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Simulation of Tram Stops and their Influence on Traffic – Case Study in Sofia, Bulgaria

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Key Words: *Simulation; intelligent transport systems; traffic flow; AIMSUN.*

Abstract. *The article will present the usage of AIMSUN software for modeling of urban traffic at busy intersections in Sofia. Results from a case study concerning influence of tram stops on traffic will also be presented. The case study is aimed at modeling of four connected intersections that are controlled by traffic lights along Shipchenski prohod Blvd. in Sofia, Bulgaria. The hypothesis is that tram stops will affect traffic in a negative manner. However, it is more valuable to detect the extent of this influence as this may serve for the purposes of authority for making inform decisions about time tables of trams. The possibilities of AIMSUN software suit to measure various traffic indicators as well as indicators about the fuel consumption and air pollution were utilized in this study.*

1. Introduction

Road traffic is becoming an increasingly important priority, especially in urban areas. We need a simulation of this traffic to better understand the congestion problems in these areas. Generally, simulation is defined as a dynamic representation of a part of the real world in time. This is a tool that is widely used to test or evaluate an action plan prior to its implementation [10].

The topic under consideration in this paper belongs to the application of concepts of Intelligent Transport Systems (ITS) in a densely populated urban area. This topic is also related to the optimization of traffic in urban environment in which different types of vehicles like cars, buses, trams, heavy vehicles, bicycles and other types of vehicles are involved.

This research applies the software environment AIMSUN, for modelling and simulation of car traffic and tram stops at selected intersections in the city of Sofia. Observations, measurements, modeling in AIMSUN simulation environment are discussed in [3, 14, 15]. The main issues that are being addressed through modeling and simulation are change in traffic indicators and the resulting air pollution with harmful emissions. These are two interrelated problems that can be addressed by the AIMSUN simulation environment [4, 5].

2. Objectives of the paper

An additional aim of this paper is to present some basic opportunities that AIMSUN suit presents for modeling and simulation of traffic networks.

The additional constraints, which this research takes into consideration is that the network model integrates tram stops in the traffic modeling. Such additional constraints were no taken in previous developments of traffic flow control.

The new aspect of the network model that is presented in this paper is the introduction of tram stops in the simulation model. Previous studies related to modeling and simulation of car traffic do not consider such realistic case of traffic control [1, 2].

The study started with the hypothesis that the traffic control without trams will show better results in terms of traffic indicators than the case with trams. It is a realistic assumption to expect that with the presence of tram stops in the simulated network the traffic control will achieve worsen performances of the network.

This research will assess the influences of the tram stops in real transportation network in the city of Sofia. These assessments are performed by modeling a real urban transportation network in Sofia with the software environment of AIMSUN suit.

3. Modeling and simulation of traffic in the simulation environment AIMSUN

A microscopic simulation model of four signalized intersections along Shipka Prohod Boulevard (Sofia, Bulgaria) was developed. The model is implemented using AIMSUN transport simulation software. The model is presented in *figure 1*.

The simulated network is 1.5 km long. It is an urban area that is densely populated. Part of the traffic is generated by citizens and guests of Sofia, who visit mainly shopping centers and local shops in the neighbourhood. Large traffic is generated by people working in the area and by people heading to the city center or in the opposite direction.

Allowed network speed is 50 km/h. It is a small network with 4 signalling intersections in close proximity to one another. For this reason, acceleration and deceleration often occur in the simulated network and this results in increased emissions from cars. An additional problem is the constant increase in the vehicle fleet, which leads to an increase in traffic intensity and hence to a variable mode of motion, frequent stops and accumulation of cars at intersections [6, 12].

