Micro-simulation of vehicles and pedestrians to assess the impacts of high demand public events in urban areas

Telmo Fernandes, Faculdade de Ciências e Tecnologia da Universidade de Coimbra, Portugal, telmo_f@hotmail.com

Gonçalo Correia, Faculdade de Ciências e Tecnologia da Universidade de Coimbra, Portugal, gcorreia@dec.uc.pt

Abstract

This work is the result of a master dissertation thesis developed in the University of Coimbra in partnership with Engimind (Mobility and Transport Consultants) with the objective of evaluating the impacts caused by the occurrence of hypothetical events in urban areas. Given the number of factors present in this type of situation, it was decided to use the micro-simulation approach in order to represent the reality as closely as possible. The representation of the three main systems: traffic, pedestrians and public transport taken into account in this analysis was based on the micro-simulation software VISSIM (PTV AG). A case-study of an event in the city of Coimbra was characterized and the impacts of the crowd flow of pedestrians exiting that event were measured. During the model building and running states, solutions were created for the limitations that transport modelling tools still have on translating the interaction between all these systems. We were able to conclude on the advantages and disadvantages of considering these interactions in micro-simulations models in order to take better informed decisions.

Keywords: Micro-simulation; Modeling; VISSIM.

Introduction

In the last decades there has been increasing concern with the problems caused by the great use of private vehicles in urban areas. For studying these impacts computer modeling tools have been created, namely macro-simulation where vehicle flows are aggregated per time period. This type of simulation is geared towards a strategic planning on these systems. With the development of computer technologies, it was possible to start making decisions at a more operational level with micro-simulation where each vehicle is modeled individually using an agent by agent rational to represent the traffic system environment and the interactions between vehicles. Despite increasing model complexity associated with its use, recently pedestrian simulation has been added to these models since the pedestrian system takes a very important role in the urban mobility.

For studying the importance of pedestrian flows in transportation planning we have simulated a hypothetical event in a square on the city of Coimbra (Portugal), focusing on the

interactions between three different systems: Traffic, Pedestrian and Public Transport. To achieve the research objectives, a micro-simulation software known as VISSIM (PTV AG) was used. During the building and running of the model, solutions were created for the limitations that transport modeling tools still have on translating this interactions. We were also able to conclude on the advantages and disadvantages of considering these interactions in micro-simulation models in order to take better informed decisions.
In the following section we present the mathematic background inherent to the micro-simulation model used, followed by the description of the process of designing the model for Coimbra. The paper continues with an analysis of results, and ends with the main conclusions to be drawn from this work.

Mathematic Background

A micro-simulation process is based on an agent by agent representation, which can represent a vehicle or a pedestrian and is influenced by the surrounding environment where it moves. The simulation results are the interaction between all the agents present in the traffic system. However, to obtain reliable results is necessary to calibrate and validate correctly the system where the agents are moving, as their interactions (Traffic Management System, random events, etc.), in this case this is accomplished through mathematic formulas that represent those interactions. This creates a special challenge: to predict the driver's behavior, even if conditioned by the reality (one way street, speed limits), becomes impossible because of the stochastic behavior of the agent's decisions, in this case the human being.
In this work, the micro-simulation model besides containing the already pointed interactions between agents, it also includes in his analysis two different systems and their interactions. If on the one hand we have the traffic system, already extensively studied in the past few years, on the other hand we have the pedestrian system, a recently new system that has been gathering more and more importance.

Traffic System

For the traffic system, the software VISSIM uses a model for representing traffic that is discrete, stochastic, based on time intervals and wherein the micro-simulation considers all the agents individually. Its representation is the combination of four different types of behaviors (longitudinal behavior, changing lane, lateral behavior and conduct towards traffic lights), giving rise to the "driving behavior". From all of them, the longitudinal behavior is the one that takes the most important role in micro-simulation. This behavior is based on variables that give information on changes in circumstances in which the driver is at the moment (different safety distances, speeds, accelerations or decelerations). In Figure 1 we show the graph that briefly illustrates the model used by the software in the representation of vehicles behavior.

