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A diverging diamond interchange (DDI) in conditions of road network in Slovakia

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Abstract This article focuses on the comparison of the current uncontrolled intersection and the new type of intersection. To obtain the most accurate results the intersection is simulated in the Aimsun software. The intersection is situated in Bratislava. It is formed by exits and entrances to the highway D2. The new type of the intersection is denoted as a Diverging diamond interchange (DDI) which increases the safety and fluency of the road traffic. It is most used in the interchanges.

Keywords Intersection, Delay Time, Diverging Diamond Interchange

JEL classification of article according JEL

1. Introduction

The diverging diamond interchange (DDI) is also known as a double crossover diamond (DCD) and is an alternative to the conventional diamond interchange or other alternative interchange forms. The primary difference between a DDI and a conventional diamond interchange is the design of directional crossovers on either side of the interchange. This eliminates the need for left-turning vehicles to cross the paths of approaching through vehicles. By shifting cross street traffic to the left side of the street between the signalized crossover intersections, vehicles on the crossroad making a left turn on to or off of ramps do not conflict with vehicles approaching from other directions. [1]

2. DDI Overview

The DDI design has shown to improve the operations of turning movements to and from the freeway facility and significantly reduces the number of vehicle-to-vehicle conflict points compared to a conventional diamond interchange. The DDI also reduces the severity of conflicts, as conflicts between left-turning movements and the opposing through movement are eliminated. The remaining conflicts are reduced to merge conflicts for turning movements, and the reduced speed crossover conflict of the two through movements. Chapter 4 provides additional discussion of these conflict points and DDI safety benefits. [1]

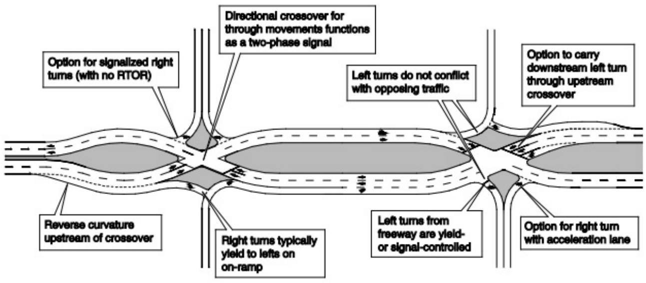

Figure 1. Key characteristics of a DDI

The street segment between the crossovers can be designed as an underpass or overpass depending on the site characteristics. The interchange design will be directly affected by whether or not the arterial passes over or under the limited access facility. In most cases, DDIs designed with a cross road as an overpass offer the most design flexibility in serving pedestrians. The majority of DDIs evaluated have reconstructed existing diamond interchanges, and the decision to go over or under the limited access facility had already been determined. [1]

Traffic Volume Relationships in the figure 2 conceptually depicts the relationship of conventional intersections, alternative intersections, and grade separations in their ability to serve increasing traffic volumes. [2]

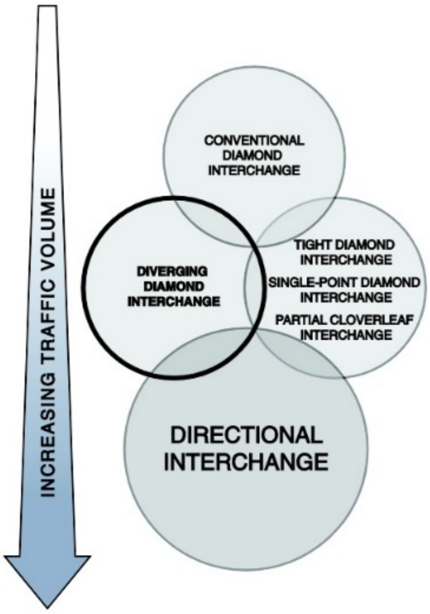

Figure 2. Relationship between volume and interchange type

The DDI is an alternative to the conventional diamond interchange, as well as other interchange forms like a single-point interchange or a partial cloverleaf. The primary difference between a DDI and a conventional diamond interchange is the design of directional crossovers on either side of the interchange. This eliminates the need for left-turning vehicles to cross the paths of approaching through vehicles. Cross street traffic is shifted to the left side of the street between the signalized ramp intersections. Drivers on the cross street who are making a left turn onto the ramps are allowed to continue to the ramps without conflicting with opposing through traffic and without stopping. The DDI design has shown to improve the operations of turning movements to and from the freeway facility, as well as significantly reduce the number of vehicle-to-vehicle conflict points compared to a conventional diamond interchange. [2]

3. DDI application in road network of Slovakia

In the Slovak republic as an example for the implementation of intersection DDI we may use the intersection in the urban part of Bratislava – Lamač. The intersection consists arms of D2 highway and of road II/505. This intersection is characterized by the fact that it does not have sufficient capacity in the morning, as well as in the afternoon traffic peak and. We expect a significant increase of traffic intensity in this area due to its development.

