A Computational Model to Study Urban Traffic Control

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***Abstract*—The purpose of this paper is to develop a computational model to study vehicle flow on urban roads. The model presents a study undertaken at a two-way intersection where vehicle flow is controlled by traffic lights operating according to fixed intervals of times. This model is computationally simulated using Matlab/Simulink. Several simulations were processed and in practice the model proved to be stable and reliable. It is expected that the results will contribute to the creation of a stochastic predictive model to anticipate situations that lead to traffic jams.**

***Index Terms*—Simulation model, traffic lights, traffic simulation.**

I. Introduction

Computer simulation means running a computer program that will reproduce an abstract model of a given system, enabling these systems to be studied to assess their behavior relevant to the variations in the study environment. According to [1], the advantage of computer simulation is the ability to answer questions without disrupting the systems investigated.

This paper presents a computational model to study urban traffic, aiming to optimize traffic flow and reduce traffic jams by reducing the average time vehicles remain stationary at traffic lights.

II. Methodology

This paper presents an exploratory study of traffic lights and their impact on urban traffic conditions. To do so, we conducted a bibliographic study to establish parameters allowing us to develop a computational model that accurately represented reality. Vehicle flow in urban traffic and the quality of service were studied by analyzing frequency of stops, speed of operation, travel time, traffic density and the operational costs of the vehicle. The computational model was developed and simulated using Matlab/Simulink, a tool projected for this type of study. So that the model accurately represented real-life demand for the system, information regarding traffic light cycles and other aspects were taken data published in the National Traffic Department Traffic Lights Manual - [2]. Additionally, the traffic light times were calculated using the Webster method, the algorithm of which is provided in [2].

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III. Computer Simulation and Systems Modeling

Modeling is the development of a model to represent a given phenomenon. A model is the representation of a real or imaginary system using a language.

A Matlab environment application, Simulink, was used for the simulation in this paper, given that this tool provides an interactive environment based on block diagrams, designed specifically for modeling, simulation and analysis of continuous, discrete or hybrid dynamical systems [3].

According to [4], the models are classified as either ‘static’ or ‘dynamic’. Dynamic models are then sub-classified as ‘deterministic’ and ‘random’. The random models adopted in this paper are divided into discrete and continuous change, as shown in Fig. 1.

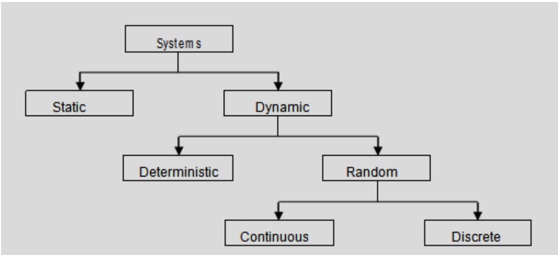

Fig. 1. Classification of simulation models. Source: [4].

IV. Urban Traffic

The degree of randomness intrinsic to real systems, scaled specifically to random occurrence of events in these systems, necessarily implies proportionate application of Monte Carlo method. The use of this technique consists in the artificial generation of data by employing a random number generator (RNG) and a frequency distribution of the target variable. The RNG is a computer program capable of generating independent and uniformly distributed random values between zero and one [1].

This study uses the terminology proposed by [5]. The term transit refers to the displacement of people or vehicles and traffic is applied when it refers to the study of these displacements. The concept ‘traffic jam’ is related to the concepts of road capacity and service level. Road capacity represents the maximum number of vehicles that moving along a stretch of raid over a given period of time, in a specific set of conditions of composition of traffic demand and environment; service level is a measure of the quality of service provided to the road user.

This quality of service can be analyzed according to frequency of stops, speed of operation, travel time, traffic density and operational costs of the vehicle. According to [5], service level is a parameter that reflects the conditions of flow, safety and comfort on any given space that is occupied.

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The traffic volume per hour on a lane varies depending on the demand and speed, which in turn varies according to, for example, traffic light coordination, efficiency of monitoring of prohibited parking spaces, or topographical conditions. In addition, demand varies during the day according to the peak hours, and traffic jams occur when the traffic volume exceeds the road capacity [6].

In order to better align the model with real-life conditions relevant to system demand, traffic light cycle times and other information was obtained from the data published in the National Traffic Department Traffic Lights Manual - [2]. Additionally, traffic light times were calculated using the Webster method, the algorithm of which is described in [2].

V. Development of the Computational Model

In this paper we develop a model to study macroscopic traffic, aiming to coordinate traffic lights through isolated control of the intersection using an automatic and fixed interval for the cycle, duration and signal change [2].