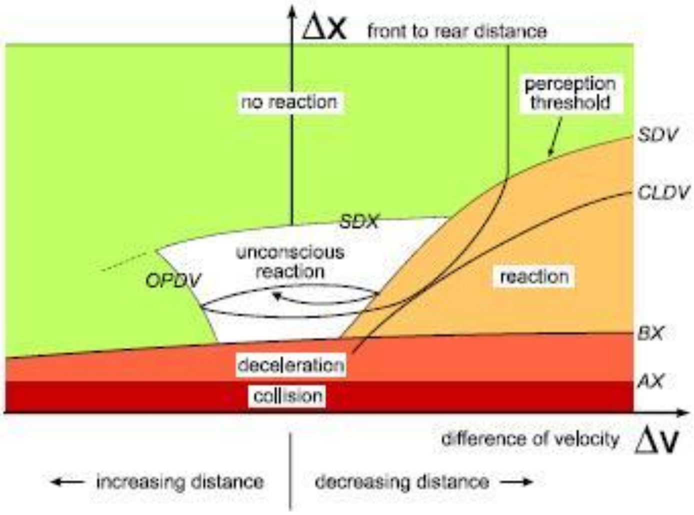

Figure 1 – Car Following Model (Wiedemann, 1992)

Pedestrian System

The principles by which the pedestrian system works are certainly different from those that compose the traffic system. In this case the approach suggests a behavior based in "social forces", i.e., the agent (in this case the pedestrian) is influenced by "forces" that are not fully explained by the surrounding environment, but also by "inner motivations" relating to each individual in performing a given task (i.e. movements). However, looking at human behavior it can be said that this is very difficult to recreate because of its unpredictable nature, nevertheless, in the more usual case there are stochastic models that represent the behavior from the individual himself to a group of individuals. In Figure 2 it can be seen a simplified methodology followed by the model that is adopted:

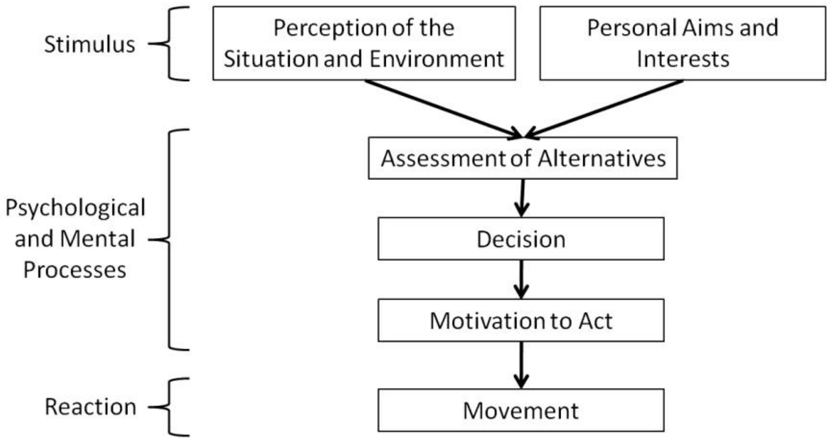

Figure 2 - Social Force Model flowchart (Helbing, 1995)

As a result of this methodology, the pedestrian behavior is often characterized by three different levels. The highest level is called "strategic level", where the agent plans his route to the final destination (in terms of timing decisions ranging from minutes to hours). At the intermediate level lies the so-called "tactical level" where usually the agent makes decisions as a result of an unexpected event on the route outlined (in terms of timing decisions these are already in the range from seconds to minutes) and finally the lower level dubbed "operational level", where the movement is created in the agent itself, i.e., avoid contact with other agents (in terms of temporal decisions goes from millisecond to second).

Concept of the Model – Case Study

Focusing on the case study, we have considered the occurrence of an hypothetical event in the República Square in Coimbra, it is a location with huge potential due to its centrality and proximity to the University Campus, but it is also considered to be an emblematic place in the city of Coimbra. From the scientific point of view this is the most critical step, because it is where you build, calibrate and validate the model in order to represent the real system. Although we followed an order to build the model in relation to the features of the modeling tool, sometimes it was necessary to go back and make some adjustments, giving an iterative character to this phase.

As in every micro-simulation model, the first step was to define all the links, connectors, areas, etc. from the study area using the satellite images of Google Earth. Still in the construction phase, we had to define the BUS routes, crosswalks and road markings in accordance to the reality in Coimbra. Having defined the basis of the model, it was necessary to collect data from the study area, thereby ensuring greater realism by the model.

The first data collected concerned the parking spaces feature where 763 places were observed of which only 724 were accounted for the model due to issues related with the software, i.e., there is a strong limitation on the placement of parking spaces at the borders between links and connectors. The parking spaces were divided into three different geometry types (parallel, oblique and perpendicular) to represent the impact that vehicles have on traffic when entering or leaving each geometric type of parking place.

