OCJENA KVALITETA SIMULACIJE NESIGNALIZIRANE RASKRSNICE UPOTREBOM PTV-OVOG ALATA *VISSIM*

ASSESSMENT OF THE QUALITY OF THE SIMULATION OF AN UNSIGNALIZED INTERSECTION USING PTV'S *VISSIM* TOOL

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REZIME

Efikasno planiranje i modeliranje saobraćaja su ključni za održivi razvoj modernih gradova i saobraćajnih mreža. Simulacija saobraćaja predstavlja proces modeliranja kretanja vozila i pješaka unutar saobraćajne mreže. Omogućava analizu i predikciju ponašanja saobraćaja pod različitim uslovima, kao što su različiti dizajni puteva, mjere kontrole saobraćaja i varijacije u obimu saobraćaja. Simulacijom stvarnih scenarija, simulacija saobraćaja pomaže inženjerima i planerima da procijene efikasnost promjena infrastrukture, optimiziraju protok saobraćaja i poboljšaju ukupnu sigurnost i efikasnost u saobraćajnim sistemima. Ovaj rad se fokusira na mikroskopsku simulaciju koristeći PTV VISSIM, sofisticirani alat dizajniran za dubinsku analizu saobraćaja. Kako se urbane oblasti i saobraćajni sistemi neprekidno razvijaju i evoluiraju, potražnja za preciznim procjenama saobraćajnih uslova postaje sve istaknutija. Napredne tehnologije, kao što je PTV VISSIM, omogućavaju detaljne simulacije koje pružaju tačne uvide u protok saobraćaja, ponašanje vozača i ukupne performanse transportnih mreža. Ove simulacije su ključne za planiranje, optimizaciju i efikasno upravljanje saobraćajnim sistemima, osiguravajući da se rastuće potrebe moderne mobilnosti zadovolje efikasnim rješenjima.

Short original scientific paper

SUMMARY

Effective traffic planning and modeling are cruicial for the sustainable development of modern cities and transportation networks. Traffic simulation is the process of modeling the movement of vehicles and pedestrians through a traffic network. It allows for the analysis and prediction of traffic behavior under various conditions, such as different road designs, traffic control measures, and varying traffic volumes. By simulating real-world scenarois, traffic simulation helps engineers and planners evaluate the effectiveness of infrastructure changes, optimize traffic flow and improve overall safety and efficitiency in transportation systems. This paper focuses on microscopic simulation using PTV VISSIM, a sophisticated tool designed for in-depth traffic analysis. As urban areas and traffic systems continuously grow and evolve, the demand of precise assessments of traffic conditions has become more prominent. Advanced technologies, such as PTV VISSIM, allow for detailed simulations that provide accurate insights into traffic flow, driver behavior, and the overall performance of transport networks. These simulations are essential for planning, optimizing, and managing traffic systems efficiently, ensuring that the growing demands of modern mobility are met with effective soulutions.

1. INTRODUCTION

It has been known for a long time that simulation models represent a useful tool for improving the urban and non-urban traffic systems. By creating replicas of various real processes and phenomena in the virtual world, they enable engineers to discover new or confirm existing knowledge. By simulating, models are formed that will imitate the real system, i.e. the original that is further analyzed. Due to the increasing traffic and growing technology, engineers mainly use microscopic simulation models. Today, there are dozens of microsimulation software tools, and in this paper, a simulation will be performed in the software tool VISSIM, of the German company PTV, which is used worldwide with the aim of analyzing basic traffic indicators such as delays and waiting times.

2. INTERSECTIONS

Intersections or hubs are places of intersection of 'two' roads at the same or different level [1]. These are road sections that are a relatively perilous component. They usually represent the most important 'bottleneck' for the smooth flow of traffic and are the main point of potential traffic accidents [2]. In the case of intermittent traffic flow management, the advantage is safer traffic flow, however, the disadvantages are large time losses of the traffic flow as well as unnecessary stopping of vehicles on secondary traffic routes [3]. There are urban and non-urban intersections, and in both cases the general design principles are the same. The basic differences are the distance, the projected speed, the limited space for performance as well as the availability of pedestrians and cyclists on a larger scale in urban areas [2]. Basically, there are three basic types of intersections:

- uncontrolled intersections at the same level
- high priority intersections
- signalized/time separated intersections at the same level.

