The dynamic simulation of the urban traffic: A literature review

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Abstract

The establishment and planning of an urban traffic that meets all the requirements of mobility is the basis for achieving of effective economic and social activities within an agglomeration. To do this, several models and software simulations have been developed for very different purposes. The Traffic simulation is a tool to study the design and operation of facilities, to estimate the evolution of the traffic conditions on a network and to evaluate their consequences. Through this article, we propose an overview of the models and tools for modeling and simulating road traffic. At first, we start, through some definitions, to make an epistemological distinction between the notions of modeling and simulation in the field of traffic. We will then discuss the different modeling approaches used for the road traffic study. Subsequently, a classification of dynamic simulation tools and software will be presented.

Keywords
Modelization, Dynamic simulation, Simulation tools, Urban traffic.

1. Introduction

The problematic of the simulation of the road traffic is attracting a great deal of interest from researchers in the field of transport. Many problems, such as congestion and priority management, can not be solved by traditional analytical tools because of their complexity (Barceló, 2010). In order to understand and model these phenomena, several models and simulation software have been developed in the literature with very different purposes. Traffic simulators allow the study of the entire road system and the evaluation of different traffic management alternatives in order to estimate the different scenarios that can occur in a given network. This work tries to portray as synthetically as possible the various approaches and tools of modeling and simulation of road traffic. It also aims to propose a methodology for the dynamic simulation of urban traffic.

The article is divided into two main parts. The first part is structured in the following way: first, we propose to define the main usual notions in the field of road traffic. Subsequently, an overview of traffic simulation models will be presented. In particular, we present models of traffic planning and flow. A presentation of the most common simulation software is covered in the last section of this section. In the second part of this work, we propose the methodology deployed for the modeling and simulation of road traffic in urban areas.

2. Simulation models of road traffic

2.1 Definitions

In this section, we are interested in distinguishing between modeling and simulation in the field of road traffic. On the one hand, a model is an image reflecting reality. It is based on a set of simplifying assumptions (Buisson & Lesort, 2010). The purpose of modeling is to design a model to better understand the physical reality of a given phenomenon or system, which is too complex to grasp directly (Dimon, 2013). In the domain of traffic, modeling involves two different strategies: the first concerns the study of the assignment process. This is the way in which the demand is distributed over a set of paths forming a given network. The second strategy proposes to describe the flow of vehicles along a certain path (Costeseque, 2013). It is therefore complementary to the first since it exploits these results.

On the other hand, the model is then simulated and tested through simulation tools. Therefore, the simulation will rely on the outputs of modeling to study the effects of a set of actions on the studied system. Traffic simulation is a communication and visualization tool in 2D and 3D. It is used to study the sizing and operation of facilities, to estimate the evolution of traffic conditions on a network and to evaluate their consequences (Olivier, 2014). The major problem of dynamic simulation studies is their sensitivity to parameters and input data. Thus, they require good practice of the software used (Costeseque, 2013). Dynamic traffic simulation is based on models that must be valid. Therefore, calibration is an essential step to make models useful and valid on the ground (Barceló, 2010).

2.2 Typology of the traffic study models

The phenomenon we are interested in is the circulation of vehicles. At this level, two components present themselves: the flow of vehicles on the tracks and the allocation or distribution of vehicles on the network (Buisson, 2005).

Given the multitude of models used to describe traffic behavior, it is useful to give a classification to highlight the main existing types. We have tried, in this article, to detect the parameters explaining the diversity of the models, which we have classified according to the following criteria: the objective, the variation of the demand and the horizon of temporal and spatial planning (Costeseque, 2013). Traffic simulation models can be grouped into four classes: travel demand prediction models, ground occupancy models, traffic flow models, and traffic control models. (Costeseque, 2013).

Taking into account the criterion of variation of the demand, the models can be static or dynamic. On the one hand, static models are generally used to plan long-term transportation. Based on the logic of assignment (static or dynamic) of the demand, they make it possible to predict the traffic for the best dimensioning of the infrastructures built for the long term (Barceló, 2010). On the other hand, dynamic models of displacement determine the evolution over time of the physical flow of road traffic (López-Neri et al., 2010). Within this framework, there are three large scales for describing and evaluating the phenomena of traffic flow, in this case macroscopic, microscopic and mesoscopic (Derbel, 2014).

a) Traffic regulation models

This type of model generally concerns the regulation and control of the operation of a given development network. There are two sub-approaches in this model category: fire control models; and speed regulation models (Treiber & Kesting, 2013). These models make it possible to understand the effects of dynamic regulation on the flow in order to correctly model these effects in the simulation tools and to estimate the gains (Duret, 2013). Thus, the speed regulation makes it possible to homogenize the levels of utilization of the tracks to increase the capacity of the sections and to reduce the volumes of congestion.

b) Models of land occupation

These models make it possible to evaluate the reciprocal interactions between the spatial organization of the network and the urban distribution. The data used in this approach targets indices relating to the vehicle, the commodity, the number of tours, the cost per tour, the emission level of a particular pollutant, etc. (Ducret, 2014).

c) Demand forecasting models

- *The four-step model:*

This model makes it possible to analyze the demand at the scale of an agglomeration and to evaluate the foreseeable consequences for this or that sector of transport networks (Ducret, 2014). In particular, it makes it possible to evaluate the utility of an infrastructure or a change of operation (Antoniazzi, 2011).