Then we proceeded to record timings of traffic lights, observing a relationship between all existing signs in the study area with a cycle of 112 seconds. The volumes of traffic and pedestrians were obtained from the area in question during the afternoon peak hour (18h to 19h), being essential for the construction of the OD matrices used in the software (dynamic assignment for the traffic system and static routes for pedestrian system). After data processing the traffic resulted in 97.9% of cars, 1,5% of motorcycles and 0.6% of heavy good trucks. Regarding the pedestrian volumes, it was observed an equilibrium distribution between male and female pedestrians, approximately 46% and 54%, respectively.

Finally, all the bus lines, occupations, pedestrian entrances and exits of each bus were counted through a point check strategy in all existing stops in the study area. To verify the closeness of the model to reality, we performed a statistical validation with very positive results for both systems, based on the indicator "travel time".

Being the model finished and validated, the next step consisted in representing the hypothetical event, thus giving the possibility to carry out an analysis of the results based on the comparison between the current situation and the event scenario. In Figure 3 it is identified where the event takes place in the network and how it is created, i.e., by the existence of three input areas for pedestrians, who subsequently join a main area, thereby recreating an audience of 1500 people at the event.

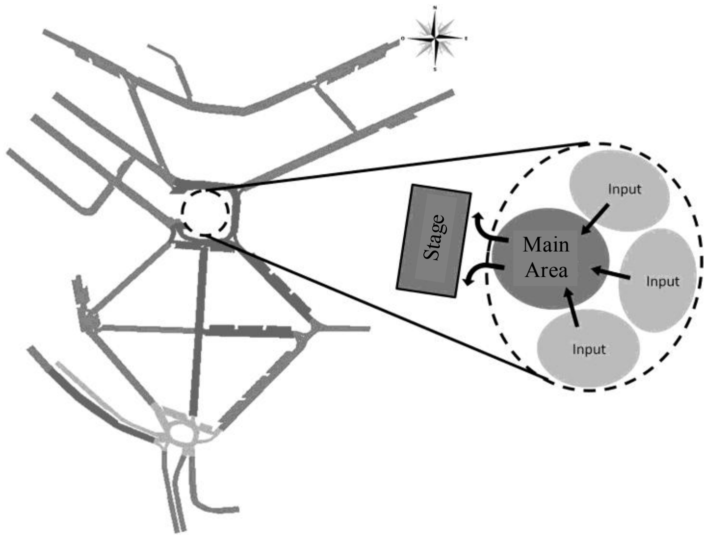

Figure 3 – Event location in the case study zone

Results

With the conclusion of the model, consisting in both transport systems and the event scenario, we could move on to a phase of assessment of its developments in the state of the network over time and comparison of both scenarios, with and without event.

Since the analysis period considered was the afternoon peak hour, the simulation necessarily have to have a duration of 3600 seconds (60 minutes), however, to exist a uniformity of parameters it was necessary to include a warm-up period, in this case, about 900 seconds (15 minutes).

In Figure 4 we present the evolution of the number of vehicles (a)) and pedestrians (b)) along the simulation in the current situation and the scenario with the event.

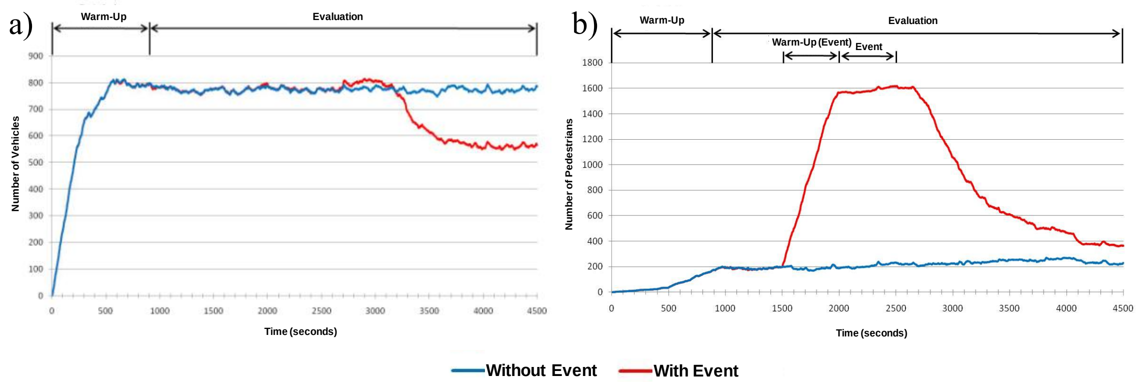

Figure 4 – Evolution of the number of vehicles (a) and pedestrians (b).

