Computer simulation for operational traffic improvement in urban intersections

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Abstract: Micro-simulation of traffic flow in urban networks has become a popular tool to analyze and evaluate the operation of complex transportation systems under congested conditions. Within this article, using the micro-simulation software AIMSUN, there were analyzed several options for the systematization and traffic control in terms of measure of performances (average delay, average number of stops at intersections, average speed of passing through the intersection for different periods and different traffic lights cycles). The case-study set-up a solution which reveals the improvements in traffic flows through one of the most complex and homogeneous intersections in Bucharest (Grozavesti area).

Key-Words: micro-simulation, congestion, operational improvement, traffic signal timing

1 Introduction

Road traffic congestion has become one of the most irritating problems of the modern world which comes as a result of the increasing in motorization rate, extension of city outskirts, increase of urban population and its mobility needs. While the development of the urban road network is extremely limited both from physical and financial reasons, methods to mitigate congestion in urban agglomerations are mainly aimed to reduce social mobility (in terms of citizen travel needs and freight transfer) and to take actions for the better use of the existing road infrastructure (by reducing spatial and temporal variability of the traffic flows and by improving the traffic flows fluency as a result of the traffic systematization in conflict areas - intersections) [7]. This study was undertaken in order to reduce the traffic congestion, and mitigate the traffic flows within the studied area.

The traffic control within intersections by the use of traffic lights is designated to provide an orderly movement of the traffic established and to alternate the right of way for different access ways. Thus, is evident that poor traffic control for both permitted and permissive traffic movements can lead to traffic congestion, whereas well-designed traffic control plans, such as efficient traffic signal timings, can significantly reduce traffic congestion. In fact, in traffic signal systems the control of the traffic light signal timings is one of the least expensive and most effective means of reducing congestion in metropolitan road networks.

Complex dynamic processes that occur between the main components of the traffic systems (roadways, traffic controls, drivers, vehicles) are hardly described by analytical models. Each system entity’s behaviour and the huge amount of interactions between entities cannot be represented mathematically with an acceptable degree of accuracy. Thus, the studying of road traffic is more suitable for computer simulation [4] [6]. In addition, traffic simulation can be applied to explore new scenarios without modifying or interrupting the system’s activity, which may be very costly and unsafe. Microscopic models describe the temporal and spatial behaviour of the vehicle and their interactions. For example, the lane change manoeuvre uses car-following models compared to the leading vehicle and then with the presumptive one as well as its close follower from the next lane [3].

The general urban plan of the city of Bucharest included the road network improvement by building up new expensive art-works, such as the Basarab overpass. With all these measures, the traffic on the passing area of Grozăvești still remains congested during peak periods (morning and afternoon). A reorganization of the road is proposed in order to improve the traffic flows. Using AIMSUN...
micro-simulation software, a series of performance indicators (average delay, average number of stops at intersections, average speed of passage through intersections etc.) for different periods and phases of the traffic lights cycles, both for the present situation and proposed systematisation are compared.

2 The study zone
Grozăvești area traffic systematization is regarded as being structured with four synchronized simple intersections (A, B, C, D), according to Figure 1. The input flows from A₁, B₁, C₁, D₁ and output flows towards A₂, B₂, C₂, D₂ were recorded as averages over 5 minute intervals for three days.

It is to be noticed that while input flows have similar values, the output flows are unbalanced: the traffic volume in A₂ is about half of C₂ or D₂ (which are approximately equal) and about a quarter of B₂. This volumes are a consequence of a high demand of traffic for passing on the left bank of the Dâmboviţa river towards important objectives (University Politehnica of Bucharest, Bucharest City Hall and other business areas) located on the right bank, as it is shown in Figure 4. A reorganization proposal it is set by allowing the right turn movement at node B.

The current traffic light cycle consists of four phases and the grouping of traffic light S₁, S₂, S₃ and their phases are shown in Figure 5.
The only change in the proposed reorganization occurs in node B, where the right turn is now permitted.

3 Measure of performance: present situation vs. proposed situation

In order to build model in AIMSUN, the following data was required [9]:
- Intersection layout - map of the area, details of the number of lanes for every section, possible turning movements for every junction, speed limits for every section and turning speed for allowed turns at every intersection.
- Traffic Demand Data - vehicle types and their attributes, flows at the input sections (entrances to the network), turning proportions at all sections.
- Traffic Control - location of signals, the signal groups into which turning movements are grouped, the sequence of the phases and, for each one the signal groups that have right of way and duration of each phase.

The geometric layout of the studied area is shown in Figure 5.

Traffic flows at the input sections (entrances to the network) $A_1, B_1, C_1, D_1$, traffic flows at the output sections $A_2, B_2, C_2, D_2$ and right turning proportions $a_{12}=0.10, b_{12}=0.20, c_{12}=0.10, d_{12}=0.20$ and $0.70$ from node E are obtain from traffic flow measurements. The percentages of the left turning movements of the inner intersection $a_{43}=0.78, b_{43}=0.13, c_{43}=0.05, d_{43}=0.36$, were determined from traffic flow conservatism.