Intersections can be of different shapes, so there are Y, T, crossed, skewed, etc. [2]. In this paper, an unsignalized intersection in Crkvice, on the Crkvice - Babino - Babina Rijeka route, is analyzed for the following reasons: the area is densely populated and frequently congested, vehicle speeds remain high despite restrictions, and in recent years, traffic has increased significantly due to construction works on the Zenica Bypass of Corridor 5C. The intersection is T-shaped, which is also shown in Figure 1.

Figure 1. *Preview of travel directions of the analyzed unsignalized T intersection*

2.1. Conflict points

Places at the intersection or at connection points where two or more roads join or cross and where there is a change in the direction of movement, are called conflict points. Thus, a conflict represents any incident caused by driving at an intersection where, due to the improper reaction of one or more traffic participants, a dangerous event can occur, i.e. a traffic accident. [1] For this reason, when designing intersections, one strives to reduce the severity and number of potential conflicts as much as possible. This is achieved with traffic signals and islands for controlling access through maneuvering. [2] A dividing island has already been built on the part of the route from Babina Rijeka, which represents good management, i.e. traffic channeling. The nine conflict points at the observed intersection are illustrated in the picture below.

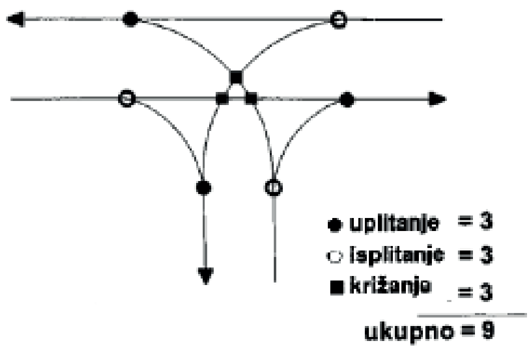

Figure 2. *Conflict points of a standard three-way intersection [4]*

2.2. Traffic signals

Traffic signals are among the most efficient and versatile systems for active traffic management and are widely implemented worldwide. There is horizontal and vertical signaling. In traffic, a cycle represents a period of time during which all available indicators are fully rotated. In the case of traffic lights, it is the period during which the traffic light goes through its phases or signals at the intersection. In the case of no traffic lights, the cycle refers to the natural, informal rhythm and order in which vehicles and pedestrians pass through an intersection or road section. Cycle length is the time required to complete one full cycle, i.e. passing the indicator through all phases and is measured in seconds [2]. The interval marks the transition from one phase to another. Thus, there are two types of intervals known as yellow and red intervals [2]. The yellow interval, also known as the change interval, represents the time between the green and red phases, serving to warn drivers of the upcoming red signal and to allow vehicles already in the intersection to clear it before the next green phase begins. The red interval, also known as the clearance interval, follows each yellow interval and represents the period during which all signal phases display red. It is used to allow vehicles to clear from the intersection [2].

2.3. Designing traffic signals

There are six key phases in creating a traffic signal project [5]:

1. design phase
2. determination of yellow interval/time
3. determination of cycle length
4. distribution of green time
5. pedestrian crossing
6. evaluation of project performance

There are also different methods for designing traffic signals:

1. Trial method
2. Approximate method
3. Webster's method
4. IRC method

The Webster's method is most often used, because it is simple and based on formulas for calculating the Webster's model [2].

3. SIMULATION MODELS

Traffic simulation models are generally divided into macroscopic and microscopic models, depending on the level of detail. Macroscopic models are mainly made for macro, i.e. large areas such as countries, regions, etc. and observe traffic as a continuous flow, without focusing on individual vehicles. Microscopic models, as one of the most detailed traffic models, enable the most precise and detailed traffic analysis. They provide a detailed analysis of drivers, vehicles and their interactions within the traffic system. It is possible to display precise information about the position, speed, acceleration and other characteristics of each vehicle. Their beginnings date back to 1955, when only tests of certain traffic solutions were carried out, while the development of microsimulations increased alongside advances in computer technology.