Intensity of traffic was obtained from the transport model which is using in the capital city of Slovakia. This is shown in the figure 1.

The simulation was processed for the morning traffic peak. Each input and their loads are shown in the figure 3 and in the table 1.

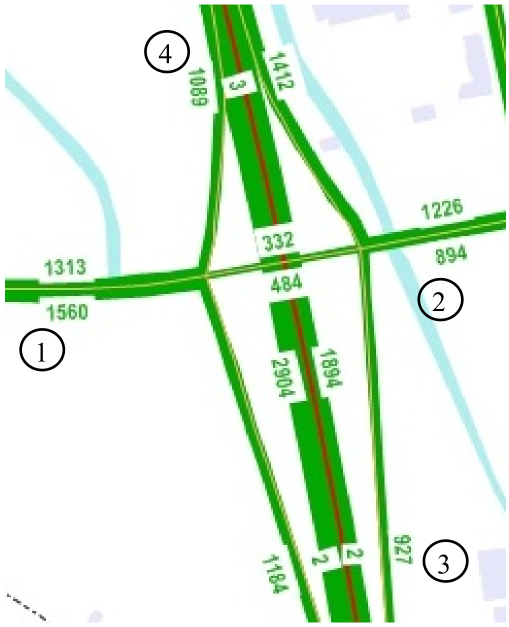

Figure 3. Intensity of road traffic during morning traffic peak [3]

Table 1 shows the matrix of traffic relations which shows the routing of the vehicles from the individual inputs.

Table 1. Traffic relations among the inputs

	Input n. 1	Input n. 2	Input n. 3	Input n. 4	Sum
Input n. 1	-	102	1138	320	1560
Input n. 2	87	-	45	1092	1224
Input n. 3	201	727	-	1894	2822
Input n. 4	1023	66	2904	-	3993
Sum	1311	895	4087	3306	**9599**

The composition of the flow of traffic has been divided in the ratio of 85% for cars, 12% for trucks and 3% for buses. The division represents approximate composition of the traffic flow. The capacity for each of the communication was for the highway set as 1 800 vehicles per lane and for the other roads it was 1 500 vehicles per lane. The speed limits for highway and entrances are at the level of 90 km/h because of going through the city and 50 km/h for the other roads.

To create a road network, we used Aimsun sotware for microscopic simulation of road traffic. The program allows to describe the road network at the requiring scale and run the microsimulation. The results of microsimulation are for both intersection types and they are used for interection comparison.

3.1 Non - signalized intersection (NSI)

Today´s shape of the intersection is non-compliant due to its load. Progress of the simulation can be seen in the following figure. In the morning traffic peak is critical especially the shoulder on the descent from the highway (entrance no. 4) and the arm in the direction of Devínska Nová Ves (entry no. 1). In the afternoon traffic peak, critical is arm no. 2 and arm no. 3.

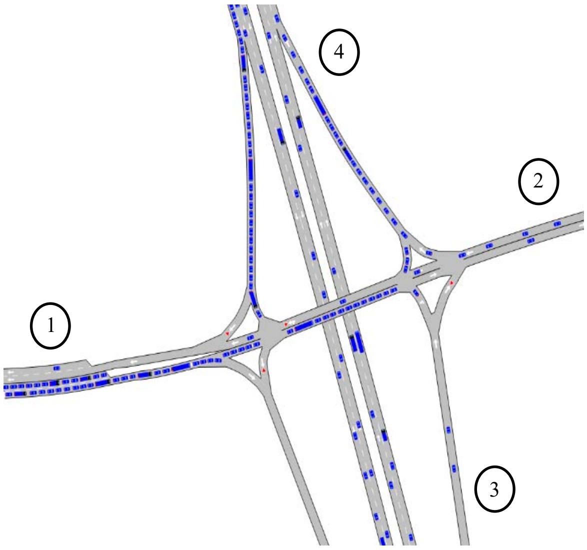

Figure 4. Situation in the morning traffic peak (NSI)

3.2 DDI

The new proposed shape of the intersection is adapted to spatial proportions and to the traffic intensity of intersection. The intersection is controlled in two stages by 60 second cycle. Phases are set to allow smooth crossing through the intersection. The total length of green sign in one phase is 27 second. This allows smooth operation in the present but also in the future higher intensity of road traffic. The new shape of intersection is shown in figure no. 5.