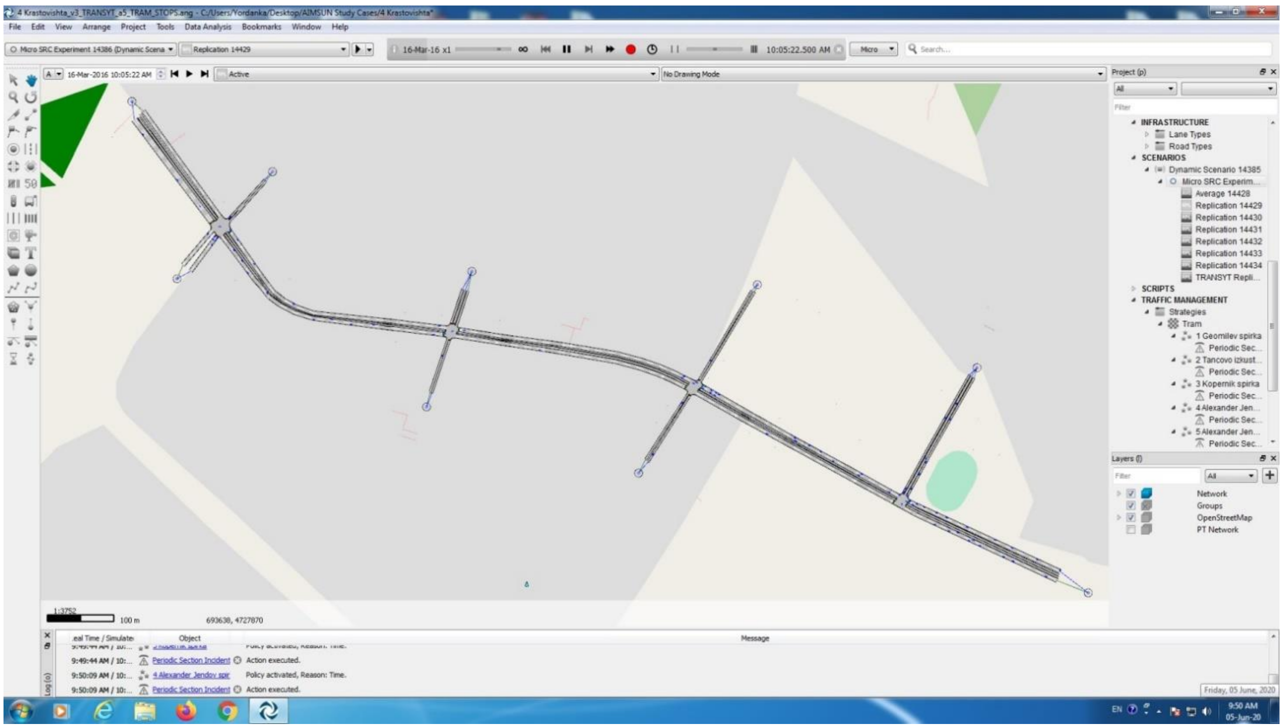

Figure 1. Simulation of four connected signalized intersections

The modelling process in AIMSUN suit is presented briefly. The traffic network under consideration is imported from Open Street Maps and small changes in the model are performed to reflect some particularities of the real road network. Sink-source points called Centroids are defined for the cars that enter and leave the network. Traffic demand from measurements is entered in the program. The flow data for each direction on each crossroad is entered as input data for the simulation. The signal timings for all four traffic lights are added to the model. After the model is prepared according to the given steps a simulation is performed that calculates traffic indicators for the traffic network without considering the tram stop. A next simulation is run with different settings, taking into account the tram stops and a comparison between the two simulations is made.

The performance of transport network is measured by various indicators, e.g. speed, flow and density, etc. [7]. AIMSUN suit calculates the traffic indicators during a simulation and shows them in a table after the simulation finishes. By comparing the output results of different scenarios an evaluation is made of the network performance. In the case of this study two scenarios are simulated – a before scenario that is prior to the introduction of tram stops and an after scenario – after the introduction of tram stops.

Besides the traffic indicators that show the movement of vehicles through the network AIMSUN suit integrates also environmental models. Based on these models the fuel consumption and air pollutants – CO_2, NOx, PM (particular matters) and VOC (volatile organic compounds) are calculated for each scenario. Although, trams are environmental friendly vehicles in comparison to buses, they still cause some issues because of the queues they provoke when stopping on tram stops. The aim of this study is to measure tram influence on traffic and environment that will be presented in the following sections. Interesting studies on synchronization of trams with signal timing are performed in [8, 13]. These studies could be a starting point for future study of the network presented in the experiment in this paper.

