method, we have choose a simple

intersection with too road having one direction traffic as shown in figure 2.

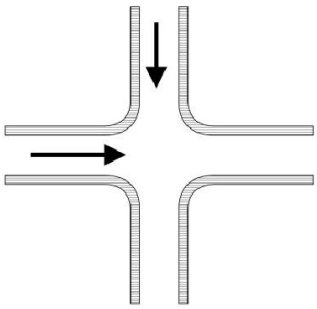

Figure 2 : Intersection design

Each link j of the intersection (there is one link for each road) is characterized by the input and output flow rate and at the time step s of the time horizon H. This values are given by simulators that we have developing.

The queue length at the time step s of the horizon H on the link j is and it calculated by:

Where is boolean variable which equal to 1 if de light is green and 0 if it"s red and t(is his duration.

For this configuration of intersection, the stopped vehicles in the storing inner area of intersection there not considered and is equal to 0. So the optimized traffic criterion is written:

$$\sum(\sum \quad)$$

V- TRAFFIC CONGESTION MODELING SIMULATION

To simulate the model we take in consideration some real traffic flow restrictions in the intersection and we define relative"s constants and variables.

A. Agent-oriented programming languages and JADE environment

Based on agent-oriented programming language, JADE is a software platform that provides basic middleware-

A. Variables

and variables is generally delivered by the magnetic sensor installed in the entry of links. In our case it given by a programmed simulator. variables depend on the controlled variables which are the switchovers from red to green and green to amber of every traffic signal group. We symbolized it by boolean variable which equal to 1 if de light is green and 0 if it"s red and t(is his duration.

At the initial time step s = 1, the queues and the storing areas inside the intersections are measured by the sensors. In our case they initialized by the system. The value of the rolling time horizon generally depends on the spatial extent of the zone. We fixed it at one minute for one intersection. The time-step value depends on the complexity and number of intersections, it must be superior to the maximum computational time for solving the optimization process. The infrastructure is defined by list of intersections, list of links, link length, list of traffic signal groups.

B. Constraints

The intersection is described as a set of safety constraints on the traffic signal groups. The main constraints are the minimum/maximum of the duration of each traffic signal state, antagonism criteria and the clearance time.

C. Simulation algorithm

- For each Horizon time H, constitute a number of matrix Q of dimension (6 X 60)
- Each 60 lines of matrix Q, correspond to vector R (, , , , ,)
  where i: input, o: output, s: time step, j, k: link of intersection.
- Calculate for each time step s of the horizon time H and each link j, k.
- or each iteration r calculate $\sum$ ($\sum$) (each iteration correspond to one vector R)
- Calculate min ( ).

VI- MODEL IMPLEMENTATION.

To implement the proposed model we used the JADE framework environment, using JAVA/J2EE object-oriented programming language and framework.

layer functionalities which are independent of the specific application and which simplify the realization of distributed applications that exploit the software agent abstraction.[3],[22].

B. Creation of Agents

The first phase of implementing the system involves the creation of some agents to meet the requirements of its corresponding link, intersection or task.

For the purposes of our case study to validate the system, the traffic network consists of one intersections. Each intersection information provided by traffic sensors are the inputs to the others agents as indicated in agents description above.

In this implementation, the system administrator at runtime enters the initial conditions for each link of the intersection, providing a snap-shot of the environment. In a real-time environment, this would be modified by RegulaAgent wich will calculate a real state of urban traffic. This would allow the SectionAgent to update the stored values of . In addition to this information, RegulaAgent stores the current state of each traffic light. With the relatively small size of this traffic network implementation, we only use vectors to hold the data. Figure 3 and 4 show the Class diagram of agents and there interactions.