Fig. 2 shows the intersection used in the study, an intersection between two two-way roads with oncoming traffic. Road A has three lanes and is comprised of approximation I and III. Road B has only two lanes, designated as approximation II and IV. Due to the conflicting traffic between the roads, those traffic lights numbered I to IV control traffic by alternating right of way at the intersection.

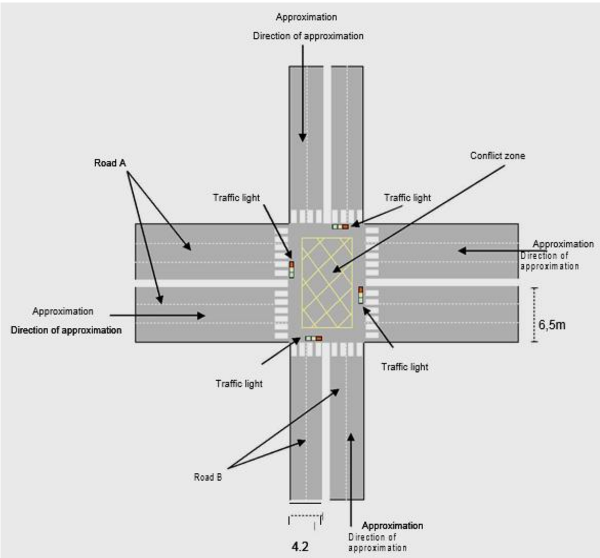

Fig. 2. Diagram of the intersection studied.

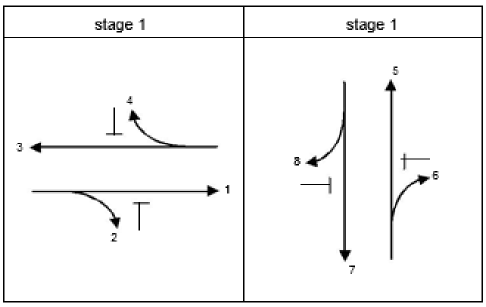

Fig. 3. Diagram of stages of the intersection studied.

The diagram showing [2] stages, Fig. 3, represents the sequence of movements permitted and prohibited for each interval of the cycle during each stage.

The following shows the Simulink subsystem developed in order to provide the control signal from the sequence of signaling for the traffic lights of the model. Each stage of the lifecycle of signaling (i.e. , each color flagged: green, yellow and red, in that order) has a value of discrete signal that will be generated in accordance with their respective duration, to be parameterized in subsystem, as will be described below. The Fig. 4 presents a general overview of the subsystem. Each block was numbered to facilitate its description:

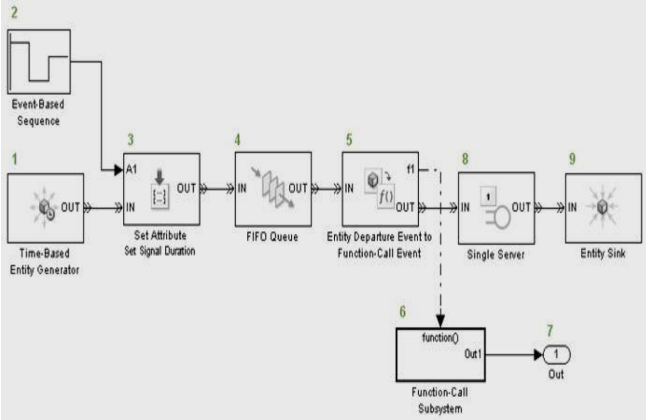

Fig. 4. Ubsystem for the generation of the control signal of the traffic lights.

1) Generates sequentially the control signal to each stage of the traffic light in the model. Each stage is representing as an entity generated a constant interval of one second. Strictly speaking, this generation time does not matter, because the control of the duration of the signal will be carried out through the block seven, which will be described hereinafter.
2) Generates a cyclic signal with the values that represent the duration of the stages of the traffic light. This cyclical signal is defined in the properties of the block by means of a one-dimensional vector formed by the parameters of the subsystem and which represent the values for each stage of the traffic light, as Fig. 5:

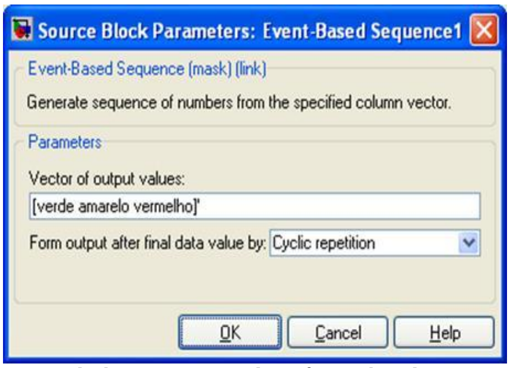

Fig. 5. Block parameters window of event-based sequence.