Tables 1 and *2* present inputs for the car flow at one of the examined crossroads. The averaged data for an interval of 1 hour for 6 days for the flow of cars at this crossroad are presented. The directions of movement of the cars are counted separately – left, through, right. The traffic flow as an average number of cars per hour is used as input in the AIMSUN suit. The traffic flow is simulated for one hour with duration 10:00 am to11:00 am.

Since AIMSUN provides an opportunity to assess environmental performance, simulations have been carried out to evaluate pollutant emissions. This model is based on [9, 11]. It evaluates the pollutants CO_2, NOx, PM and volatile organic compounds (VOCs).

Table 1. Traffic flow at traffic lights 1 and 2

	Traffic light 1					Traffic light 2		
	left	through	right			left	through	right
one hour	27.50	568.33	148.50		one hour	247.50	53.16	311.66
one hour	23.83	564.66	212.66		one hour	247.50	33.00	309.83
one hour	23.83	606.83	170.50		one hour	242.00	53.16	372.16
one hour	513.33	137.50	16.50		one hour	196.16	44.00	297.00
one hour	18.33	568.33	113.66		one hour	262.16	66.00	308.00
one hour	34.83	535.33	130.16		one hour	223.66	67.83	300.66
SUM	641.65	2980.98	791.98		SUM	1418.98	317.15	1899.31
Average	106.94	496.83	131.99		Average	236.49	52.85	316.55

Table 2. Traffic flow at traffic lights 3 and 4

	Traffic light 3					Traffic light 4		
	left	through	right			left	through	right
one hour	436.33	540.83	31.16		one hour	11.00	36.66	25.66
one hour	401.50	584.83	20.16		one hour	12.83	31.16	12.83
one hour	429.00	452.83	36.66		one hour	16.50	34.83	16.50
one hour	401.50	432.66	18.33		one hour	11.00	20.16	11.00
one hour	396.00	480.33	47.66		one hour	9.16	20.16	14.66
one hour	443.66	504.16	34.83		one hour	5.50	22.00	12.83
SUM	2507.99	2995.64	188.8		SUM	65.99	164.97	93.48
Average	417.99	499.27	31.46		Average	10.83	27.49	15.58

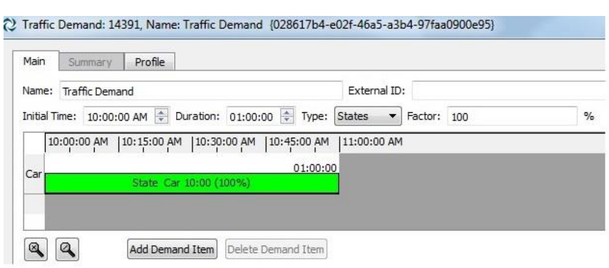

Figure 2. Traffic flow for one hour from 10:00 o'clock

These pollutants were selected because of their strong health impact compared to other pollutants. The emission model is based on empirical measurements that link vehicle emissions to the type, instantaneous speed and acceleration of the vehicle [11] (see *figures 3* and *4*). The emissions model of Panis et al. [11] requires information on the type of vehicle and fuel used by the particular vehicle type. Fuel type data is calculated based on data provided by the Bulgarian government website for open data (see *figure 4*).