4. MICROSCOPIC SIMULATOR VISSIM

VISSIM is a microscopic simulation computer program based on the simulation of traffic flows and the emphasis is on analysis of traffic flows. Using real behavior models, the microsimulation simulator can predict interactions between vehicles, pedestrians and other traffic participants and analyze various parameters and conditions of the traffic system. [6] Using VISSIM's microsimulation model, all types of traffic surfaces such as highways, local roads, bicycle paths, etc. can be simulated, as well as all types of traffic - motorized and non-motorized, as well as public traffic, i.e. buses, trams, subways, etc. At the base of every simulation program is a mathematical model by means of which the basic physical laws of traffic - technical and organizational - are defined [7]. As such, the program is based on object-oriented C++ code and is focused on object-oriented programming (OOP). The Gap Acceptance Model and the Car Following Model are most often used. One of the main advantages of

VISSIM is that, instead of the conventional 'link/node' modeling system, it uses a 'link/connector' system which allows the modeling of highly complex and demanding geometries [7]. Accordingly, the process of traffic modeling in VISSIM consists of the following basic steps:

1. creation of links and connectors
2. entry of traffic loads
3. traffic signaling (traffic lights, non-traffic lights)
4. determination of legality of behavior vehicles (advantages, turning directions, areas of analysis)
5. analysis of results

Like all simulators, VISSIM also uses a mathematical model that integrates three basic components that are interconnected: infrastructure, traffic and control. There is another additional component that generates simulation results. The infrastructural part is the first part that is composed of road and railway infrastructure (public transport stops, parking lots and individual physical and stationary elements of the network - signs, detectors, etc.) [7]. Technical characteristics and specifications of traffic flows represent the second part, while the third part represents all the elements that are related to control, i.e. traffic monitoring [7]. All three parts are interconnected, so, for example, current traffic (2nd part) activates detectors (1st part) that make a change on the portal (3rd part). The fourth part is intended for all types of output data without back loops [7].

4.1. Basic mathematical model in VISSIM

The Gap Acceptance Model and the Car Following Model are most often used in the VISSIM program code. The Acceptable Time Gaps model offers two ways to determine time gap parameters used in bandwidth analyses, namely 'Rules of Priority' and 'Conflict Areas'. We use priority rules in all cases of crossing traffic flows. It is important to note that in this analysis method, both the value of the time gap - which directly affects throughput - and the length of the conflict area play significant roles. The vehicle sequence model is based on the quality of vehicle modeling, i.e. the method of moving vehicles in the network. VISSIM uses a psychophysical mathematical model originally developed by the German expert Wiedmann (PTV AG, 2013). The basic principle of the model is based on 'imitation' of specific reactions and decisions made by drivers when driving behind another vehicle. When drivers reach the vehicles in front, they start braking at the moment they individually notice the slower vehicle ahead. Since it is not possible to determine the exact speed of the vehicle ahead, the driver's adjusted speed will be lower than that of the vehicle ahead. Then the driver begins to accelerate the vehicle again until the next perception threshold is reached. The process continues iteratively with alternating acceleration and braking. From this model, we can determine the desired (safe) distance between two vehicles in the queue as well as the desired minimum distance of the vehicle sequence [7].

4.2. Validation of model results

Validation of input data often implies model calibration, which is a key phase that ensures that the simulation maintains the real state of the traffic system. The goal of calibration is to minimize the differences between simulated and real data by adjusting model parameters. Calibrating microscopic models requires a lot of effort due to numerous modeling parameters. It used to be difficult to do this, but today, with the many measurements and data collection methods available, the process has been made easier. Previously, a mechanical device placed between two vehicles was used to measure the distance and speed difference between two vehicles, but the lack of more general data limited the use of the model in the areas of use. Today, smart transportation systems equipped with sensors to measure speed and distance between vehicles provide a solid database for calibrating vehicle sequence models. There is also GPS equipment as well as many highway control systems that provide a huge amount of data [8].

As the student version of PTV VISSIM was used for this paper, the possibility of calibrating the model is limited. This is because the simulation in this version lasts only 600 seconds, whereas proper calibration requires testing all simulation values over a period of 1 hour. In any case, according to [9], the calibration process consists of seven steps:

1. Defining the goals and objectives of the study
2. Collecting real data from the field
3. Selecting performance measures
4. Establishing evaluation criteria
5. Presenting the network
6. Driver behavior when choosing a route
7. Evaluating the model results