3) Perform the read signal generated in block two, concerning the duration of the stage of the traffic light, and generates with its value an attribute to the entity generated in block one. As a result, the entity will carry the duration of their internship that which represents.
4) Represents a queue of type first-in-first-out (first to enter is the first to exit) needed to standardize the signal generation. The queue control at this point it is necessary because the block seven, which will be explained hereinafter, retains the entities for a given time interval,

hanging their port of entry and, by consequence, hanging the entire signal exchange of blocks predecessors.

5) Transforms the entity that arrives to the block at the moment of execution in a function call, whose ultimate goal is to generate the discrete signal for the control of traffic lights, and that will be described below. After the function call, the entity follows the flow from the OUT port on the destination block 8.
6) Function whose objective is to generate the signal discrete for each stage of the traffic light. The function block is a subsystem, once executed, generates a signal sequence defined in the properties of the block by means of a one-dimensional vector.
7) Provides an output port for the discrete signal control the traffic generated, to be consumed externally.
8) Responsible for controlling the duration of the signal (stage). Acts as a server for entities that serves each entity individually, during a certain time interval. The service duration is defined via the attribute that each entity loads (duration of internship). In This way, it has been the generation of each signal from the stage of the traffic lights at intervals of time, because each individual entity generated (stage) is converted into a discrete signal through the block six and this signal is conservatism outlined the subsystem through the door seven, being the duration of the signal controlled by the server that, while serves an entity, does not allow another is processed. Therefore, while an entity is served, the subsystem lock and no other signal is generated, remaining the signal generated previously unchanged.
9) Provides a mechanism to terminate the path of an entity throughout the model. Entities that affect this block has fulfilled its purpose and are discarded from the system.

Fig. 6 shows a signal generated by the subsystem in a two-minute interval, whereas the times of each stage, defined for the model.

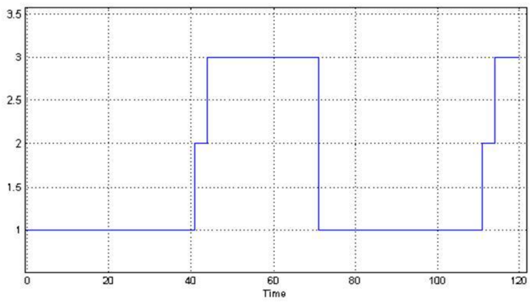

Fig. 6. Example of signal for control of the stages of the traffic lights.

VI. Simulation

The simulation period was four hours and was randomly chosen. Although the volume of results did not provide sufficient evidence for analyzes, the goal was to evaluate the stability of the model during simulation.

Fig. 7 shows the signs for the simulation of vehicle demand in the approximations:

Fig. 8 shows signs collected in the simulation of vehicle demand:

Analysis of this graph shows that the mechanism for retaining vehicles of the control traffic light remained stable throughout the simulation.

Additionally, no distortions were observed in the graphs obtained in the crossing time at the approximations collected in the simulation (see Fig. 9). The absence of peaks and deformations allow us to conclude that the system indicated a consistent pattern of operation.

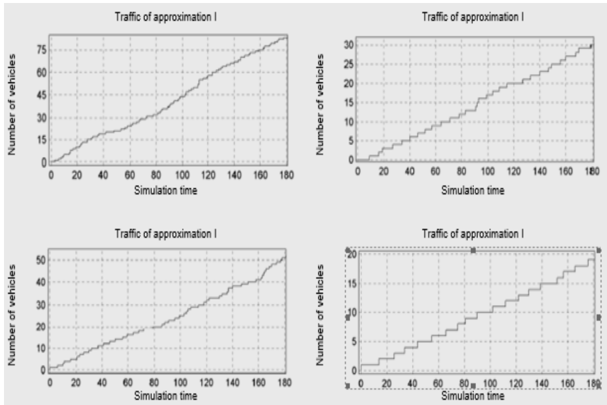

Fig. 7. Signs for the simulation of vehicle demand in the approximations.