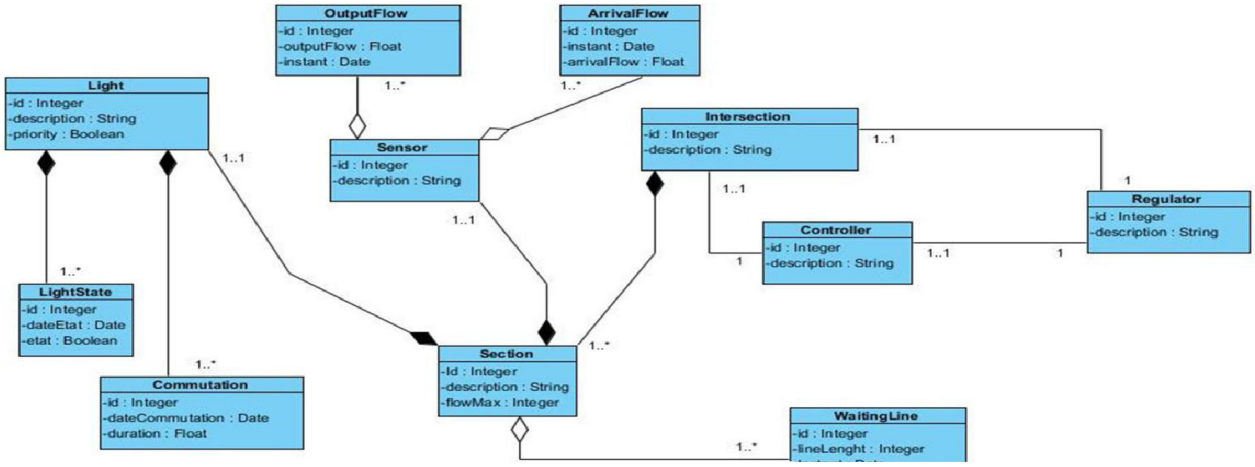

Figure 3 : Class diagram of agents

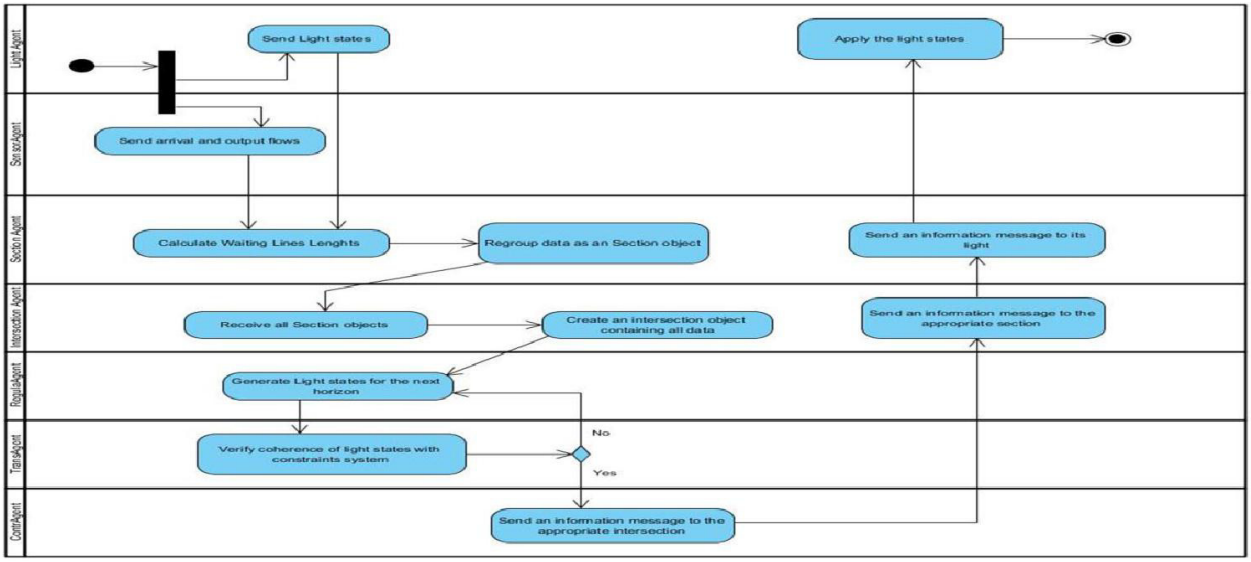

Figure 4: Agents interactions

calculated for each time horizon H on several sample of matrix to find optimal traffic criterion corresponding to low level of congestion. The obtained results, are compared to those given by the same system using fixe pattern light which. For this pattern light strategy we fixed green light duration to

To realize this comparison we calculate total delay obtained by summing every queue length, measured in terms of number of waiting vehicles at a traffic signal each second on the all link of intersection over the one entire hour.

Figures 5, 6, 7 show the principal results of simulation and the benefits of our system.