Thus, Park B. and Schneeberger J. D. in their work [9] described the calibration procedure of microscopic model simulation in VISSIM on the Lee Jackson Memorial Highway, USA. The data needed for the test was collected directly from the field, but also from the Virginia Department of Transportation (VDOT). These data include geometric characteristics of the observed road network, distances between intersections, lengths of left and right turn lanes, inclinations between intersections, location detectors, and speed limits. As a data source, they also used the Management Information System for Transportation (MIST) located in the Smart Travel Laboratory at the University of Virginia, which is connected to time plans and provides real-time results. The measurement was also performed by a group of students, and video recordings were used to a large extent. In principle, calibration is based on the adjustment of key parameters that directly affect the behavior of the simulation. It requires measurements at the level of individual vehicles. [8] Setting the parameters and their ranks used in VISSIM include the length of the emergency stop, the length of the road change, the desired speed, the number of observed vehicles preceding, the average of the stopping distance, etc. As the number of combinations between the parameters that can be controlled is huge, possible scenarios cannot be evaluated in a reasonable time. This is why Park B. and Schneeberger J. D., in their work, conducted a planned experiment using the principles of Latin Hypercube Sampling (LHS), which enables the use of a smaller number of combinations. Statistical processing is also performed [9]. There are eight combinations of parameters, and each combination includes: the length of the emergency stopping distance, the distance required to change lanes, the number of observed vehicles, the distance while stopped, the waiting time before diffusion, and the minimum distance between vehicles. It was noticed that multiple simulations were not statistically equal to the distribution in the field, i.e., the results or output data of the simulation differed statistically in percentage for each combination of parameters. Although the number of simulations has been reduced, variability in the simulations still persists. Travel time data in the far-left eastbound lane was collected from 50 random simulations. The results of these simulations were compared with real travel times collected in the field. The average time on the field was 613,16 s with a standard deviation of 66,2. The average value of the average values of the eight combinations is 523,35 s with the medium value of the standard deviation of all standard deviations of the given combinations of 73,74. Instead of comparing the average travel time from 50 simulations directly with the field data, it is better to compare the field data with the distribution of travel times from the simulations and thus take into account the variability. To determine the statistical equality of VISSIM results with field data, a t-test was used. A t-test was applied to the VISSIM data for each case that was closest to the average field data. In most cases, the results show a statistical difference from the travel time distribution, except for a few simulations that are close to the average field time. With this approach, the t-test showed that VISSIM accurately showed field conditions at least once in 50 random simulations for cases 2 to 7. This means that the data, i.e. the situation on the ground, is just another variation of an infinite stochastic process, which looks normal. Therefore, the results of individual measurements are not applicable for statistical testing. Therefore, only results approximately equal to those on the field can be taken into account. If the results pass the test, it can be said that the situation on the ground was presented at least once in the simulated model [9]. Validation represents the process of controlling the precision of traffic parameter values as a result of simulation and parameters that were measured in the field. Validation includes testing under different traffic conditions as well as comparing predicted data with data collected in the field. The importance of visualization in this process is unquestionable. Animations and graphs for displaying calibrated data in relation to those in the field are very important. The purpose of microscopic simulations is to represent the real world as accurately as possible, and visualization is a powerful tool [9].

4.3. Infrastructure Modeling

The level of detail necessary to replicate the road infrastructure is determined by the persistence of the VISSIM software. The basic sketch is suitable for the analysis of the intersection, that is, for the logical analysis of the traffic-induced signal, but for detailed simulation assessments, a detailed model is required, and the model must always be replicated to scale. The scaled mesh can be manually traced or imported from CAD drawings, aerial photography, etc. The basic elements that can be modeled are shown in Figure 4 [2].

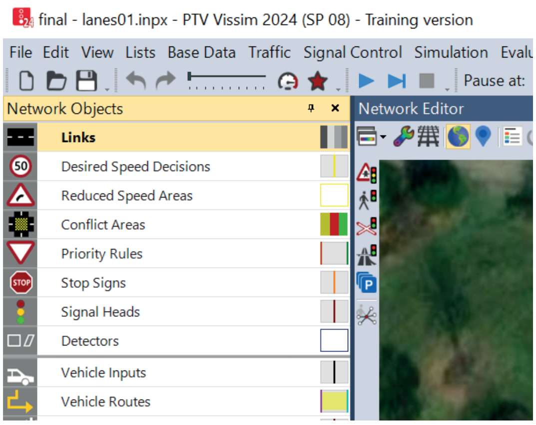

Figure 3. Submenu - Mesh Elements in VISSIM

4.3.1. Links and Nodes

One of the most basic components of a VISSIM network is the link. It is actually a link of road sections that has one specific flow direction. In principle, all links are connected by nodes, if it is necessary to connect and determine the transition of one lane to another, which means that only connected links have the result of traffic continuity.

