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EXAMINATION OF A ROAD INTERSECTION USING STATE OF THE ART TRAFFIC SIMULATION SOFTWARE

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Abstract: In the paper, the authors present a transportation optimization problem related to the mobility of the citizens of the University of Miskolc. The essence of the problem is that during the morning mobility period unnecessary bottlenecks are regularly created in certain sections of the transportation system around the university. The paper focuses on one of the three bottlenecks, a relatively complex intersection before the university which connects several larger traffic areas. This traffic junction was analyzed with the use of a state of the art traffic simulation software - PTV Vissim - and the results were utilized for the optimization of the signal program of the intersection. The modified signal program was again tested in the simulation environment, which showed a significant increase in the throughput capacity of the transport node. Further increases in efficiency could be achieved with the utilization of an adaptive signal program, which could be the focus of further research.
Keywords: traffic control system, signal head programming, traffic simulation, traffic analysis

1. INTRODUCTION

In a simplified manner, the basic dynamics of urban traffic can be described as follows: in the morning, the number of travelers to the frequented points of the city increases greatly, and in the afternoon, the traffic flowing out of the city is dominant [1]. This conclusion is true for both private and public transport. In addition to the high-traffic travel routes outlined above, there are also traffic flows in different directions, as industrial parks located in the outer districts of the city are also a frequent travel destination between 7 a.m. and 8 p.m [2]. Nevertheless, in the largest percentage of cases, public transport does not provide an easy and convenient way to meet individual needs. Moreover, during the pandemic period, most passengers left the public transport option. For example, most travelers prefer private car-based transport to take their children to school and then to work [3]. The same can be said for the inverse of the former process, when after the working period the children have to be taken from the school, other routine afternoon tasks have to be arranged and finally the trip to home must be realized.

These processes are reflected in the traffic, which has led to a sudden increase in the number of passengers on the roads both in the morning and in the afternoon. It is more spectacular when the maximum transmittance of a predetermined traffic light program at intersections proves to be low, which causes traffic congestion in some directions [4]. These congestions can also have a negative effect on other parts of the given traffic or traffic management network. In addition, it is not a negligible fact that the individual traffic light phases are constant at an intersection, which means that a single traffic light program handles the traffic of the different unique phases of the day coming from different directions. Nodes with multiple light programs that select a light program that matches the

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current traffic situation based on some pre-programmed scenarios or artificial intelligence are rare [5]. Nor is the purpose of this article to develop a management concept based on completely new foundations, but to increase the efficiency of an existing traffic light-controlled road junction in line with real traffic needs.

2. INTRODUCTION OF THE TRAFFIC AREA TO BE EXAMINED

In this article, we examine the morning mobility of the students and the lecturers / researchers at the University of Miskolc. The campus can be accessed from 4 traffic zones, some of which have other alternatives. Figure 1 shows the accessibility of the neighborhood. The university town is located at the bottom of the Dudujka Valley, which has many restrictions in terms of transport planning. The traffic bottlenecks are marked with a red circle in the figure, of which 1 and 2 are described in detail following the Figure, while 3 will be described in the following chapter.

