

The Comparison between the Risk Perception of Drivers and Statistic Indicators of Traffic Safety in the Analysis of Effects of Reconstruction of Selected Urban Intersections

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Summary

One of the basic criteria of the analysis of intersection reconstruction effects is the traffic safety criterion. Intersection traffic safety is determined by indirect indicators, like the number of conflict points, and direct indicators, like the number and severity of traffic accidents. In order to make the direct indicators of traffic safety comparable, they have to be analyzed in the context of the intersection traffic load before and after the reconstruction. The desired trend in the statistics of traffic accidents is, among other things, influenced by subjective experience of traffic participants about the traffic safety at an intersection. For the purposes of this study, a pilot testing of the subjective risk perception of safety of selected intersections, in the urban network of Osijek before and after a reconstruction, has been done on a random sample of drivers, by means of an anonymous questionnaire. Within the questionnaire, the socio-demographic features of drivers, education level, driving experience and the involvement in the traffic accidents (active and passive) were examined. The questionnaire encompasses the subjective perception of risks in the urban network of Osijek in general and at the selected intersections before and after the reconstruction. Perception of risks is segregated into an emotionally based risk perception (feeling of insecurity), assessment of probability of a traffic accident (with slighter and heavier consequences) and the concern about the personal safety and the safety of other traffic participants (with a special emphasis on children safety). Results gathered through questionnaire among drivers about their perception of the risks in selected intersections are compared to the direct (statistic) indicators of traffic safety in the selected intersections before and after the reconstruction.

Key Words: Traffic safety indicators, risk perception, effects of reconstruction, roundabout

1. Introduction

Intersection reconstruction has a number of traffic and spatial implications that need to be analysed, and one of the most important is the impact on traffic safety. Traffic safety can be analysed through a series of direct and indirect mutually comparable indicators [1].

For a reconstruction of a classic intersection into a roundabout, indirect indicators show a significant reduction in the number of conflict points at the intersection [12]. The principle of preventing high speeds at an intersection by the geometry of the intersection (roundabout) showed better results than the principle of sanctioning (classic intersection with the main and the side direction). Lower speed and an angle of a conflict between vehicles from opposing traffic streams have a significant influence on the severity of traffic accidents [8].

Objective information about the safety of the intersection can be provided by statistical indicators of traffic accidents, but the real picture takes longer period of monitoring. Insight into the intersection safety is also provided by subjective perception of traffic participants about the safety or dangers of an intersection [3, 4]. The intersection perceived as unsafe by traffic

participants is positively correlated with a larger number of errors and conflict situations, which ultimately lead to a larger number of traffic accidents [2, 5 and 10].

Surveyed drivers in the traffic network of the town of Osijek perceive the two-lane roundabout "Đakovština" as unsafe, but the data on the traffic load before the reconstruction for this particular roundabout are not available, so the two one-lane roundabouts, Divaltova-Huttlerova St. and Vinkovačka-Drinska St. roundabouts, also singled out by drivers as unsafe, are taken into consideration. Both examined intersections are at the primary functional level, and, before the reconstruction, they were classic intersections of traffic regulation that separate main and side direction. This paper analyses the statistical indicators of traffic accidents and the traffic load before and after the reconstruction. A separate chapter explains the subjective perception of safety at the examined intersections and the reasons why the tested drivers feel unsafe.

2. Selected Intersections

2.1 Divatova – Huttlerova St. Roundabout

Divaltova-Huttlerova roundabout has been reconstructed into the one-lane roundabout in 2003 (Figure 1) by merging two existing conventional intersections – Divaltova-Huttlerova St. and Divaltova-Srijemska St. Visibility was reduced at both existing intersections, especially at the Divaltova and Srijemska street intersection where even the placing of traffic mirrors did not reduce the number of traffic accidents and difficulties while entering Divaltova St. From the direction of Srijemska St. Improvement of the traffic safety was the main motivation for reconstruction of the existing intersections into a roundabout.

The reconstructed roundabout has the form of an ellipse with the external diameters of $D_{IC1}=24\text{m}$ and $D_{IC2}=42\text{m}$. Elliptical shape, with inscribed circle diameters with the ratio of 1.74, is not convenient, according to the criterion of homogenous dynamic conditions. Achievement of positive effects of the roundabout arises from homogenization of relevant speeds – speed of entering, driving through the intersection and exiting [6]. Ellipse radii ratio larger than 15% entails different relevant speeds causing the implications on safety and traffic flow.



Figure 1: Roundabout after the reconstruction (2005)

The reasons for the inauspicious shape of Divaltova-Huttlerova roundabout are unfavourable spatial conditions boundaries, development and availability of space. The intersection has one lane and five access roads. Right turns from the eastern part of Divaltova St. to Huttlerova St. are led by a separate lane and do not enter the roundabout.

Data on an individual traffic counting at Divaltova-Huttlerova and Divaltova-Srijemska intersection, before the reconstruction, are unavailable, and traffic counting was performed in 4 daytime and one nightly term in 2005. The counting results are shown in the Table 1. Analysis of the approximated daily traffic load curve (Figure 2a) provides the information about the total daily load in 2005 of 16,912 PCU/day. The total traffic load in current conditions is presented in the Table 1, and the daily approximation of traffic load is shown in the Figure 2b. Data obtained on the

basis of one counting should be considered as relative indicators, and the conclusions derived from the analysis of those data should be considered in that context.