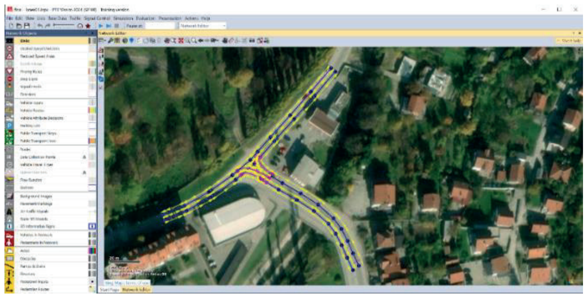

Figure 4. Links and connectors of the analyzed intersection

4.3.2. Other elements of the traffic network

In addition to the basic infrastructure elements, i.e., links and nodes, it is necessary to define additional elements that correspond to individual lanes or points. These can be speed reduction areas, passing and stopping signs, stop signs, etc.

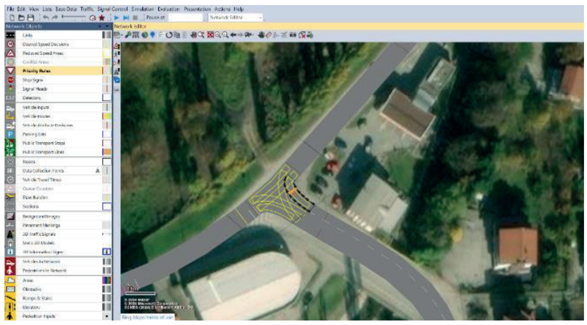

Figure 5. Speed reduction areas at the analyzed intersection

4.4. Traffic modeling

After entering the data, it is necessary to specify the vehicles' movement and travel direction on the infrastructure. The classes of vehicles and pedestrians that can be defined in VISSIM are shown in the figure. Vehicle routing is also necessary to show where vehicles are moving or in which direction, especially at intersections.

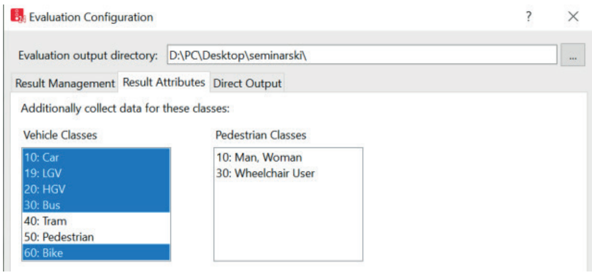

Figure 6. Vehicle and pedestrian classes

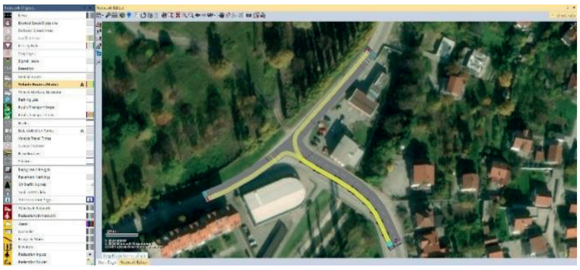

Figure 7. Directions of vehicle movement

4.5. Traffic control

Unsignalized intersections are intersections where two traffic directions cross at the same level. Traffic is regulated by giving priority of passage to one direction using horizontal and vertical traffic signals.

Priority rules are applied in the following cases [7]:

1. unsignalized intersection where the rule of the right side applies
2. unsignalized intersection where vehicles from the secondary traffic direction must give priority to vehicles from the main traffic direction
3. an intersection that has a STOP sign on two access directions and an intersection that has a STOP sign on all access directions
4. a roundabout
5. a traffic merging area where vehicles from the access ramps do not have priority over vehicles from the main traffic direction
6. turning onto signalized intersection, such as a left and right turn that conflicts with the traffic flow of vehicles from the opposite direction
7. a bus entering traffic from a stop has priority over other vehicles if signals its intended direction using the blinker.

Basic types of unsignalized intersections [10]:

1. Standard.
   a. WSC (All Way Stop Controlled)
   b. TWSC (Two Way Stop Controlled)
2. Non-standard
   a. TWSC (Two Way Stop Controlled)

Standard three-way non-signalized intersections are those where the priority road continues straight, while in non-standard intersections, priority is given to the road that turns [10].