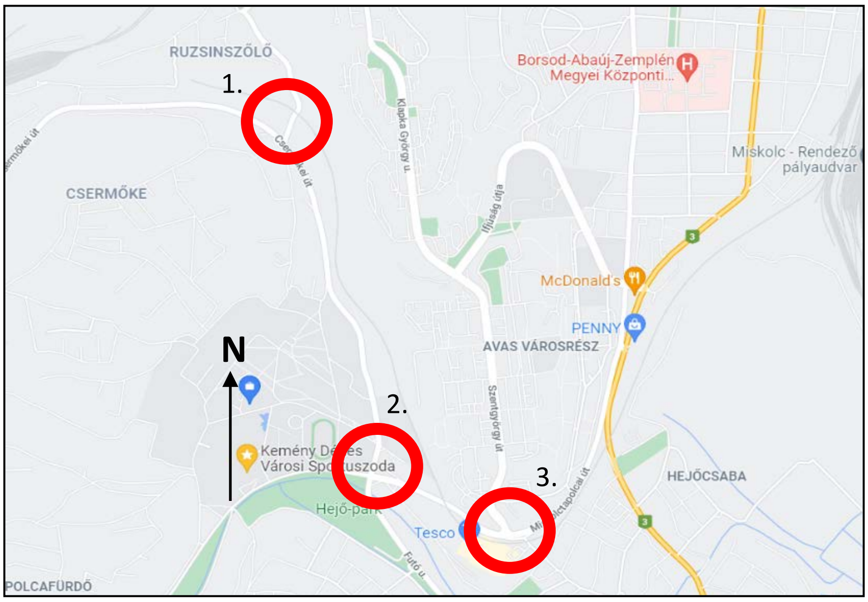

Figure 1: The mobility bottlenecks of the University of Miskolc

➊ **bottleneck:** „Hideg-sori” underpass on a high-slope road. The one who comes from the university town has priority when crossing the subway. Thus, congestion develops in the high-slope lane of this underpass in a hard-to-see bend, especially in the morning. Stalling and collisions due to forced braking are common due to difficult sections.

➋ **bottleneck:** Traffic from the south and east tends to be quite high in the morning. The traffic light at the intersection adjacent to the north is aligned with the traffic light at this intersection, but not at the traffic lights adjacent from the other directions. Thus, the quality of intra-network traffic is unpredictable due to the lack of coordination.

3. INTRODUCTION OF THE INTERSECTION TO BE EXAMINED

3.1. Basic description of the ❸ bottleneck node

Despite the clearly identifiable and repairable properties of the previous nodes, we still chose this intersection as the purpose of the study because it is more complex than the others (the analysis was conducted with the utilization of the academic version of the PTV Vissim software) [6]. Furthermore, increasing the traffic throughput present here alone could bring a quality improvement to the interoperability of the area.

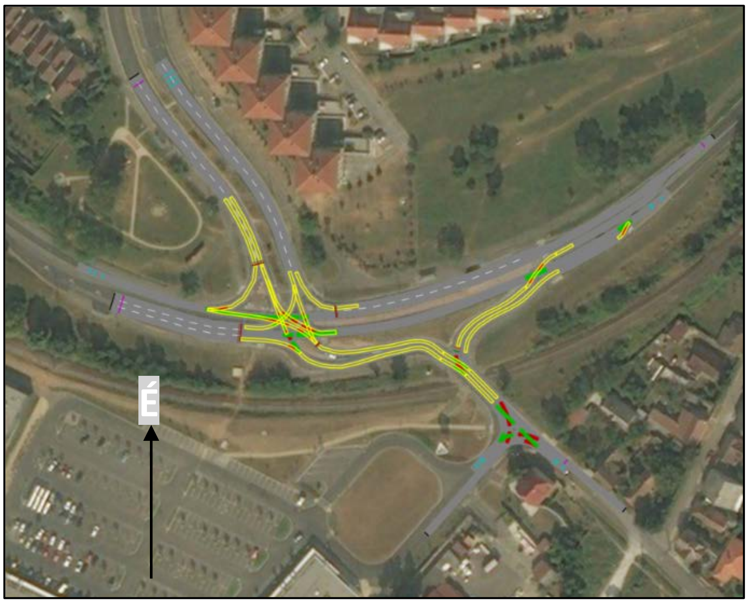

Figure 2: The ❸ intersection modelled in the PTV Vissim software

This junction is one of the most intersections with the following characteristics in relation to Miskolc:

- **Congestion occurs during peak hours due to a sudden change in traffic volume:**
    - **in the morning from the direction of the city,**
    - **in the afternoon from the direction of „Tapolca" (a suburb of Miskolc)/University;**
- **In the traffic light program, from certain branches the green time has low utilization depending on the traffic;**
- **the underutilization of the free cornering phase in case of traffic light control;**
- railway crossing;
- **Intersection of roads with significant elevation / slope at the junction;**
- bus stop without bay;
- bus departure is not aided by a priority traffic light signal;
- there is a cycle path in the east-west direction;
- not all pedestrian crossings are supported by traffic light control.