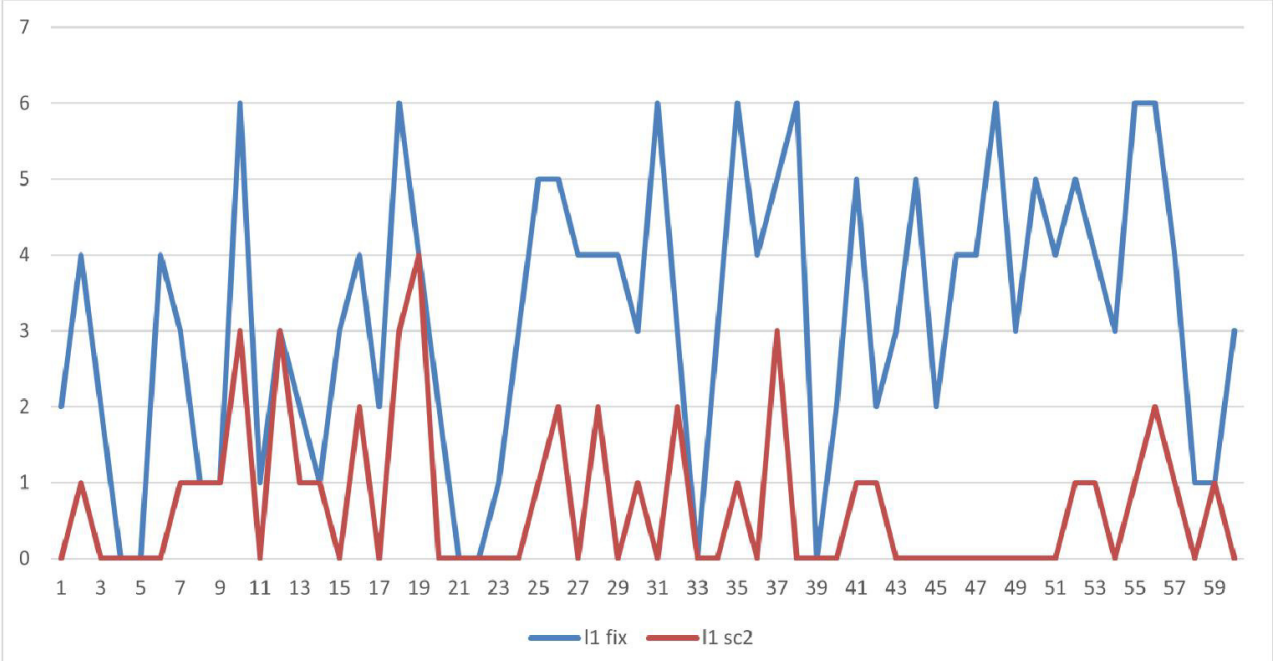

Figure 5: Link 1 length queue by fix pattern (blue) and proposed system (red)

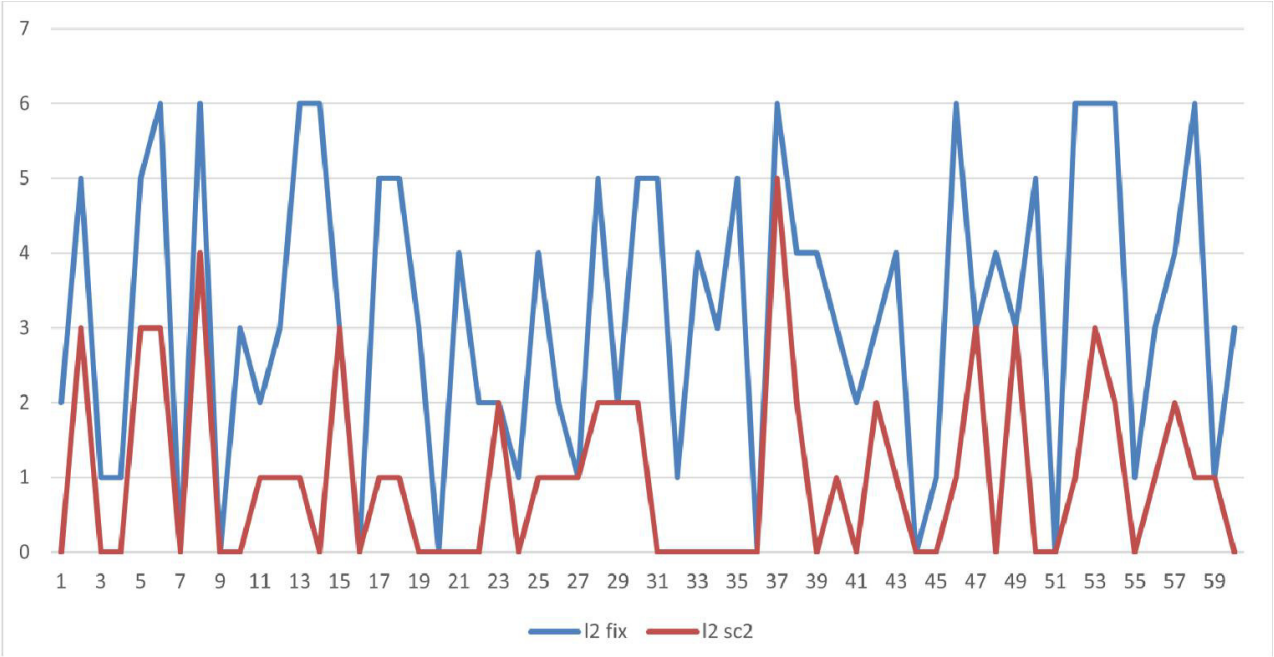

Figure 6: Link 2 length queue by fix pattern (blue) and proposed system (red)

