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Simulating traffic and environmental effects of pedestrianization and traffic management. A comparison between static and dynamic traffic assignment

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Abstract

Traffic simulation models are capable of evaluating traffic management measures determining their impacts to mobility and environment. This paper presents a study that evaluates traffic management measures designed for the central area of the city of Thessaloniki, Greece, and estimates the environmental effects generated by the proposed measures. The analysis was performed with the use of the traffic simulation software Aimsun. Traffic assignment was conducted both statically and dynamically and all possible comparisons among the tested scenarios were performed. Travel time, delay time, queues and speed were the traffic performance measurements used in the evaluation process. Fuel consumption and carbon dioxide (CO2) emissions were estimated for the determination of the environmental impacts. A sensitivity analysis was also conducted in order to evaluate the effects caused by the variation in traffic demand. Different scenarios regarding particular traffic management schemes were tested and the outcomes indicated that mobility in the centre of the city can be improved in qualitative terms if more public space is given to the mass transport and other modes of mobility such as biking and walking.

*Keywords:*microscopic simulation; traffic assignment; traffic management, pedestrianization, Aimsun
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1. Introduction

Traffic flow models have been developed and used to understand, describe and predict traffic flow since the beginning of the twentieth century (Van Wageningen-Kessels, 2014). The evolution of technology has enabled integration of the models with traffic simulation software, which can typically replicate the movement of units of traffic along a simulated network, considering the interactions between the environment, the vehicle and the driver (Elefteriadou, 2014). Categorizing traffic flow models can be done according to various criteria, depending on their scope, scale and approach (Van Wageningen-Kessels, 2014 and Elefteriadou, 2014). A basic categorization of traffic flow models can be considered, depending on the level at which traffic flow is being represented, as being micro-, meso-, or macroscopic (Elefteriadou, 2014).

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Depending on the available traffic demand data, two different types of traffic assignment simulation are considered: i) static and ii) dynamic (Elefteriadou, 2014).

Dynamic simulation models lay on the concept of user equilibrium which is formulated in terms of Wardrop's (1952) first principle: "*The journey times on all the routes actually used are equal, and less than those which would be experienced by a single vehicle on any unused route.*" That is travelers try to minimize their individual travel times by choosing routes that they perceive as the shortest under the prevailing traffic conditions. These models are known as user equilibrium models as opposed to static models in which the objective is to optimize the total system travel time independently of individual preferences.

Static simulation is based on input traffic flows and turning percentages, which are not affected by the passing of time or by the conditions of the network (Elefteriadou, 2014). This means that vehicles are generated at the input section in the model and perform turnings at intersections according to probability distributions (Barcelo& Casas, 2002). On the other hand, dynamic simulation evolves in time as a function of various elements and is based on O/D matrices and routes or paths (Elefteriadou, 2014). Dynamic traffic assignment consists of two main components: a method to determine the path-dependent flow rates on the paths of the network, and a network loading machine, which determines how these path flows give raise to time-dependent arc volumes, arc travel times and path travel times (Florian et al., 2001). Thus the dynamic version of Wardrop's user equilibrium is formulated in the following terms: "*If, for each OD pair at each instant of time, the actual travel times experienced by travelers departing at the same time are equal and minimal, the dynamic traffic flow over the network is in a travel-time-based dynamic user equilibrium (DUE) state.*"(Ran and Boyce, 1996). Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS) integrated with a dynamic traffic model capable of providing on time information about the prevailing conditions throughout the network can lead to the optimization of real-time traffic assignment (Ben-Akiva et al., 1994 and Florian et al., 2001).

This traffic simulation approach has the ability to capture the full dynamics of time dependent traffic assignment procedure due to a route based microscopic simulation. Demand data is defined as a time dependent O/D matrix and vehicles drive along the network following specific paths in order to reach their destination. (Barcelo et al., 2002) This is the substantial change from static simulation in which there are vehicles that have neither origins nor destinations and move randomly on the network (Barcelo et al., 2002).

This paper examines traffic and environmental impacts arising from the implementation of three scenarios, which include traffic management measures and pedestrianization schemes in Thessaloniki's city centre. It is known (Chiquetto, 1997, Pitsiava-Latinopoulou & Basbas, 2000 and Ghafghazi and Hatzopoulou, 2014) that changes in the transport system can lead to enhanced quality of life and safety for vulnerable users, by facilitating or restricting traffic flow conditions, while Sheffi (1985) states: "*...not every addition of capacity can bring about the anticipated benefits and in some cases the situation may be worsened. In fact, traffic engineers have known for a long time that restrictions to travel choices and reductions in capacity may lead to better overall flow distribution patterns. This is the underlying principle behind many traffic control schemes.*" This situation is known as Braess' paradox.

The analysis was performed with the use of the microscopic traffic simulator Aimsun. Aggregated and disaggregated simulation output statistics have been obtained through static and dynamic traffic assignment simulation. A comparison between static and dynamic disaggregated simulation results was also conducted.

2. Microscopic traffic simulation models

2.1 Models' operation

Microscopic models distinguish and trace the behavior of each individual vehicle and are the earliest that incorporate dynamics (Van Wageningen-Kessels, 2014). Most of the currently existing simulators are based on the family of car-following, lane changing and gap acceptance models to model the vehicles' behavior (Barcelo et al., 2002). That is vehicles adjust their behavior taking into consideration the interactions between vehicles as well as geometric conditions and traffic control (Barcelo et al., 2002). Drivers' decision such as accelerating, decelerating, overtaking or stopping, are based on these models. Each time-step of the simulation, these models are used to update