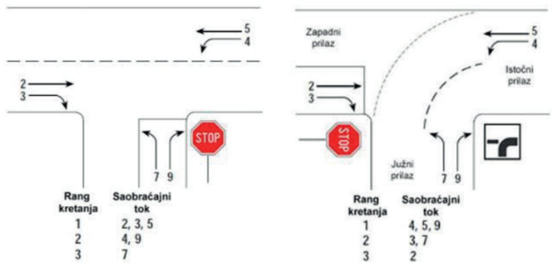

Figure 8. Flows and ranks at a standard (left) and non-standard (right) signalized intersection

The traffic signs placed at standard unsignalized intersections are [11]:

Figure 9. Traffic signs at standard unsignalized intersections

1. The ‘Yield’ (II-1) sign indicates that the driver must give the right of way to vehicles on the road being crossed.
2. The ‘Mandatory Stop’ (II-2) sign indicates that the driver must stop the vehicle and yield to vehicles on the road being crossed.
3. The ‘Road with Right of Way’ (III-3) sign indicates the road or part of the road where vehicles have priority over vehicles on intersecting roads.

5. METHODOLOGY

For the purposes of this analysis, an unsignalized intersection located in Crkvice, on the route Crkvice - Babino - Babina Rijeka, was chosen. The width of the lanes from the direction of Crkvice (1) is 3.5 m in both directions, from the direction of Babino (2) is also 3.5 m in both directions, while the lane in the direction of Babina Rijeka (3) is 9.5 m wide, i.e. the lane from the direction of Babina Rijeka is divided into two lanes of 3 m each, and the lane in the direction of Babina Rijeka is 3.5 m. The traffic count was carried out on August 29, 2024 in the period from 10:45 AM to 11:45 AM. The following results were obtained:

Table 1. Results

Direction (from)	Number of Vehicles
Crkvice	172
Babino	412
Babina Rijeka	280

Another simulation was performed with double the number of vehicles to compare the results of delays and vehicle waiting times.

5.1. Steps for replicating the model in VISSIM

STEP 1 – The first step in VISSIM is to create a link and connectors, which are basic elements for designing any road or intersection. By connecting the intersection's directions, we aim for a more accurate representation of the real situation. Using the map available in VISSIM, we can then obtain an approximate view of the analyzed intersection.

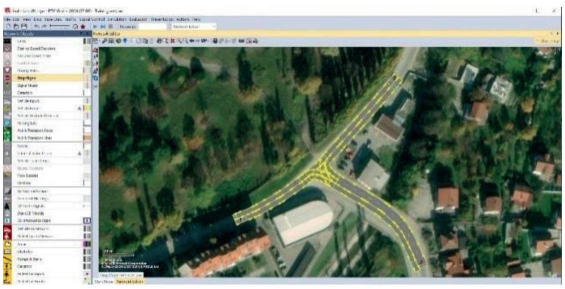

Figure 10. Links of the analyzed intersection with defined directions

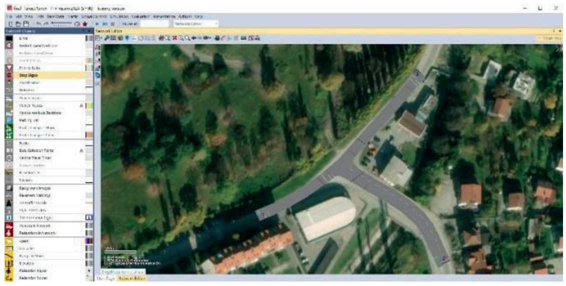

Figure 11. Display of the analyzed intersection

STEP 2 - In the second step, it is necessary to adjust the speed reduction areas using the commands from the bar on the left side of the VISSIM system interface. Figure 13 shows the area of speed reduction in the conflict area of the intersection.

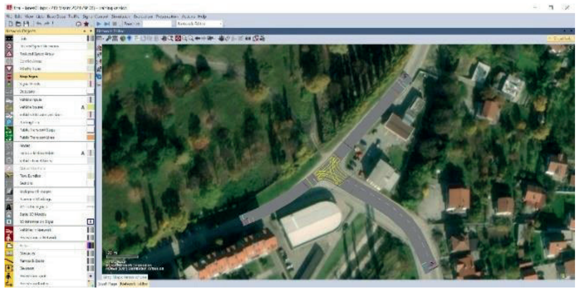

Figure 12. Speed reduction areas in the conflict area

STEP 3 - In Step 3, the total number of vehicles for all three lanes is entered [2]. For the purposes of this project, vehicles include light vehicles, heavy vehicles, bicycles, and motorcycles. All are assumed to travel at a speed of 50 km/h in every direction.