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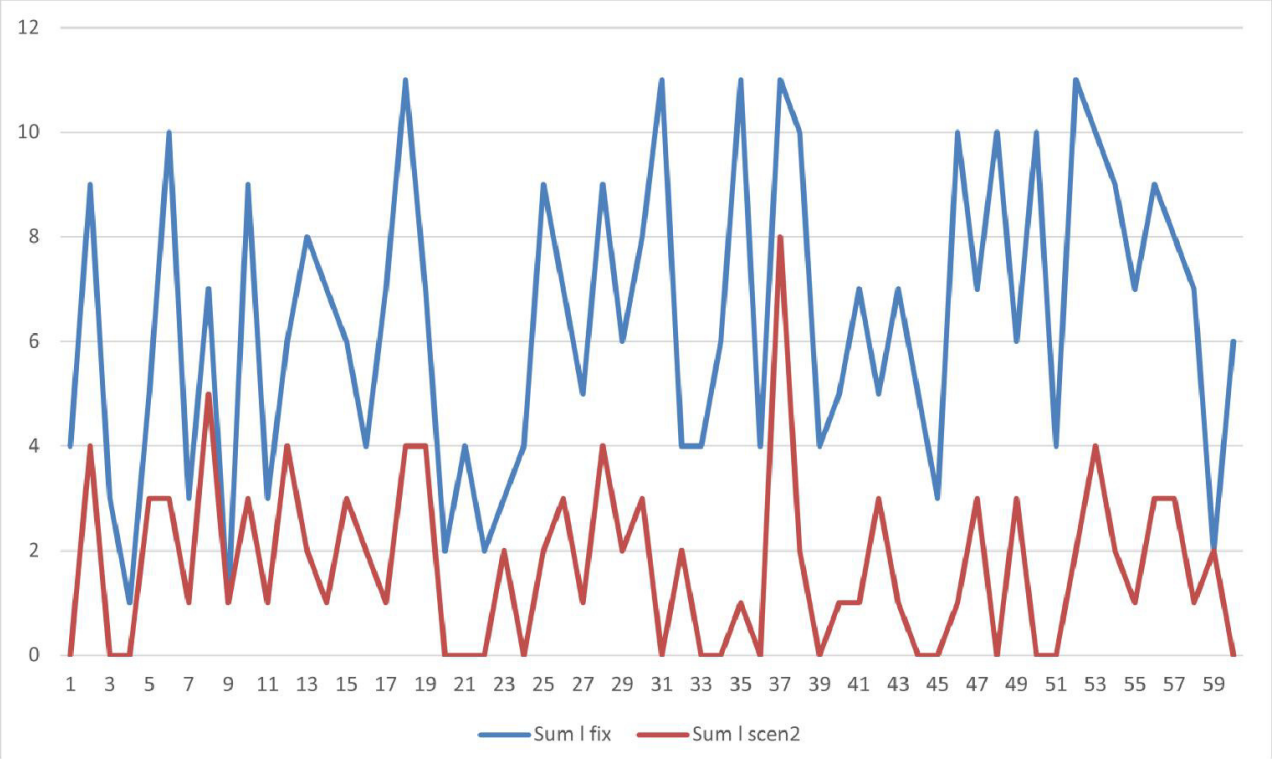

Figure 7: Sum of length queue by fix pattern (blue) and proposed system (red)

VIII. Conclusion

In this study, we proposed a method to calculate and optimize the urban traffic congestion in the intersection. We adopt a simple case to validate the system and methodology. In a future work we will developing our system and intersection sample to take in consideration a real situation of urban traffic and taken into account a maximum of urban traffic variables to improve system accuracy. Generally The real-time CRONOS strategy gives higher benefits on almost all of the traffic variables studied whatever the traffic situation peak or low. These opportunity is due to the CRONOS characteristics, especially its high flexibility and its global traffic optimization of the intersection, and due to the use of real-time video-based measurements witch are simulated in our case.

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