It can be seen that this is a complex node for the above description, so repairing all parameters would be a high degree of complexity. Therefore, only the traffic throughput affected by the highlighted parameters is analyzed, for which a proposed new phase plan is also prepared.

3.2. System analysis of the ❸ bottleneck node

System boundaries should also be defined for further investigation. Only the flow of road vehicles is taken into account in the system. During traffic light traffic control, only the phases involved in the road are surveyed and modeled in the current phase plan. The entry and exit matrix of the node was surveyed during traffic counting. The survey was conducted in the morning hours. Figure 3 shows in a red rectangle the geographical extent of the delimited system, as well as the actual speed limits assigned to the network elements in the model, as well as the ascent / descent conditions.

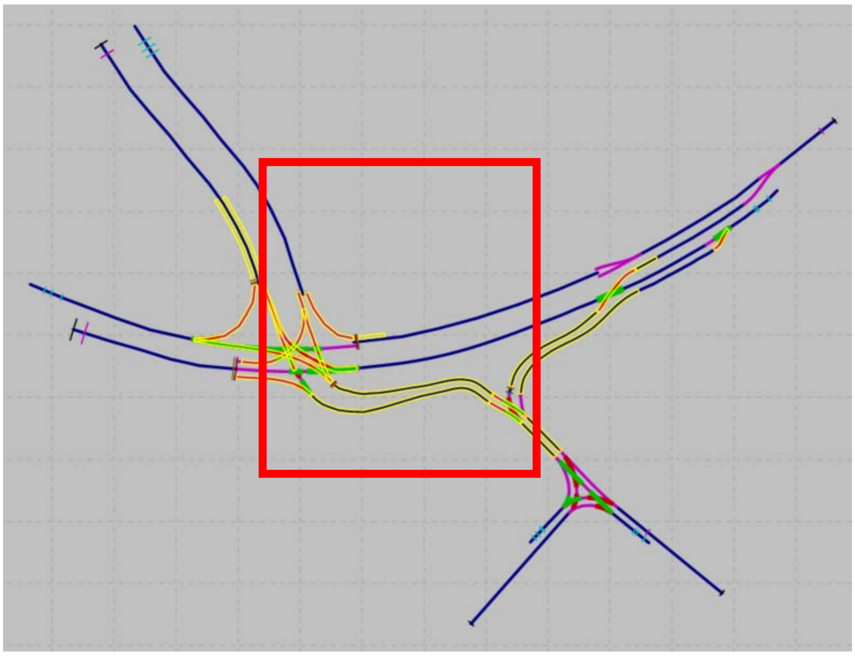

Figure 3: The delimited system of the intersection modelled in the PTV Vissim software

The node also has traffic light traffic control, whose representation in the PTV Vissim edit window is shown on the next page (Figure 4). This traffic light program can be said to be quasi-4 phase, as traffic is released from each incoming direction at the same time. All possible green times are not fully utilized for the features of this traffic light program. However, it can also be observed that the signal sequence is has 4 signals according to the rules, where red means “STOP”, red + amber means “getting ready to start”, green of course means “free passage” and finally amber is the "stop warning if the vehicle can stop safely". The total cycle time is 169 seconds.