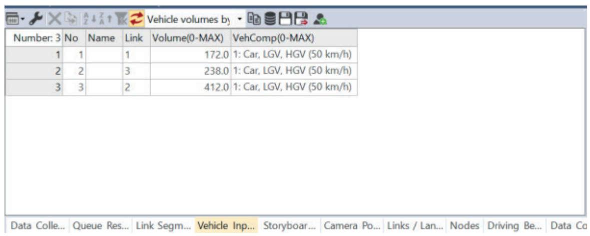

Figure 13. Vehicle entry in VISSIM (Simulation 1)

STEP 4 - After defining the number of vehicles for each direction, the routes – that is, the directions of vehicle movement – are also set.

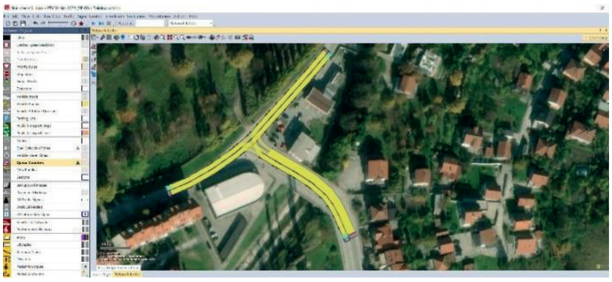

Figure 14. Defined directions of vehicle movement through the intersection

As this is a three-way unsignalized intersection, three basic movement maneuvers are possible: going straight, turning left, and turning right. This results in six possible vehicle movements: moving straight from Babino to Crkvice; moving straight from Crkvice to Babino; turning left from Babina Rijeka to Crkvice; and turning left from Babino to Babina Rijeka; turning right from Babina Rijeka to Babino; and turning right from Crkvice to Babina Rijeka. Since the traffic count did not determine the exact number of vehicles choosing each direction, the VISSIM standard was applied, assuming an equal split. That is, 50% of vehicles were assumed to choose one direction and 50% the other - for example, 50% of vehicles from Babina Rijeka were assumed to turn right and 50% to turn left.

STEP 5 - After entering all the necessary data, the simulation is performed.

Figure 15. Traffic simulation in VISSIM

The results needed for the analysis can be displayed. In this case, the results of vehicle delays and vehicle waiting times, i.e., queues at the points shown in Figure 16, were analyzed.

6. RESULTS

Number: 6	SimRun	TimeInt	QueueCounter	QLen	QLenMax	QStops
1	1	0-3600	1	0.01	24.74	0
2	1	0-3600	2	0.00	0.00	0
3	1	0-3600	3	0.28	36.49	1
4	1	0-3600	4	0.17	10.64	1
5	1	0-3600	5	0.63	21.37	8
6	1	0-3600	6	1.68	26.29	9

Figure 16. Queue results (Simulation 1)

Number: 6	SimRun	TimeInt	DelayMeasureme...	StopDelay(All)	Stops(All)	VehDelay(All)	Vehs(All)	PersDelay(All)	Pers(All)
1	1	0-3600	1: A	0.12	0.08	0.55	12	0.55	12
2	1	0-3600	2: B	0.00	0.00	1.96	9	1.96	9
3	1	0-3600	3: C	5.27	1.17	9.34	12	9.34	12
4	1	0-3600	4: D	1.63	1.11	4.96	9	4.96	9
5	1	0-3600	5: E	0.18	0.25	4.25	24	4.25	24
6	1	0-3600	6: F	0.63	0.41	3.31	34	3.31	34

Figure 17. Delay results (Simulation 1)

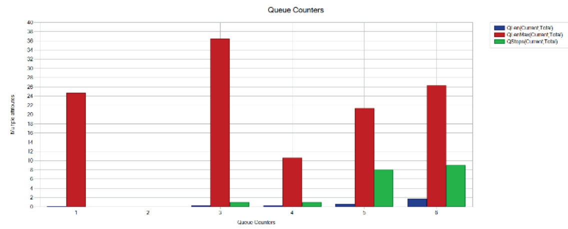

Figure 18. Graph of the queue results measured in observed points (Simulation 1)

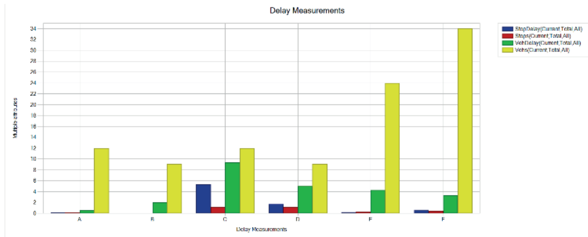

Figure 19. Graph of the delay results measured in observed points (Simulation 1)

Another simulation was performed with an increased number of vehicles, while all other parameters remained the same.