- *The input-output model of Leontief*

Used in its regionalized "Multi Regional Input Output" version, this model effectively reproduces the choices of transport operators by considering the weight of the logistics organization and evaluating the impact of policies in the freight transport sector, in particular their territorial and economic impact (Antoniazzi, 2011).

- *The Modal Choice Models:*

These models come in two types (Antoniazzi, 2011). "Consignment" models based on the characteristics of the consignment to estimate the most probable choice of the mode of transport, and the "Logistic" type models taking into account the logistical characteristics of the loader and other parameters in the global utility function such as shipment size, shipping frequency, etc.

d) The traffic flow patterns

- *Macroscopic models:*

The purpose of these models is to characterize the overall behavior of traffic on a relatively large scale of study. They are particularly used for modeling large networks (Costeseque, 2013). The application of these models covers the simulation of traffic for infrastructure management and traffic dynamics as well as the evaluation of the policies of these management a posteriori.

With the macroscopic approach, traffic is represented as a flow. In this case, we divide the road into homogeneous sections to which we associate global variables: density (also called concentration), speed and capacity (or flow) (Yin & Qiu, 2011). These parameters can characterize the states of the fundamental diagram of a traffic which consists of two zones: a first zone characterized by an increase of the density which results in an increase of the flow; a critical point characterized by an average density and a maximum flow rate and a congested traffic zone characterized by an increase in traffic density and accompanied by a decrease in the flow rate. Figure 1 illustrates an example of a fundamental diagram for a maximum speed of 50 km / h (Dimon, *2013).*

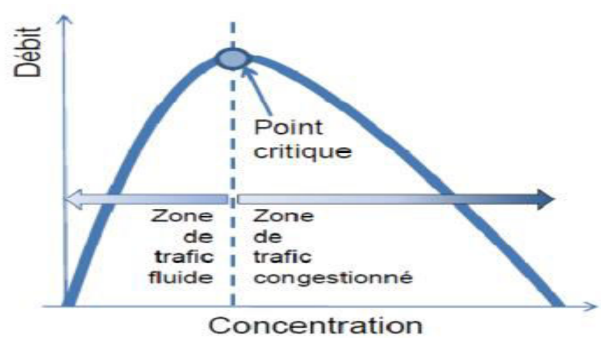

Figure 1. Example of a fundamental Flow / Density diagram

- *Microscopic models :*

In the microscopic approach, traffic is represented vehicle by vehicle. The parameters involved in this approach are the speed, distance or density of each vehicle. Two types of models are considered: the longitudinal model and the lateral model (Duret, 2013).

- The longitudinal microscopic model is used to describe the movement of the vehicle alone or to represent its tracking behavior of another vehicle. Each vehicle is modeled individually via its acceleration from laws of pursuit (acceleration depends on the acceleration of the previous vehicle and the characteristics of the infrastructure). As a result, microscopic models are called stochastic (Olivier, 2014).

- The lateral model is used to manage the change of lanes of the vehicles in a traffic with two or more lanes. This model usually incorporates two steps: decision making and lane change action. This type of model is generally based on the notion of insertion niche (Olivier, 2014).

The microscopic models offer a great wealth of details but require a proper calibration due to the variety of parameters used. The figure 2 represents a microscopic visualization of a given network:

Figure 2. Example of microscopic visualization of a network

- *Mesoscopic models :*

Mesoscopic modeling of traffic appears as an intermediate approach between the first two approaches. They make it possible to model the network without much effort on the coding of the parameters, while ensuring a better representation of the dynamics of the traffic and the individual behaviors of the participants. This makes them more flexible compared to macroscopic models (Dimon, 2013). In the mesoscopic approach, traffic is represented by a group of vehicles for which activities and interactions are described at a low level of detail (Yin & Qiu, 2011).

