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Simulating an impact of road network improvements on the performance of transportation systems under critical load: agent-based approach

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Abstract
In this paper, we analyze the impact of planned road network development on the dynamics of the automobile transportation system during the departure of visitors after the semifinal match of the 2018 FIFA World Cup, which will take place in the newly built stadium on Krestovsky Island. To perform such an analysis, we utilize an agent-based traffic flow simulation, which requires the construction of several models. This paper covers the following progress: (1) modeling the road network in Saint Petersburg, Russia (2) a population synthesis based on data provided by the Russian Federal Migration Service (FMS) (3) a comparative analysis of the simulated system behavior using the current and improved road network and (4) a sustainability analysis of the transportation system of the studied area. We estimate the impact of road improvements on traffic flow by simulating various scenarios and determining changes in distribution of agents travel time and load redistribution among exits from the area of interest. This paper is part of the project which aims to develop a large-scale agent-based traffic flow model of Saint Petersburg urban area applicable for a wide range of research tasks from transportation planning to disaster management.

Keywords: transportation systems, agent-based modelling, travel demand, traffic flow

1 Introduction

Mass public events such as sport games, festivals, concerts and demonstrations, are attracting thousands or even millions of people [1] to the relatively small area. This raises various issues from people safety and security to efficient management of crowd flows and transportation. These are the issues which have to be carefully considered and handled well before event occurs. This determines the

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necessity of building computer models which will be able to reproduce (realistically to a certain extent) an event and to provide a framework for testing different scenarios and policies, analyzing and comparing them, and finally for supporting authorities in their decision making.

This paper covers results of our case study made during our work on a global project of construction of large scale agent based traffic flow model of Saint Petersburg, Russia. The purpose of the study was to analyze and to obtain a numeric measure of impact of the improvements of road network aimed to optimize automobile transportation system during the FIFA World Cup 2018 in Russia. As the match with the most extreme load semifinal match in Saint Petersburg has been considered. Departure of spectators from it is a process which includes multiple scales or levels: crowd behavior in the stadium, pedestrian flows from the stadium to the parking areas and traffic flow when people finally get into their cars. This paper reports results of the modeling of the latter layer. Models of the first two layers have been already designed specifically for the case of Saint Petersburg and utilized to simulate evacuation of people from the Vasilievsky Island due to the flood [2] and from the stadium after match [3]. Coupling all these models into one multiscale model is the subject of our future work. Input spatial and temporal distributions of agent departures in our model are supposed to be later provided as output of higher levels, and therefore to serve as coupling mechanism.

For simulation of people departure from parking areas and heading to their homes in personal automobiles MATSim [4] has been used. It is an agent-based traffic flow simulation package which utilizes simple queue-based principle of agents microsimulation, which omits interaction between vehicles, but nevertheless reproduces the most important properties of traffic flow [4, pp. 353-358]. For the case study, covered by this paper, simulation packages implementing car following microsimulation of agents (such as SUMO [5], which was used to simulate scenarios of Pope's visit in 2005 and FIFA World Cup 2006 in 2006 in Cologne, Germany, or TRANSIMS [6]) could look more appropriate. However the final aim of the project is the simulation of similar scenarios not only for the area nearest to the location of event, but on the scale of the whole city, which for the Saint Petersburg scenario means number of agents exceeding 1.5 million. This is a scale which, even with today available computational power, is hardly feasible for simulation with car-following micromodels in reasonable time (see [7] for a comparison of simulation times).

This paper is organized in the following way: general description and characteristics of the considered event and planned transportation management measures related to it are the subject of the Section 2. Section 3 is devoted to description of the models built to provide an input data for simulation runs: road network, spatial distribution of living places of agents, model of departure times distribution. Results of these simulations are reported and analyzed in Section 4. Finally in Section five we discuss methods and results and try to give insights into our future plans on improvements of this particular study and the project of traffic flow model of Saint Petersburg in a whole.

2 FIFA World Cup: event and new road scenarios

According to the preliminary calendar of the 2018 FIFA World Cup, 7 matches are planned to be held in St. Petersburg, including one semifinal and the third place playoff matches [8]. These matches will certainly attract full stadium of spectators. While the capacity of the stadium is 67.8 thousand of visitors the number of those who will come to stadium by personal automobile is estimated to be between 5 and 7 thousand [9].

One of the FIFA security requirements is that there should be no private parking in a 1.5 km radius from the stadium, so parking for private cars is planned on the territory of the Primorsky District [9]. The scheme of parking locations is shown in Figure 1.