Through observation of Figure 4 we can say that the warm-up period adopted was the correct one, since we achieved the desired uniformity in the number of vehicles and pedestrians at the beginning of the analysis period. With the introduction of the event in the simulation we obtained new data that met our expectations, i.e., particularly in the traffic system the number of vehicles increased at the time steps immediately following the end of the event (resulting from congestion) while reducing considerably after that period because the vehicles of the event attendants are exiting the area. The number of vehicles stabilizes after 10 minutes.

Looking at the pedestrian system it is possible to observe a difference in the number of pedestrians at the end of the simulation between scenarios, resulting from the existence of pedestrians still waiting for the public transport.
In Figure 5 we show different stages of the simulation in the event scenario through thematic maps. This allows identifying the most critical places, as well as the duration of the impact.

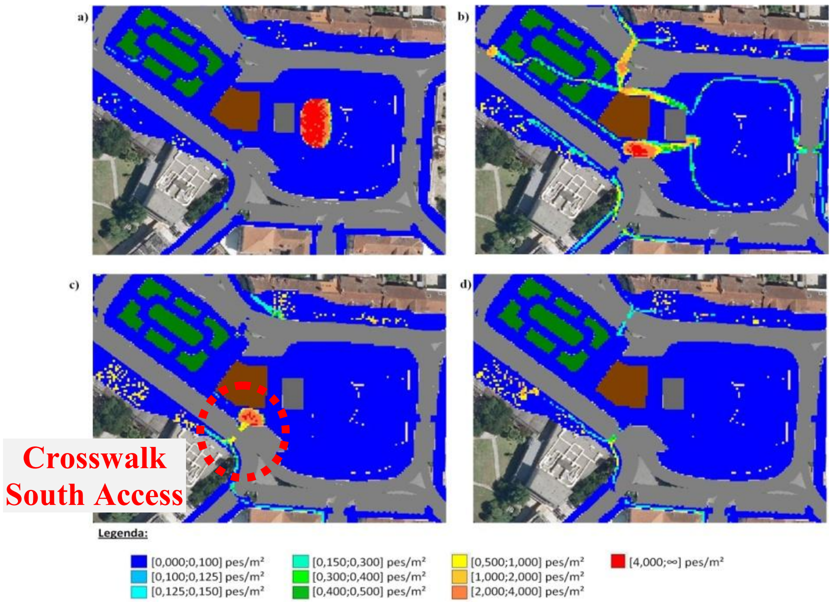

Figure 5 –Evolution of the pedestrians' densities after the end of the event: a) Event final; b) After 5 minutes; c) After 10 minutes; d) After 22 minutes.

Analyzing Figure 5, it can be pointed out the most important result of this work, which is that the impacts on the Square where the event occur are felt up to 22 minutes after its end, that is, until the moment when the densities in the event scenario get back to values observed on the current scenario in the study area. Beyond this, it is confirmed that pedestrians use all the available paths connecting the Square. Again looking at the figure, we see that after 10 minutes only the South access meets a large number of pedestrian waiting for an opportunity to reach the other side of the street through the crosswalk.

Traffic System

After analyzing indicators such as the number of vehicle/pedestrians and densities, the next step was the study of more specific indicators to be easier to notice the impacts caused by the hypothetical event. For this purpose, we considered an analysis period of 25 minutes after the end of the event, dividing it into five intervals of 5 minutes each. For the analysis thereof was considered a division by systems, i.e., initially the traffic system was analyzed, then the pedestrian system and finally the analysis of public transport. Figure 6 shows the analysis results of the traffic system indicators.

