8th INTERNATIONAL CONFERENCE
''TOWARDS A HUMANE CITY''
New Mobility Challenges
Novi Sad 11th and 12th November 2021

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# REORGANIZATION OF THE FOUR-LINE INTERSECTION IN VRANJE

**Key Words**

Intersection

Traffic flow

Regulation of traffic flow

**Abstract**

An intersection is a place on the traffic network where conflicts occur between traffic flows, which come in two or more different directions. As part of this research, an analysis of traffic conditions was conducted. After that, the forecast of traffic load at the four-line intersection in the city of Vranje is given. Based on the obtained data, adequate measures are proposed and then a functional evaluation of the proposed solutions is conducted in order to improve existing traffic conditions.

## 1. INTRODUCTION

In the field of traffic regulation and management, traffic conditions at intersections are often the most complex. An intersection can be defined as the place in the traffic network in which traffic conflicts occur between vehicles that arrive from two or more different directions. Therefore, the intersection represents a crossing of different traffic flows.

Traffic regulation at intersections depends on the intensity of traffic. When the intensity of traffic increases the capacity of the intersection decreases and therefore traffic regulation at intersections needs to be adjusted. These adjustments include the installation of vertical traffic signals, construction interventions, installation of traffic lights, etc.

In this paper, an analysis of traffic conditions at the four-lane intersection in the city of Vranje is presented. The four-lane intersection encompasses the following streets: Bora Stankovic Street, Maricka Street, Nemanjina Street, and Pariskih Komuna Street. The analysis is performed on Wednesday, the 23rd of June, 2021., between 7 AM and 7 PM. After that, the obtained results are analyzed and set of measures are proposed for the optimization of traffic. In this research the analysis of pedestrian flows at marked pedestrian crossing was not performed, because the mentioned four-lane intersection is mostly used by vehicles.

## 2. THE CHARACTERISTICS OF ANALYZED INTERSECTION

The analyzed four-lane intersection is located in the wider central zone of the city Vranje (Figure 1). The intersection is about 1 kilometer away from the city center.

*Figure 1. Satellite image of analyzed intersection*

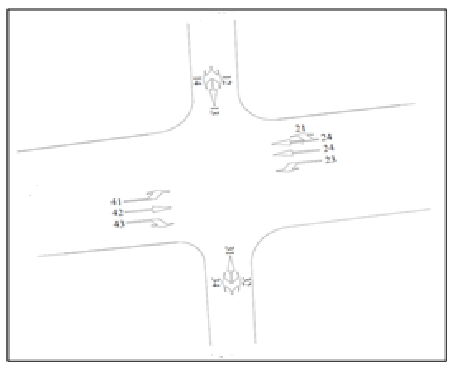

*Figure 2. Inflow heads and directions of movement at the analyzed intersection*

The four-lane intersection encompasses the following streets: Bora Stankovic Street, Maricka Street, Nemanjina Street, and Pariskih Komuna Street. At the analyzed intersection, traffic is allowed in both directions on all lanes. The traffic is regulated by light traffic signs. The directions of movement is shown in Figure 2.

The northern lane (Nemanjina Street) consists of an entry and departure lanes which are not separated by a median. The road lanes are separated by an unbroken dividing line, which has faded. The pedestrian crossing was partially marked, while the stop line was not marked, and other markings on the road are also faded. There is a vertical signalization which includes the sign - road with priority.

The eastern lane (Maricka Street) consists of an entry and departure lanes that are not separated by a median. The road lanes are separated by an unbroken dividing line, which has faded. The pedestrian crossing is partially marked, while the stop line is not marked. The traffic light is placed on the right edge of the road and there is also a vertical signalization that includes a sign - mandatory stop and a sign - pedestrian crossing.

The southern lane (Pariskih Komuna Street) consists of an entry and departure lanes which are separated by a median. The road lanes are separated by dividing line without defined priority. The pedestrian crossing is partially marked, while the stop line is not marked, and other markings on the road are faded. The traffic light is placed on the median between the traffic lanes. The traffic sign intended for pedestrian traffic is placed on both sides of the road.

The western lane (Bora Stankovic Street) consists of an entry and departure lanes which are separated by a median. The road lanes are separated by a dividing dashed line with defined priority. The pedestrian crossing is partially marked, while the stop line is not marked. In addition to the traffic light signs that are placed on the left edge of the right lane and on the median between the left and right traffic lanes, there is a vertical signalization that includes a sign - mandatory stop and a sign - pedestrian crossing.