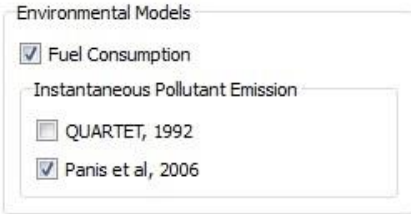

Figure 3. Environmental models in AIMSUN [1]

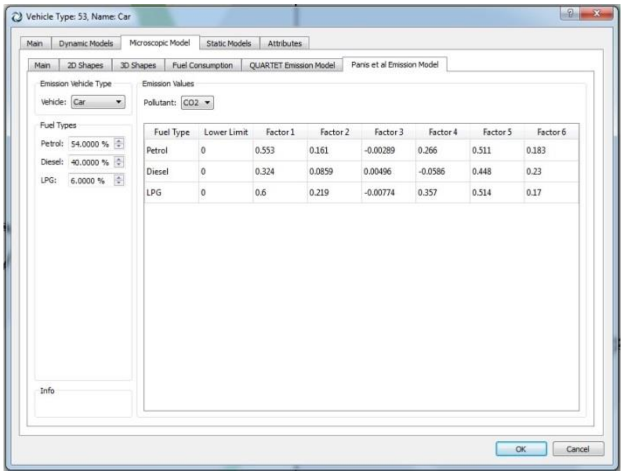

Figure 4. Panis et al. [11] model for harmful emissions

4. Case study of the influence of tram stops on traffic

Eight tram stops along Shipchenski prohod Blvd. were simulated. For each stop a periodic incident with duration of 30 seconds and interval of 6 minutes between each "incident" was simulated (see *figure 5* and *figure 6*). Periodic incidents are the mean to simulate a tram stopping on a tram stop in AIMSUN suit. All lanes remain blocked for the time of the periodic incident. Thus the delay and number of stops of cars increases as well as several other traffic indicators.

Waiting cars in front of a tram stop are presented in *figure 5*. *Figure 6* shows a screenshot of the project window more precisely the traffic management strategy is presented. In the traffic management strategy eight existing tram stops are defined – from number 1 to number 8 with the corresponding name of each tram stop. A periodic section incident is assigned to each tram stop.