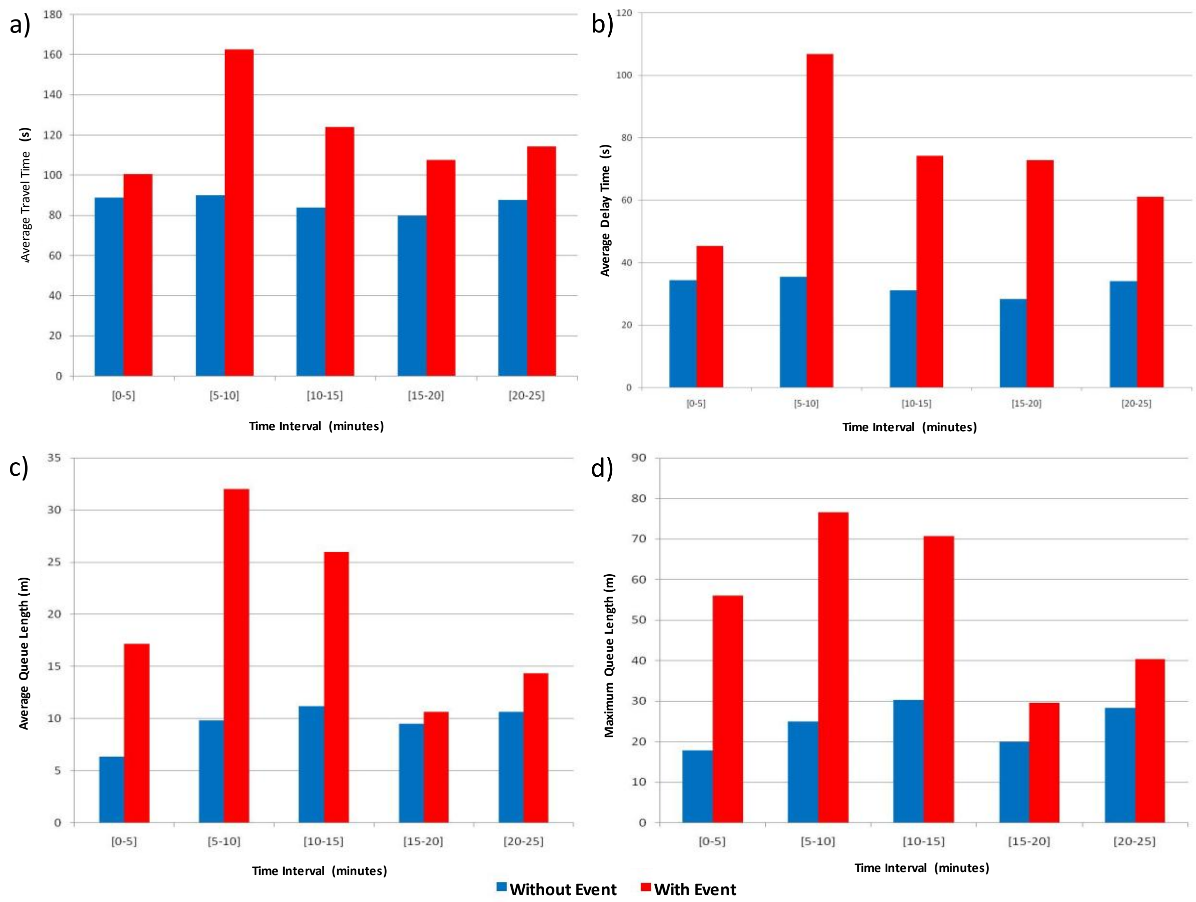

Figure 6 – Different traffic parameters analyze: a) Average Travel Time; b) Average Delay Time; c) Average Queue Length; d) Maximum Queue Length.

Looking at the figure above conclusions can be drawn about the effect of the event. By checking all of the results, the selected indicators follow the expectations of an event of this type. The measurements of the travel times, delays, average and maximum lengths are consistent with each other and provided a good characterization of the consequences of the event, i.e., the existence of a critical interval for the traffic system between [5 - 10] minutes after the end of the event.

Pedestrian System

Based on Figure 5, it is clear that there is a problem related to the high concentration of pedestrians that lasts for too long on the south access. Considering this point, we carried out an analysis of the indicators related to the pedestrians who pass by that crosswalk, in order to show tangible results about the issue in question. Figure 7 shows the average travel time and average delay time from pedestrians affected from the event scenario.