At the entrances, the vertical and horizontal signalization is not positioned in accordance with the Rulebook on traffic signalization ("Official Gazette of RS", no.85/2017 and 14/2021).

## 3. THE TRAFFIC FLOW ANALYSIS

Traffic counting at the four-lane intersection was performed on Wednesday, the 23rd of June, 2021. Traffic counting was performed by the method of manual counting on the basis of a simple counting pattern, in the period from 7 am to 7 pm. The peak hour is chosen to be between 2 pm and 3 pm.

The obtained data show that the following vehicles participated in the traffic flow: passenger cars, buses, light, medium and heavy trucks, auto trains, motorcycles, bicycles, and tractors. Table 1 shows the structure of traffic flows by directions in the interval of 60 minutes. In the total sample, the number of passenger cars is incomparably the largest (see Table 1).

The most dominant category of vehicles in the sample in terms of number of vehicles is passenger cars (1146 veh/h or 84.8%). The following categories are: light trucks (88 veh/h or 6.5%), motorcycles (3.0%), medium-sized trucks (1.4%), buses (1.3%), cyclists (1.2%), heavy goods vehicles (1.1%), and motor vehicles (0.1%).

By converting the share of traffic load into PAJ, it is concluded that in the period after the noon peak load, the size of the traffic flow is most pronounced in the direction "31" when the flow rate is 279 PAJ/h, while it is least pronounced in the direction "14" when the flow rate is 14 PAJ/h. Also, the magnitude of the flow is most pronounced in Approach 3 (514 PAJ/h), while it is least pronounced in Approach 4 (227 PAJ/h), as shown in Figure 3.

*Table 1. Traffic Flow Structure by Direction of Movement*

| Approach | Direction | BIC | MOT | WELL | THE BUS | CARGO VEHICLES | | | AV | Tractors | Total (veh/h) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LT | ST | TT | | | |
| **1** | 12 | 4 | 5 | 97 | 2 | 10 | 2 | 0 | 0 | 0 | 120 |
| | 13 | 0 | 2 | 151 | 2 | 24 | 1 | 0 | 0 | 2 | 182 |
| | 14 | 0 | 0 | 13 | 0 | 1 | 0 | 0 | 0 | 0 | 14 |
| | Total | 4 | 7 | 261 | 4 | 35 | 3 | 0 | 0 | 2 | 316 |
| **2** | 23 | 0 | 3 | 114 | 2 | 10 | 0 | 3 | 0 | 0 | 132 |
| | 24 | 0 | 2 | 78 | 4 | 4 | 0 | 0 | 0 | 2 | 90 |
| | 21 | 1 | 6 | 75 | 1 | 4 | 2 | 0 | 0 | 1 | 90 |
| | Total | 1 | 11 | 267 | 7 | 18 | 2 | 3 | 0 | 3 | 312 |
| **3** | 34 | 1 | 3 | 52 | 0 | 1 | 0 | 0 | 0 | 0 | 57 |
| | 31 | 6 | 11 | 241 | 3 | 14 | 3 | 1 | 0 | 0 | 279 |
| | 32 | 1 | 4 | 141 | 3 | 10 | 0 | 10 | 0 | 0 | 169 |
| | Total | 8 | 18 | 434 | 6 | 25 | 3 | 11 | 0 | 0 | 505 |
| **4** | 41 | 1 | 1 | 27 | 0 | 2 | 3 | 0 | 0 | 0 | 34 |
| | 42 | 0 | 2 | 87 | 0 | 6 | 1 | 0 | 0 | 0 | 96 |
| | 43 | 2 | 3 | 70 | 1 | 2 | 7 | 1 | 1 | 0 | 87 |
| | Total | 3 | 6 | 184 | 1 | 10 | 11 | 1 | 1 | 0 | 217 |
| Total (veh/h) | | 16 | 42 | 1146 | 18 | 88 | 19 | 15 | 1 | 5 | 1350 |