Figure 3. Example of mesoscopic visualization of a network

In summary, we recall that each model has its own limits of representation and its field of application. Indeed, it is relevant to specify the spatial and temporal scales of a road traffic study in order to choose the appropriate simulation model according to the means available and the objectives that are pursued. In Table 1, we propose a classification of the different models treated in the literature in the field of road traffic studies:

Models category	**Sub categories**	**Objective**	**Time scale**	**Spatial scale**	**References**
Land occupation	-	Planning, management	Very long term	Global	(Derbel, 2014)
Network Management	Fire regulation	Planning, regulation	Long and short term	Local	(Duret, 2013); (Treiber & Kesting, 2013)
	Speed regulation	Control, regulation	Long and short term	Local	
Traffic flow	Macroscopic	Evaluation, planning, management	Long and short term	Global	(Yin & Qiu, 2011); (Costeseque, 2013); (Dimon, 2013)
	Microscopic			Local	

	mesoscopic			Global or local	
Demand forecast	Four steps	Planning, management	Very long & long term	Global	(Derbel, 2014); (Antoniazzi, 2011)
	Entries exits		long term	Global	
	Modal choice		Short term	Local	

Table 1. Typology of models processed in the field of traffic studies

Models related to traffic studies are transcribed quickly in dynamic simulation tools. As part of our study, we are particularly interested in models of dynamic simulation of road traffic. As a result, the most commonly used road modeling and dynamic simulation tools will be detailed in the next section.

2.3 Modeling tools and dynamic simulation of the road traffic

Many tools exist in the literature for each component of the simulation (law of pursuit, queuing changes, conflicts, etc.) and commercial software does not use all the same models. Dynamic traffic simulation software can simulate microscopic, macroscopic or mesoscopic scales (Buisson & Lesort, 2010). The presentation of these tools is divided according to whether the software is purely commercial or that it comes from the field of research. Table 2 shows a list of the most commonly used dynamic traffic simulation software.

Scale	Typology	Software		References
Microscopic	Commercial Software	Aimsum	Software developed and marketed by Transport Simulation System (TSS). it allows to model the circulation of any type of network and to simulate different scenarios taking into account even public transport.	(Costeseque, 2013)
		Dynasim	Developed and marketed by Dynalogic, it is multimodal software for modeling and microscopic simulation. It allows to model as finely as possible the flow of traffic on a network. This software integrates the functions of dynamic simulation of road, rail and river infrastructures.	(Costeseque, 2013)
		Vissim	This software is developed by the German company Planung Transport Verkehr (PTV). It is a simulation tool for urban and interurban areas. It proposes a microscopic simulation of the vehicle-driver pair based on a psychological analysis of driver behavior	(Fellendorf & Vortisch, 2010)
		Sim Traffic	It is a microscopic traffic simulation tool capable of modeling arteries with intersections and roundabouts. SimTraffic can be used to generate reports, or just for animation purposes.	(Shaaban & Kim, 2015)
	Software from of research	Mitsim	It is a microscopic simulation tool incorporated into the MitsimLab software developed by the Massachusetts Institute of Technology. It also includes a simulator for traffic management and traffic control and road guidance systems.	(Burghout et al., 2005)
		Dracula	It is a dynamic micro-simulation tool developed at the University of Leeds in 1993. In this type of software the emphasis is on a coupling between a historical model of traffic and a model of microscopic tracking.	(Costeseque, 2013)
Mesoscopic	Commercial Software	Transims	Transims offers macroscopic simulation modules as well as the possibility of hybridization with microscopic modules. This allows them to be used also in the case of mesoscopic simulation	(Costeseque, 2013)
	Software from of research	Dynamit	It is a mesoscopic simulation tool used to present the queues specific to each channel. The tracks are represented in detail in a state of congestion.	(Dimon, 2013)
Macroscopic	Commercial Software	TransModeler	Developed by Caliper, TransModeler offers macroscopic simulation modules and a possibility of hybridization with microscopic modules. This possibility is reflected in the ability to simulate, in the same model, large networks and more precisely a particular crossroads.	(Costeseque, 2013)
		Visum	Developed by the German company PTV, Visum is macroscopic simulation software that allows determining the travel times on an infrastructure network. The calculation is done statically through the results of assignment of the request on the branches of the network.	(Costeseque, 2013)

	Logiciels issus de la recherche	**Symuvia**	It is a software developed in the laboratory of engineering, circulation and transport (Licit). It is based on a macroscopic flow model using a triangular fundamental diagram.	(Costeseque, 2013)
		Metacor	It is a tool from the Metanet program (Inrets) that proposes a dynamic assignment of traffic. It is intended for the macroscopic simulation of large networks such as motorways and highways	(Costeseque, 2013)

Table 2. Typologie des logiciels de simulation dynamique du trafic

3. Conclusion

This work was intended to present the different models, from the literature, that can understand, model and quantify road traffic. As well as the simulation software most commonly used in this field. We have proposed a table of the models treated in the traffic studies, which we have grouped into four classes, namely: displacement demand forecast models, ground occupancy models, flow models traffic and traffic regulation models. These models differ according to the objective envisaged, the planning horizon and the spatio-temporal scale chosen.
In a simulation study the quality and quantity of the data is very often the first difficulty that arises to analyze a network. Through this article we proposed the general approach of a study of traffic.

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Biography

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