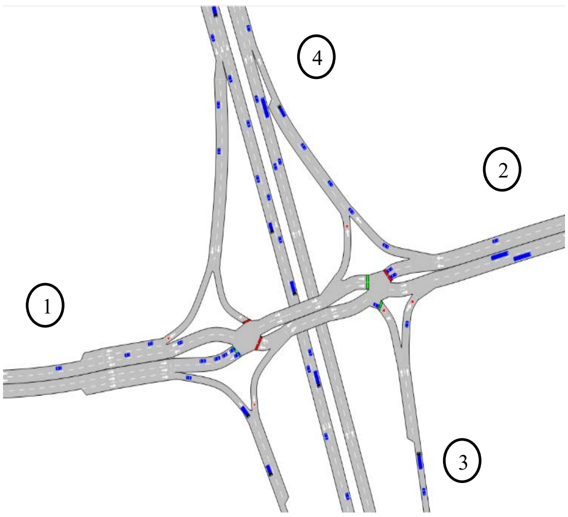

Figure 5. Situation in the morning traffic peak (DDI)

As we can see in figure no. 5, it is clear that there is no creation of congestions to the same extent as at the present. The proposal includes a separate lane for each turn on the descent and at the entrance to the highway. This solution allows a smoother crossing of vehicles.

3.3 Comparison of DDI and NSI

One of the most important indicators in the intersection comparison is growth of delay time. It shows the average delay of a vehicle for one kilometer in seconds. The average values were obtained from the 10 runs of simulations for each intersection separately. Comparison of the delay time for NSI and DDI and their average values is set in the following table and it is calculating for the whole described network.

Table 2. Delay time comparison

	Delay Time [sec/km]	
Time	**DDI**	**NSI**
7:00	8,15	39,78
7:10	8,24	40,32
7:20	8,65	95,15
7:30	8,78	136,72
7:40	8,25	97,41
7:50	8,27	123,57
8:00	8,54	124,33
Average	**8,41**	**93,90**

The average delay time for the DDI is 8,41 sec/km and for NSI is 93,90 sec/km. It shows a significant time saving and the faster crossing of vehicles through the intersection. The DDI reports 85,49 sec/km less delay than in the NSI. In the following figure, it is possible to see the course of the delay time at the intersection.

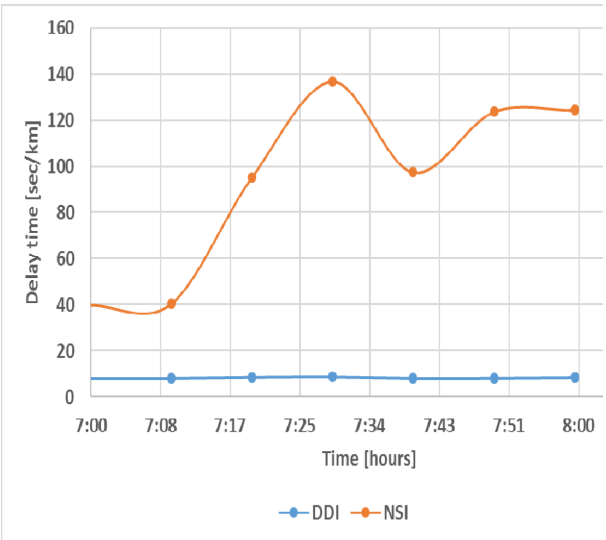

Figure 6. Course of the delay time

The course presents that DDI saves time in comparison with the NSI. We can conclude that the delay time at DDI is almost constant. The other recorded values are presented in the table 3.

Table 3. Other measurable traffic values

	NSI	DDI	Difference	Units
Harmonic Speed	24,59	66,89	42,30	km/h
Mean Queue	89,34	3,40	85,94	veh
Mean Queue	536,04	20,40	515,64	m
Total Travel Time	177,52	94,22	83,30	h

Harmonic speed is verified for the whole network while it is about 42,30 km/h higher for DDI than NSI. The length of the column is about 85,94 vehicles lower for DDI. Due to the current technical conditions (TP 102) it is possible to recalculate the length in meters. Thus it´s possible to state that a new type of intersection brings significant time savings and increases transit and harmonic speed.