Vehicle volumes by ti

Number: 3	No	Name	Link	Volume(0-MAX)	VehComp(0-MAX)
1	1		1	350.0	1: Car, LGV, HGV (50 km/h)
2	2		3	480.0	1: Car, LGV, HGV (50 km/h)
3	3		2	750.0	1: Car, LGV, HGV (50 km/h)

Vehicle Inputs / Vehicle volumes by time interval | Delay Results | Queue Results

Figure 20. Entry of vehicles in VISSIM (Simulation 2)

Number: 6	SimRun	TimeInt	QueueCounter	QLen	QLenMax	QStops
1	1	0-3600	1	0.19	30.16	1
2	1	0-3600	2	0.14	28.23	2
3	1	0-3600	3	1.36	32.48	4
4	1	0-3600	4	10.25	44.28	24
5	1	0-3600	5	26.68	78.53	107
6	1	0-3600	6	5.87	26.27	25

Figure 21. Queue results (Simulation 2)

Number: 6	SimRun	TimeInt	DelayMeasurement	StopDelay(All)	Stops(All)	VehDelay(All)	Vehs(All)	PersDelay(All)	Pers(All)
1	1	0-3600	1: A	0.09	0.10	1.18	30	1.18	30
2	1	0-3600	2: B	0.00	0.00	2.48	18	2.48	18
3	1	0-3600	3: C	19.87	2.75	34.40	28	34.40	28
4	1	0-3600	4: D	2.13	1.54	9.23	28	9.23	28
5	1	0-3600	5: E	4.54	1.37	20.51	41	20.51	41
6	1	0-3600	6: F	4.91	1.97	21.03	59	21.03	59

Figure 22. Delay results (Simulation 2)

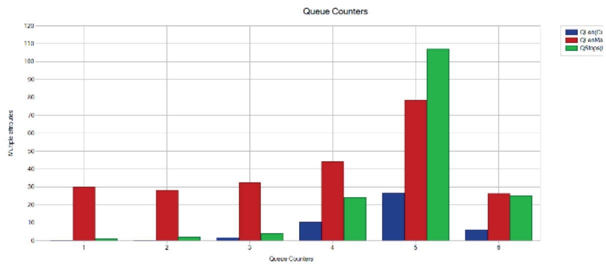

Figure 23. Graph of the delay results measured in observed points (Simulation 2)

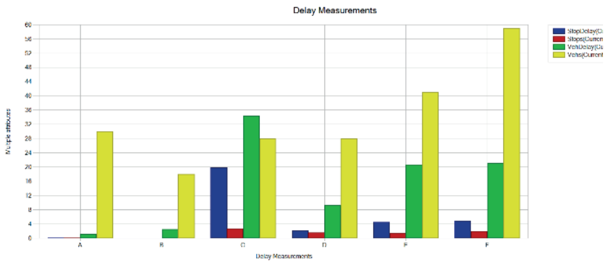

Figure 24. Graph of the delay results measured in observed points (Simulation 2)

The results show that increasing the traffic density - that is, the number of vehicles – affected the waiting times and delays in certain situations. At measuring point 2, where no waiting occurred in the first simulation, queues appeared in the second simulation. Additionally, both the number of delayed vehicles and their total delay time increased. All this shows that the increase in traffic density in some situations can lead to the creation of congestion and crowding, which entails many other consequences for all road users.

7. CONCLUSION

Today, many traffic simulation software programs are used worldwide, offering various benefits, including improving traffic safety at different intersections. Among them, the microsimulation software VISSIM is widely preferred, primarily because it provides more accurate results compared to other programs [2]. The basic traffic parameters - vehicle delay, queue length, and congestion - can be easily determined by replicating the model using data, without endangering people's lives. The results show that an increase in traffic can lead to higher delays and greater congestion, which in the future poses new challenges for engineers in both traffic management and the design or rehabilitation of existing intersections and their components.

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