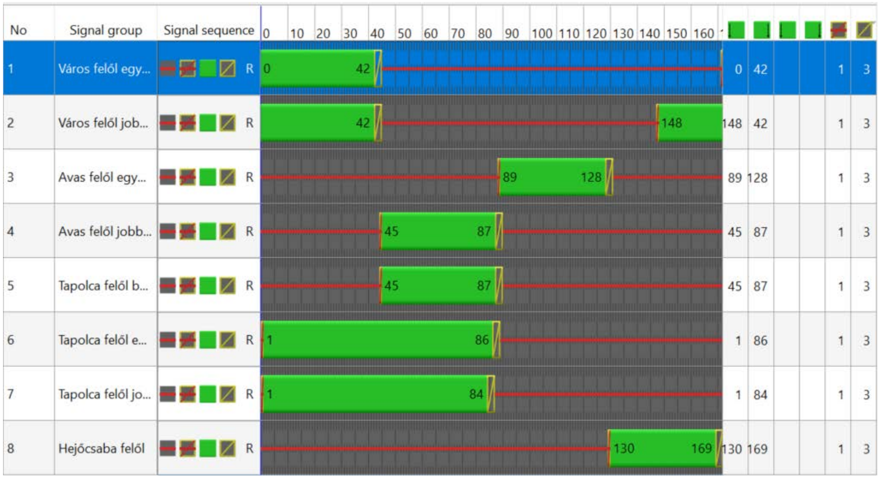

Figure 4: The realistic signal program of the examined intersection shown in the editor window of the PTV Vissim software

The starting point of the present study was that, based on the traffic count, the current operation can obviously be significantly improved. This can be accomplished through a so-called manual efficiency improvement procedure, which can result in significant efficiency improvements through minimal modification of the lamp program.

4. EXAMINATION OF SIMULATION RESULTS

4.1 Description of current data and results

This section begins with the definition of the test system boundary. Data obtained by traffic counting were observed and recorded during the morning period from 07:30 to 08:15. Here, the number of cars coming from each direction that passed through the green time of that direction was observed. This can be greatly influenced by the behavior of road users (mainly drivers), such as acceleration habits, the amount of tracking distance at congestion and reaction time. This is why the “transit” data differ to a lesser extent. The dimension of the data [number of vehicle / hours] can be specified in the software, so it was necessary to compare it from the measured data to determine the hourly intensity. The simulation was then run with a default simulation setting over the study period.

$$KPI^{seq} = \frac{N_{seq}^{veh}}{t_{seq}} = \left[\frac{db}{sec}\right]$$

In the previous formula N_{seq}^{veh} is the number of vehicles passing through one green phase, and t_{seq} is the time of the green phase. After the simulation, the data can be imported and further examined using various statistical methods. In this case, the most effective test KPI is the throughput per second. Using this, the simulation result of a system design with a modified lamp program can be easily compared with the current one.

Table I.

The result of the simulation run with the data from the current system supplemented by the unique indicator

	Current system				
Directions	**Phase time** [sec]	**Delay** [m]	**Max. delay** [m]	**Number of Vehicle** [pcs]	**KPI**^{seq} [pcs/sec]
[From Tapolca To Centrum]	86	19,66	58,15	9	0,10
[From Tapolca To Avas]	42	19,66	58,15	5	0,12
[From Tapolca To Hejőcsaba]	84	19,66	58,15	7	0,08
[From Centum To Avas]	42	29,03	72,92	6	0,14
[From Centum To Tapolca]	42	29,03	72,92	12	0,29
[From Avas To Tapolca]	42	11,42	25,64	6	0,14
[From Avas To Centrum] [From Avas To Hejőcsaba]	39	11,42	25,64	5	0,13
[From Hejőcsaba To Avas] [From Hejőcsaba To Tapolca]	39	41,3	116,1	15	0,38
			Σ	**65**	

It can be seen from this table that the directions **[From Centrum To Tapolca]** and **[From Hejőcsaba To Tapolca / Avas]** have the highest transit rates in the present case.

4.2 Description of the data and results of the modified system

The increase in efficiency can be done by modifying the signal programs for each phase. To do this, the prospective values must be examined. According to the measurement, a significant part of the phase **[From Avas To Centrum / Hejőcsaba]** is not used in the morning, ie at the beginning of the green period the congested vehicles pass and the vehicles in the other phases are just standing and no vehicle passes through the phase in question. Thus, this is a phase whose time can be reduced, but if it is reduced during the signal program cycle, the time taken should be added to another phase so that the time / start-end of the other phases does not slip.

Table II.

Changed phase times

Direction	**Phase time [sec]**	
	Current system	*Planned system*
[From Avas To Centrum] [From Avas To Hejőcsaba]	39	26
[From Centrum To Tapolca]	42	58

The signal program is shown in the following figure after leaving the signal sequence with minimal slip and implementing the modifications in the previous table (Figure 5). Furthermore, it is necessary to increase the time of the green phase in the direction [From

Cetrum To Tapolca] because this is where the "max line length" is the longest, i.e. this is the busiest direction.