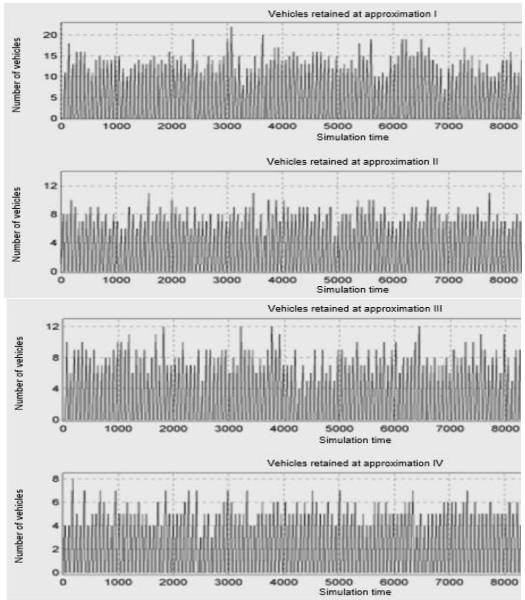

Fig. 8. Signs for the simulation of vehicle demand collected in the simulation.

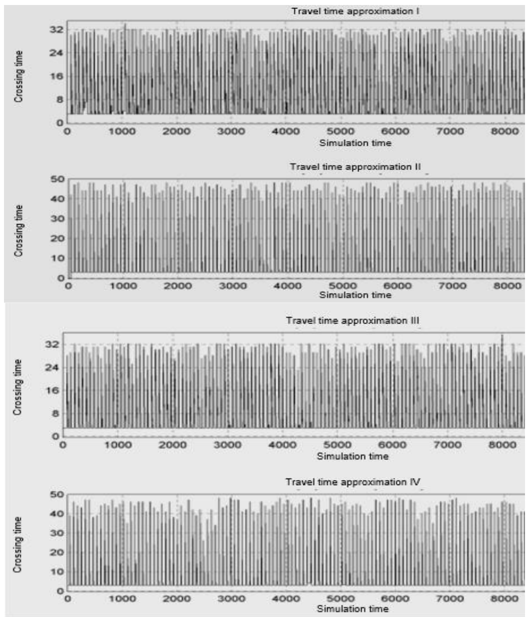

Fig. 9. Crossing times in the approximations collected in the simulation.

Finally, the stability of the system could be evidenced with the last test performed with the traffic lights flow collected in the simulation (see Fig. 10).

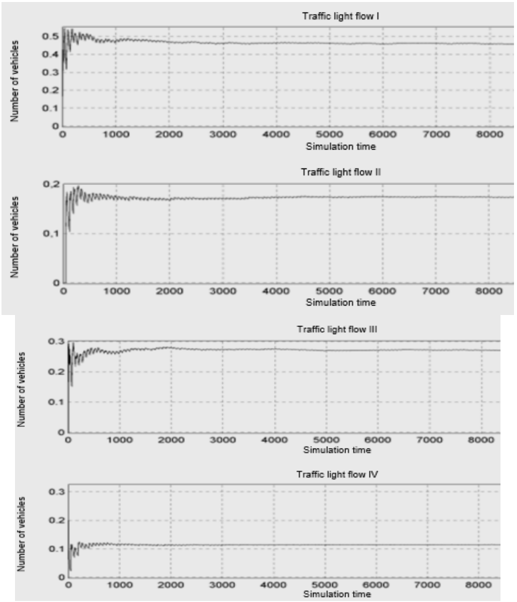

Fig. 10. Flow of traffic lights collected in the simulation.

VII. Final Considerations

The paper presented a technique that proved to be very powerful for modeling and studying dynamical systems, computer modeling and simulation.

Despite the complexity of the study system, the development of the study model was facilitated by the technique employed and the tool used which provides all support necessary for its development, the Matlab/Simulink. The creation of the model through the orchestration of blocks is extremely simple and fast. In addition, the visual aspect formed by the model, based on a block diagram, aids understanding and creation.

The simulation of the model allowed the extraction of some response variables which enabled analysis and comprehension of the system. Some results were presented in this study, however, after the creation of the model, new responses can be extracted by modeling new response variables. It should be noted that no specialist consultants were consulted in this study and that the model was developed based on publicly available technical documents. A professional could intensify the representation of the model in addition to applying her/his experience to better extract the necessary responses.

We expect this study can contribute to show the potential of the computer modeling and simulation technique as a tool for the study of dynamical systems. Furthermore, we expect that the model generated could be used as a basis for development of more comprehensive models objectifying study of urban traffic, serving as a reference for professionals from different areas, providing guidance and reflection.

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