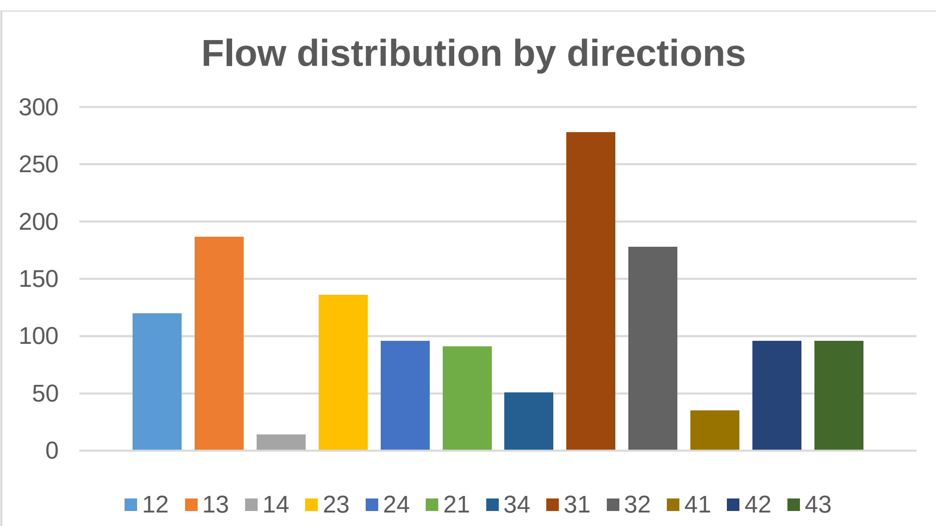


*Figure 3. Graphical representation of flow distribution by directions*

## 4. MEASURES FOR IMPROVING THE TRAFFIC AT THE ANALYZED INTERSECTION

Reorganization of the observed four-lane signalized intersection is reflected primarily in the change of the signaling timing plan, the geometry of the intersection, as well as in defining the purpose of traffic lanes.

**Traffic lane 1.** Three traffic lanes on the departure should be organized. The left traffic lane would be intended for left turns, the middle traffic lane would be intended for vehicles continuing their movement straight, and the right traffic lane would be intended for right turns. Vertical and horizontal traffic signalization should be installed (including the sign - road without priority). At least one traffic lane on the entry should be organized.

**Traffic lane 2.** Three traffic lanes on the departure should be organized. The left traffic lane would be intended for left turns, the middle traffic lane would be intended for vehicles continuing their movement straight, and the right traffic lane would be intended for right turns. At least one traffic lane on the entry should be organized.

**Traffic lane 3.** Three traffic lanes on the departure should be organized. The left traffic lane would be intended for left turns, the middle traffic lane would be intended for vehicles continuing their movement straight, and the right traffic lane would be intended for right turns. Vertical and horizontal traffic signalization should be installed (including the sign - road without priority). At least one traffic lane on the entry should be organized.

**Traffic lane 4.** Three traffic lanes on the departure should be organized. The left traffic lane would be intended for left turns, the middle traffic lane would be intended for vehicles continuing their movement straight, and the right traffic lane would be intended for right turns. Vertical and horizontal traffic signalization should be installed (including the sign - road without priority). At least one traffic lane on the entry should be organized.

All input data needed to determine the capacity and level of service and to propose the conceptual solution are obtained from traffic counting (Figure 4).

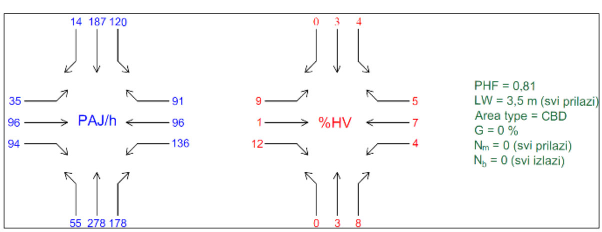


*Figure 4. Display of input data in the conceptual solution*

Application software – HCS was used to obtain the optimal cycle duration of 60 seconds. The mode of operation of the proposed variant would consist of two characteristic states, that is two phases. The duration of individual phases, with the period "all red" (protection times $\Delta t_{12}$ and $\Delta t_{21}$), are shown in Figure 5.

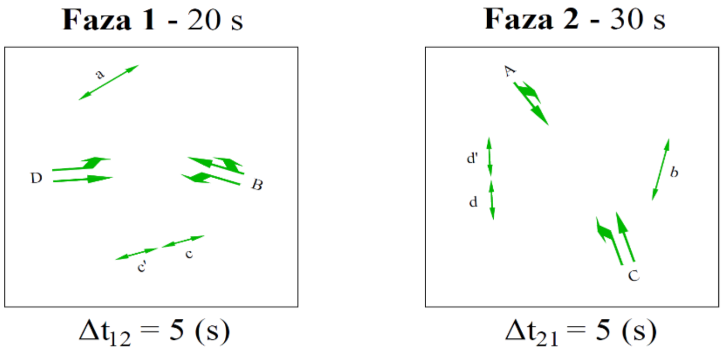


*Figure 5. Phase plan for the proposed Variant*

Based on the matrix of protection times and the phase plan, a timing plan for light signals is developed. The output results for the proposed variant are presented in Table 2.