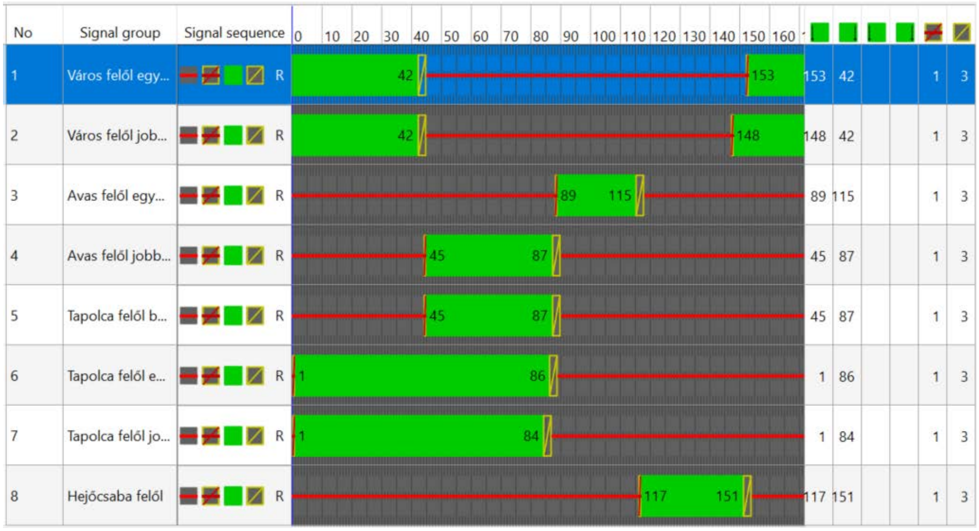

Figure 5. The planned system's program of the examined intersection shown in the editor window of the PTV Vissim software

It can be seen that only the signal program was modified in the simulation, and the results are shown in the following table after the run.

Table III.

The result of the simulation run with the data from the planned system supplemented by the unique indicator

	Planned system				
Directions	**Phase time** [sec]	**Delay** [m]	**Max. delay** [m]	**Number of Vehicle** [pcs]	**KPI^{seq}** [pcs/sec]
[From Tapolca To Centrum]	86	19,66	58,15	9	0,10
[From Tapolca To Avas]	42	19,66	58,15	5	0,12
[From Tapolca To Hejőcsaba]	84	19,66	58,15	7	0,08
[From Centum To Avas]	54	29,03	72,92	7	0,13
[From Centum To Tapolca]	58	29,03	72,92	15	0,25
[From Avas To Tapolca]	42	11,42	25,64	6	0,14
[From Avas To Centrum] [From Avas To Hejőcsaba]	26	11,42	25,64	5	0,19
[From Hejőcsaba To Avas] [From Hejőcsaba To Tapolca]	34	41,3	116,1	14	0,41
			Σ	**68**	

It can be seen that KPI^{seq} decreased in all cases from 0.29 to 0.24, all the more so as the number of vehicles passing through increased by 4. This means that all vehicles waiting in line passed through the extended phase time, so phase utilization decreased but efficiency increased. Depending on the above, optimization can be performed for optimal phase utilization of a given phase if the traffic light operates in such a way that there is always enough time for the green phase to allow the amount of traffic to pass through the intersection. For green waves, this process requires network-level review, investigation, and demand assessment, followed by immediate decision-making through the development of a complex system.

5. CONCLUSION

It can be seen that there is a high data requirement for the analysis and simulation study of transport nodes. Thus, it is absolutely necessary that the given problem is properly defined at the very beginning of the study, in order to obtain appropriate results after building the model, uploading the data, and changing the simulation environment settings. In this case, only a manual change by an outside observer based on the vision of the road users achieved an efficiency increase in which, approaching the morning side of the daily commute, the results reflect 3-4 additional vehicle numbers in 1 cycle. If these are applied to the 45-minute measurement period examined above, the currently congested part of the entire destination vehicle set can also pass through the intersection in smaller increments.

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