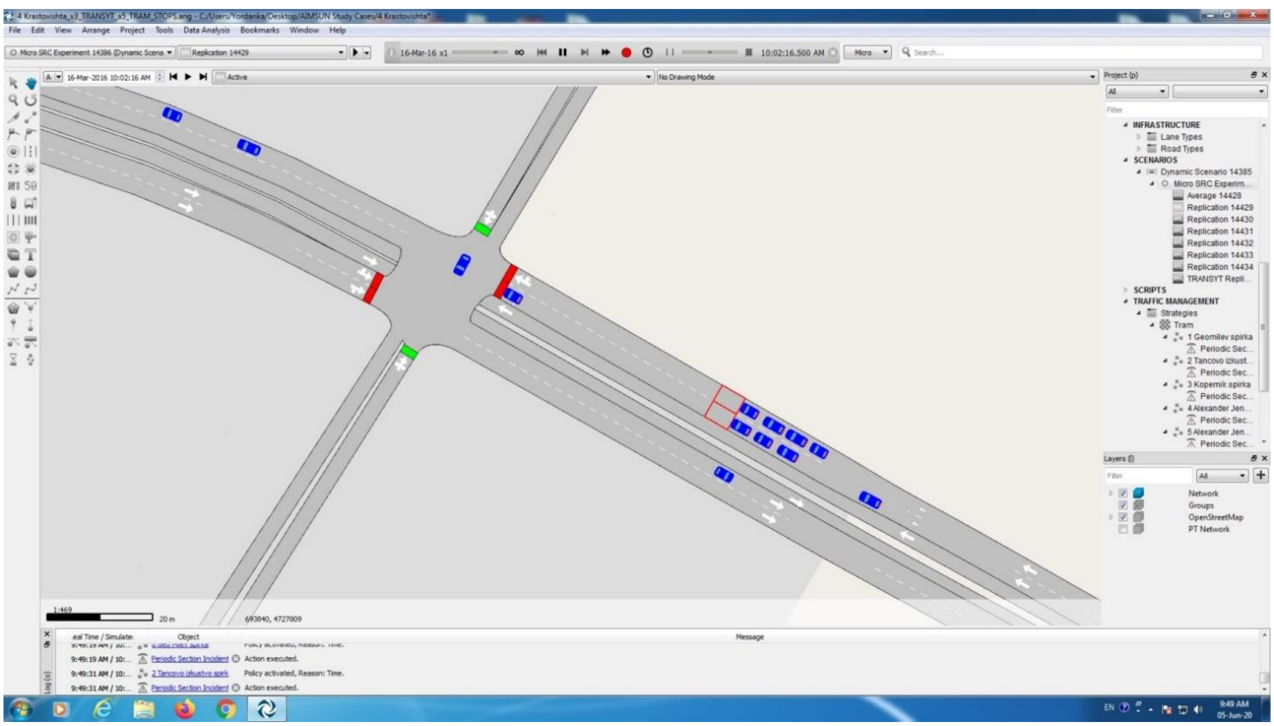

Figure 5. Queue of cars in front of a tram stop

Figure 6. Periodic Section Incidents represent tram stops along Shipchenski prohod Blvd.

5. Results and discussion

The results from the simulation and the experiment are presented in *table 3*. The core part of this experiment is comparison of traffic indicators before and after the introduction of tram stops in the model. An overview of changes in main indicators follows.

As it is obvious from *table 3* the delay increases by 7.90% in comparison to the case without trams. The biggest change is in queues, the change is by 10.02%. Stop time – change by 8.39% and total number of stops – change by 6.22% could be perceived as one of the most significant changes compared to the changes in other indicators.

This indicators change as expected because of the influence of the stop time of trams that is necessary for passengers to get on and off the tram. Air pollution indicators are also affected by tram stops. Although the change in the air pollution indicators can be perceived as not very significant with 1.43% for CO_2, 1.41% for NOx, 2.30% for PM and 3.27 for VOC. The fuel consumption also increases by 2.57%.

The speed decreases for the presented network by 2.04% and as a result the travel time per car as well as the total travel time increases by 2.95% and 3.63%, respectively.

Table 3. Results – influence of tram stops on the traffic

	Without tram stops		With tram stops		Units	Difference in %
Time series	**Value**	**Standard deviation**	**Value**	**Standard deviation**		
Delay time	39.75	37.93	42.89	39.9	sec/km	7.90
Density	6.85	N/A	7.1	N/A	veh/km	3.65
Fuel consumption	322.22	N/A	330.49	N/A	l	2.57
IEM emission – CO_2	821317.22	N/A	833030.8	N/A	g	1.43
IEM emission – NOx	1786.13	N/A	1811.27	N/A	g	1.41
IEM emission – PM	317.49	N/A	324.8	N/A	g	2.30
IEM emission – VOC	960.65	N/A	992.02	N/A	g	3.27
Mean queue	21.36	N/A	23.5	N/A	veh	10.02
Number of lane changes	440.71	N/A	445.24	N/A	#/km	1.03
Speed	37.22	10.75	36.46	11.09	km/h	-2.04
Stop time	29.31	34.46	31.77	35.88	sec/km	8.39
Total number of lane changes	5547	N/A	5604	N/A		1.03
Total number of stops	6990.34	N/A	7425.36	N/A		6.22
Total travel time	85.11	N/A	88.2	N/A	h	3.63
Travel time	106.6	38.09	109.74	40.06	sec/km	2.95

The overall impression of the presented figures is that tram stops do not affect the traffic indicators significantly. More indicators of traffic can be seen in *table 3*.

6. Conclusions

The advantage of using transport simulation environments for society is to optimize and improve traffic without creating the inconvenience to drivers that would arise when testing different options for real-time traffic lights settings.

The initial hypothesis that the simulated network will perform worse in case with trams than in the case without trams was confirmed which is not surprising. The value of this study lays in the possibility the influence of tram stops to be simulated and to provide quantitative results about the network performance. Consequently, informed decisions can be taken by authorities concerning opening or closing of tram stops, duration of tram stops, tram time tables, etc.

Once simulated the network model with tram stops can be easily modified for different scenarios and application of different control policies.

As tram time table is a known event that is predictable an interesting study would be to how to synchronize the tram arrival on a bus stop with the traffic lights.

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