



Simulation model building of traffic intersections [☆]

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ABSTRACT

Designers of traffic systems might take advantage of the *simulation-before-construction* approach that allows them to study the behavior of a new or existing system by use of simulation models. Nevertheless, the use of simulation models is often hindered by the fact that the model building activity is a critical, time consuming and error prone activity if performed by use of experience and intuition only. Moreover, traffic designers do not usually have the necessary skills to effectively carry out system simulation. This paper overcomes such problems by introducing a model building method, thus enabling traffic designers to seamlessly introduce *simulation-before-construction* into their best practices. The method is applied to the building of simulation models of traffic intersections, with an example application to a real-world intersection.

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1. Introduction

Designers of traffic systems might take advantage of the *simulation-before-construction approach* that allows them to study the behavior of a new or existing system by use of simulation models.

The simulation-before-construction approach can effectively be used either to gain insights into the system operation, before implementation, or to develop operating policies to improve the performance of an existing system.

Discovering that the just deployed traffic system is not able to accommodate the expected traffic load is indeed an example circumstance that may result in costly reworks and considerable inconveniences for users.

Nevertheless, the application of simulation to the design of traffic systems is not yet widely accepted as one would rightly expect. The reason is two-fold:

- (1) The traffic designer is not a simulation expert and does not hold the skills necessary to build a simulation model.
- (2) Model building is traditionally carried out informally and thus can be an error-prone activity.

A traffic system consists of various components, among which the traffic intersection is one of the most important. This paper introduces a step-wise method to formally specify and build simulation models of traffic intersections.

The method is applied to a traffic intersection that consists of two intersecting roads, each with one or more lanes (either one or both ways), and a set of synchronized traffic lights that manage the flow of vehicles.

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The proposed method builds a simulation model from the informal description of the traffic intersection. To this purpose, the paper first illustrates how to formally specify the traffic intersection, which is usually described by informal textual descriptions or diagrammatic sketches. The formal specification is then used to build the simulation model. To give an evaluation example the model is evaluated to obtain indicators of the intersection performance and analyze the behavior of the vehicular flows at the intersection.

The obtained model can be effectively used both to predict the configuration effects on the behavior of a new traffic intersection and to assist the designer in analyzing a current intersection to improve its efficiency.

The designer who is in charge of taking decisions about different intersection alternatives can effortlessly build the simulation model and then evaluate it to choose the alternative that better serves the expected vehicles workload, by choosing, e.g., the appropriate number of input and output lanes, the timing of the traffic lights and the allowed directions for incoming traffic.

Similarly, the designer can easily build the simulation model of an existing intersection and adjust its structure and parameters (e.g., the traffic lights' timing), to reduce the vehicles queues at input lanes or to deal with unexpected traffic growth.

To show the usefulness of the proposed approach, an example application is illustrated to build the model of alternative designs of a real-world traffic intersection. Two alternative design assumptions are considered and the proposed method is applied to easily build the corresponding simulation models. After model building the models are coded in the QNAP2 language and evaluated by use of a QNAP2 solver [11], to obtain example insights on the intersection performance and the best alternative.

The paper is organized as follows: Section 2 describes the related work. Section 3 gives an example model building use. Section 4 illustrates the formal specification of the traffic intersection and Section 5 describes how to derive the simulation model from such specification. Finally, Section 6 illustrates example results.

2. Related work

Vehicular traffic problems are usually treated in literature from the analytic point of view [13], even though, in some cases, the problems are not postulated to solve the stationary behavior of a system [6].

Simulation is instead considered a widely used technology in the research, planning, demonstration and development of traffic systems [7,10].

Traffic simulation systems can be developed either by use of traditional event-based simulation languages [1], or by use of specific languages for traffic system simulation, both at macroscopic and microscopic levels (see, e.g., ARCHISIM [3], TSIS-CORSIM [14] and VISSIM [15]).

Queueing-based models are explicitly mentioned in [12] as a viable tool to represent processes of dynamic traffic management.

The main contribution of this paper is the introduction of a model building method that derives the model from the formal specification of the intersection, thus replacing the more conventional approach (see, e.g., [8,9]) based on informal descriptions.

The model building approach is also finding applications in other fields, such as network and software design [4,5].

3. Method building use

In the following we shall denote by

- (i) *Informal description* of the intersection: the textual description of the intersection data, such as the number of input and output lanes, the position of the semaphores at the intersection, the estimated or measured rate of vehicles approaching the intersection from various directions at different times of the day, and so forth.
- (ii) *Formal specification* of the intersection: the description carried out according to the method illustrated in Section 4.

Fig. 1 illustrates an example use of the model building, which takes as input the informal description of a given traffic intersection and its performance requirements.

At step 1 the informal description is used to develop the formal specification. This is used at step 2 to build the simulation model. The obtained model is then evaluated at step 3 by use of a simulation tool that yields the performance predictions, such as the mean number of vehicles waiting at intersection entrances.

Finally, the predictions are compared against the user requirements. In case they do not match, the intersection planning (in terms of, e.g., incoming traffic, crossing trajectories, traffic lights, etc.) is to be revised, as well as the associated user requirements (in terms of, e.g., intersection throughput, waiting times, etc.). Then a model iteration is carried out with a new revised simulation model, until the user expectations are met. Example model results will be seen in Section 6

This paper core contribution is related to the definition of both the formal specification activity (step 1), which is described in Section 4, and the model building activity (step 2), which is carried out according to the method illustrated in Section 5.

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