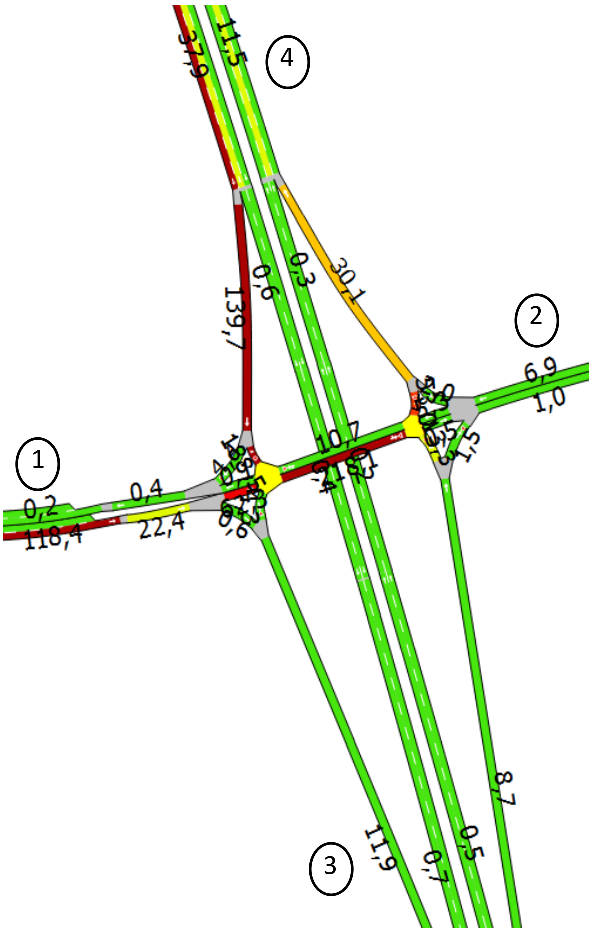

Figure 7. Delay time for NSI

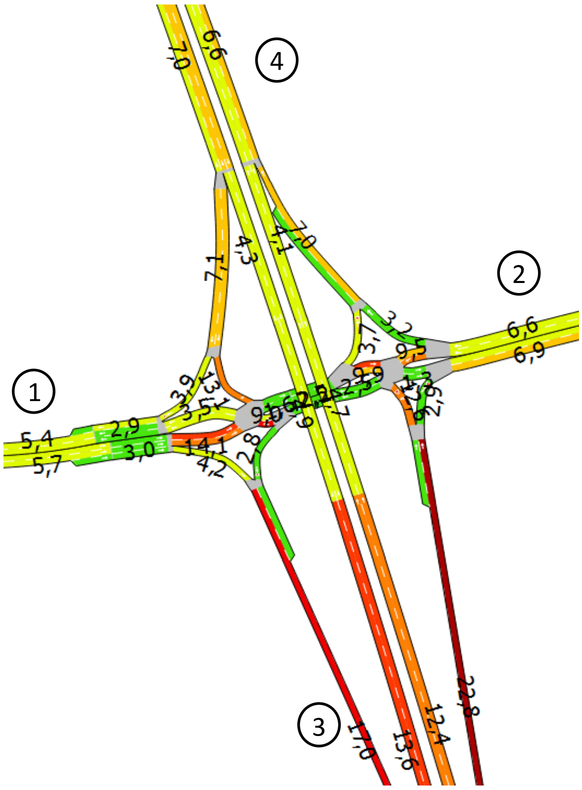

Figure 8. Delay time for DDI

In the figure 7 and figure 8, we can see the delay time for the individual sections of the road network.The green color indicates the minimum of delay and red represents a big delay. The delay depends on the length of the particular section.

4. Conclusions

Based on the results of the simulation, the result is that the current condition highly exceeds the capacity intersection.

The consequences are increased time delays which create congestions.

Although this type of the intersections in Slovakia is still not occurred, this solution is the only for increasing the capacity of the intersection. The DDI allows smoother and safer crossing through the intersection with the lower time delay. The type of intersection can also handle the increase in the intensity of road traffic in this area for the next years, therefore it appears as the only solution to the problem with growing share of individual car traffic in this area.

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[3] Traffic model of Bratislava city in PTV Visum