The simulation was done under the following assumptions:
- The simulation warm-up is one hour, long enough to limit the effects of initial elements and to reach the considered regime [2].
- The simulation time consists of 5 hours, where between 08:00-10:00 the medium traffic volume is $Q_{in}=4400$ pcu/h, and between 10:00-13:00, $Q_{in}=2800$ pcu/h.
- Different structures for traffic light cycle $T_C=100s, 120s, 140s, 160s$.

The optimal phase durations for various traffic light cycles is determined by comparing the measure of performance for the current traffic flow organization. Thus, there was considered a super-saturated regime characterized by a flow of $Q_{in}=4400$ pcu/h (passenger car unit per hour) as input flow over two hours, followed by a sub-saturated regime characterized by an input flow $Q_{in}=2800$ pcu/h for the next three hours. The waiting queue created during the over-saturated regime was dissipated partially (only on certain input points) and then fully dissipated during the sub-saturated cycle depending on traffic light cycles (Figure 6). Thus, the signalling phases can be chosen so that the durations that allows the total dissipation to be preferred.
The AIMSUN traffic micro-simulation allows measures of performance like: average speed per vehicle, the average distance per vehicle, the average time interval per km, the average delay per vehicle per km, the average number of stops per vehicle per km to be recorded and compared.

For the measures of performance to be relevant in comparing the two scenarios (current and proposed), the following requirements are mandatory: the simulation should be carried out at the same level of flow rates and the formed queues should not be influenced by outskirts of the study area. In our case, the rates between traffic inflows is approximately equal, so that the level of global demand is given by the total traffic inflows is approximately equal, so that the rates between traffic inflows is approximately equal, so that the level of global demand is given by the total traffic inflows.

As, \( \varphi_{in} - \varphi_{out} = lrs \) \( (2) \)

where, \( lrs \) is the slope of linear regression line for one period (of the formation or dissipation of queues).

Considering \( \varphi_{in} \) known (4400 pcu/h during the queue accumulation and 2800 pcu/h during the dissipation), the relation (1) provides, for a fixed traffic light timing diagram, the extreme values which correspond to the period of the queue accumulation and dissipation. The obtained output flow values are summarized for different structures of the traffic light cycles (SC1, SC2, SC3) is shown in Table 1.

**Tabel 1. Output flow values for different structures of the traffic light cycles**

<table>
<thead>
<tr>
<th>Interval</th>
<th>( \varphi_{in} )</th>
<th>lrs</th>
<th>( \varphi_{out} )</th>
<th>lrs</th>
<th>( \varphi_{out} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4400</td>
<td>267</td>
<td>4133</td>
<td>451</td>
<td>3949</td>
</tr>
<tr>
<td>II</td>
<td>2800</td>
<td>-667</td>
<td>3467</td>
<td>-575</td>
<td>3375</td>
</tr>
</tbody>
</table>

SC1-100-50-40-60-7-3, SC2-120-60-54-66-6-0, SC3-140-60-80-15-5

The values of performance indicators are presented in table 2 for a medium inflow rate of 3300 pcu/h and the following traffic light cycle: 100-50-40-60-7-3.

**Tabel2. Comparison of the measures of performance**

<table>
<thead>
<tr>
<th>Measure of performance</th>
<th>Scenario</th>
<th>Variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay time [s/km]</td>
<td>present</td>
<td>proposed</td>
</tr>
<tr>
<td></td>
<td>108,8</td>
<td>78,7</td>
</tr>
<tr>
<td>Number of stops</td>
<td>4,1</td>
<td>2,7</td>
</tr>
<tr>
<td>Speed [km/h]</td>
<td>22,5</td>
<td>27,7</td>
</tr>
<tr>
<td>Distance travelled per vehicle [km/pce]</td>
<td>0,51</td>
<td>0,44</td>
</tr>
</tbody>
</table>

The above mentioned measures of performance provide an overview of the advantages of the proposed changes in the systematisation plan of the Grozaveşti intersection in comparison with the current situation. The variation of the studied measures of performance for the whole intersection is set by a 28% decrease of the...
delay time, an increase in the average travel speed by 23% and a 34% decrease in the number of stops. Furthermore, queue dissipation is much facile for the proposed traffic lights cycles and the rate of the measure of performance kept their order of magnitude.

4 Conclusion
Traffic simulation models have proven to be helpful in analyzing complex traffic situations that exist beyond the scope of the traditional analytical methods. Traffic simulation models could also be applied in transportation planning process, due to their flexibility and feasibility in testing different alternatives that do not currently exist in the real-world.

Using the AIMSUN software there were analyzed several variants of systematization and traffic control in terms of performance indicators (average delay, average number of stops at intersections and average speed for different levels of inflow rates) and a solution which shows improvements for the continuous traffic flow movement is provided. In addition, this solution leads (by reducing the total distance travelled inside the studied area, the vehicle idle running time and the frequency of stops and accelerations) to fuel consumption reduction and therefore emissions mitigation (lower emissions of nitrogen dioxide, carbon monoxide, volatile organic compounds and particulate matter).

AIMSUN is considered as software which does not need much calibration [1]. The results of the Bosch car-following test show that the AIMSUN car-following model is able to present fairly good replication of observed values [5]. However, for further research the model parameters are to be obtained in order to reproduce the apropriate traffic operations conditions.

Acknowledgement
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