*Table 2.* Display of output results for the proposed Variant

| CAPACITY, TIME LOSSES AND LEVEL OF SERVICE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Approaching | Western | | | Eastern | | South | | | North | |
| Ribbon Groups | L | P | D | L | PD | L | P | D | IP | D |
| Capacity **c** (train/h) | 270 | 474 | 1283 | 313 | 419 | 396 | 739 | 1331 | 543 | 1398 |
| Saturation degree **X** (v/c) | 0,16 | 0,25 | 0,09 | 0,54 | 0,55 | 0,17 | 0,46 | 0,17 | 0,70 | 0,01 |
| Time losses **d** (s/train) | 17,4 | 17,9 | 0,1 | 24,6 | 23,4 | 10,8 | 13,6 | 0,3 | 20,5 | 0,0 |
| **LOS** | B | B | And | C | C | B | B | And | C | And |
| **d** in the driveway (s/train) | 10,4 | | | 23,9 | | 8,6 | | | 19,6 | |
| **LOS** in the driveway | B | | | C | | And | | | B | |
| **d** at the intersection (s/train) | **15,1** | | | | | | | | | |
| **LOS** at the crossroads | **B** | | | | | | | | | |

As can be seen from the Table 2, in case of accepting the proposed variant of the solution traffic conditions in the four-lane intersection would be close to uninterrupted traffic flow (LOS=B) with a very favorable amount of time losses (15.1 s/car). The most favorable conditions would be on the southern lane, where the speed would be equal to the conditions of uninterrupted traffic flow (LOS=A), while on the northern and western lanes the speed would be close or equal to the conditions of uninterrupted traffic flow (LOS=B), and on the eastern lane conditions would be stable traffic flow (LOS=C).

## 5. DISCUSSION AND CONCLUSION

Traffic optimization on existing roads is not always a possible solution. In some cases, it is necessary to expand or build new roads. The presented example of the four-lane intersection referred to the improvement of traffic at the individual lanes in terms of geometry with the Rulebook on traffic signalization ("Official Gazette of RS", no. 85/2017 and 14/2021).

Based on the obtained data on the size of the traffic flow at the four-lane intersection the measures for improving the traffic are proposed. First, is is concluded that at the peak hour about 1350 veh /h pass, or when it is converted into PAJ about 1387 veh/h. The busiest lane is traffic lane 3 with about 505 veh/h, or when converted to PAJ 514 veh/h. The busiest route is the route from traffic lane 3 to traffic lane 1 with about 279 veh/h. As for the structure of the traffic flow, passenger cars dominate with a share of 84.4%. The main criteria during the search for the optimal solution for regulating the mentioned intersection is that the solution is functionally justified, as well as economically viable.

The adequate measures are proposed to regulate the traffic at the analyzed intersection. With the help of HCS application software, the optimal cycle duration of 60 seconds was obtained. Based on the matrix of protection times, the development of a plan for light signalization is proposed. After that, the evaluation of the proposed solution was performed and it is concluded that in the case of accepting the proposed solution, conditions close to uninterrupted traffic flow (LOS=B) would prevail in the intersection zone, with very favorable time losses (15,1 s/veh). The most favorable conditions are on the southern lane, where the vehicles' speed is projected to be equal to the conditions of uninterrupted traffic flow (LOS=A), while on the northern and western lane the vehicles' speed is projected to be close or equal to the conditions of uninterrupted traffic flow (LOS=B), and on the eastern lane conditions are projected to be stable traffic flow (LOS=C).

However, one should keep in mind that the network regulation and management of traffic flows need to be coordinate on the whole network and not only at single intersection. Inadequate regulation at a single point of a network can create traffic problems on the entire network. The future work could deal with the intelligent light signalization which is economically very favorable, especially over a longer prediction time interval.

As a potential solution to the problem, the traffic roundabout with appropriate geometry is also considered. However, based on the cost benefit analysis, this approach is unjustified from the economic point of view. In addition, the traffic roundabout brings the problem of limited vehicle flow capacity, limited pedestrian crossing, etc.

Last, but not the least, the budget funds are the funds of all citizens of the Republic of Serbia. Unintended spending of budget funds without consulting expert associates in the field of traffic planning is a large problem in the Republic of Serbia. This paper shows the possibility of saving funds with other more adequate solutions.

## ACKNOWLEDGMENT

The results shown in this paper are part of research project "Development and application of modern tools and methods of research in the field of transport", founded by the Department of Transport of the Faculty of Technical Sciences in Novi Sad, University of Novi Sad, Republic of Serbia.

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