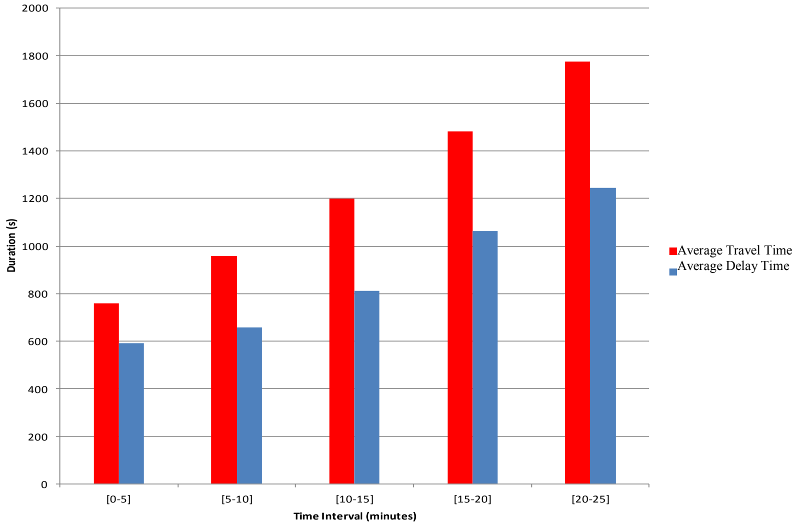

Figure 7 – Average travel time and delay time from the pedestrians that use the south access crosswalk

Once again, by analyzing the previous figure, it can be seen that as the period of analysis advances, the average travel time increases. This result would be expected, since the longer the pedestrians are in the queues, more time it will take to reach their destination. Logically, the average delay time follows the same trend as this indicator, since it is directly related to the average travel time.

Public Transport

Finally, we obtained the results for the public transport, where it is important to show if they are performing correctly. Typically, there are several indicators to represent the most important characteristics in a public transport network, however, since the study area is only a small part of the entire network of bus lines, the choice fell on representing the difference between the bus occupancy between the two scenarios. In Figure 8 one can see the evolution of the difference between passenger occupancies in public transport between both scenarios.

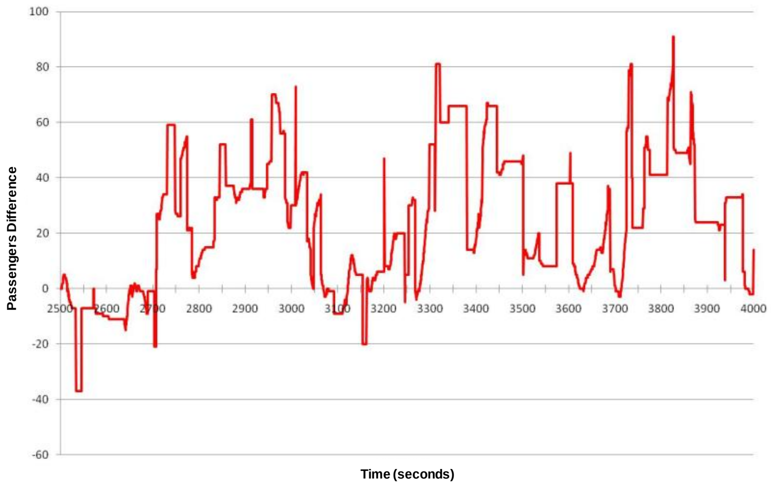

Figure 8 – Evolution of the difference between passenger occupancies in public transport.

The chart shown in the previous figure is obtained by subtracting the occupancies between the event scenario and the current situation, thus giving the notion of an increase or decrease of occupancies depending on the event. Although, at the beginning of the analysis period the difference is negative, it is observed quickly that differences become positive, showing that the occurrence of the event increases the use of public transport significantly in relation to the current situation.

Conclusions

Taking into account the increasing complexity of transport systems, the realization of studies that can predict reality in the most accurate and detailed way possible becomes essential. The use of simulation tools is becoming more frequent as the capacity of the computers increases, namely micro-simulation models that use a representation agent by agent. As a consequence from this type of representation, the building phase of the models presents itself as one of the most important in the analysis through micro-simulation. In this field, the absence of a specific function from the software VISSIM to represent the events, require the combination of different functions to achieve the goals, not assuring a precise representation of the entire phenomenon in the case study.

Focusing on the case study, it can be concluded that the model represents the reality well and that the critical interval in the traffic system when put through the impact of an event of pedestrian concentration is between 5 and 10 minutes after de end of the event. Analyzing the pedestrian system it is possible to identify the problems that are going to exist with the crosswalks, more specifically the south access crosswalk which presents the worse performance as a result from the high pedestrian volumes in conflict with the unfit traffic lights cycles for such a high pedestrian movement search. Looking into all these factors and depending on the type of event and target-audiences it can be considered that the people directly affected by the impacts are willing to accept these changes during a short period of time for the benefit of their city.

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