Table 1: Total traffic load of the intersection, after the reconstruction in 2005 and in 2013

TOTAL TRAFFIC LOAD OF THE INTERSECTION (PCU/h)		
HOUR	May 10 th 2005 Tuesday	Sept. 5 th 2013 Thursday
7-8	-	1068
8-9	945	-
11-12	987	1052
15-16	-	1340
16-17	1188	-
17-18	-	1164
20-21	882	-
22-23	-	320
Approximated DT	16891 PCU/day	19123 PCU/day

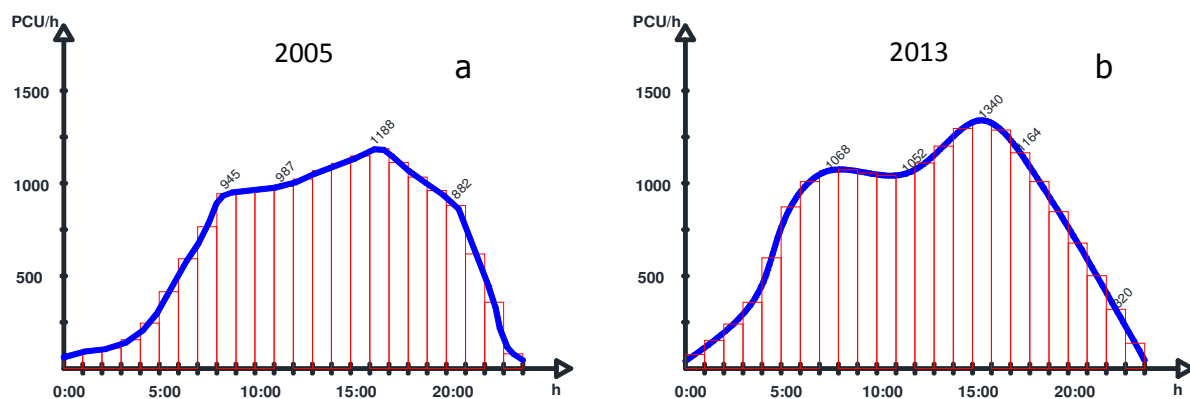


Figure 2: Daily load curve approximation for the Divaltova-Huttlerova roundabout and the data on the total number of vehicles stated in PCU/h

Due to the adverse dynamic conditions, there is a favoured direction – Huttlerova-Divaltova St. Geometry of the intersection enables entering from this direction to be faster than recommended and makes it a potential threat to the traffic safety. The additional disadvantage is the fact that a tramway was constructed in 2009 and guided through the roundabout intersecting with circular lane of the roundabout. Due to safety issues of such a solution, traffic lights were introduced in order to stop traffic flows from Divatova East, Huttlerova St. and the traffic flow inside the roundabout itself. According to functional criteria, this solution is an unfavourable solution, since it eliminates the advantages of a roundabout, and the functionality of the roundabout depends on the frequency of tram public transportation.

2.2 Vinkovačka-Drinska St. Roundabout

Vinkovačka-Drinska classic intersection (Figure 3a) was reconstructed into the roundabout in 2005 (Figure 3b). The main reason for the decision makers to decide in favour of the reconstruction was great time delays in the minor direction (the direction of the Drinska St.). The traffic distribution showed dominant left turns from the direction of Drinska Street – 66% of the overall traffic load (Figure 4). The reason for this is a significant impact of the attraction factor of “Mercator” shopping mall, opened in 2004. Measured time delays during the peak hour at the intersection [8] were in the range of 20s to 112s, and the mean value was 56.25 (s/vehicles), which was the level of service F [8].



Figure 3: Vinkovačka-Drinska St. intersection – before and after the reconstruction

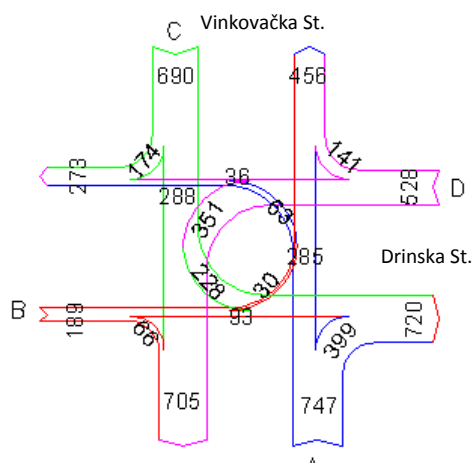


Figure 4: Traffic distribution of the measured afternoon peak load before reconstruction

The reconstruction design is made in such a way that the reconstructed intersection fits the axes and the boundary conditions of existing access roads, thus reducing the additional occupation of space to a minimum. The design keeps the lane directly leading right turns from Drinska to Vinkovačka Street which relieves the traffic at the roundabout. Levelling of the intersection is conditioned by the existing sewerage system. The transverse slope of the roadway, in this area, is within limits of 2.0-2.5%, and the longitudinal slopes are between 0.2 and 1.2%. All design elements of the roundabout are selected in such a way that they ensure the relevant vehicle (18m long truck with a trailer) can drive through the roundabout. The external diameter is 30m, and the diameter of the middle island is 14m. The width of the circular lane is 6m with a 2m wide part of the middle island covered with stone blocks.

The Table 2 shows the measured total traffic load of the intersection before (2005) and after the reconstruction (2013), and the approximation of the daily load is given in the Figure 5.

Table 2: Total traffic load of the intersection before 2005 and after the reconstruction in 2013

TOTAL TRAFFIC LOAD OF THE INTERSECTION (PCU/h)		
HOUR	May 18 th 2005 Wednesday	Sept. 5 th 2013 Thursday
8-9	1410	1638
11-12	1515	1590
15-16	-	1534
16-17	2154	-
17-18	-	1380
20-21	1446	-
22-23	-	549
Approximated DT	28172 PCU/day	26246 PCU/day

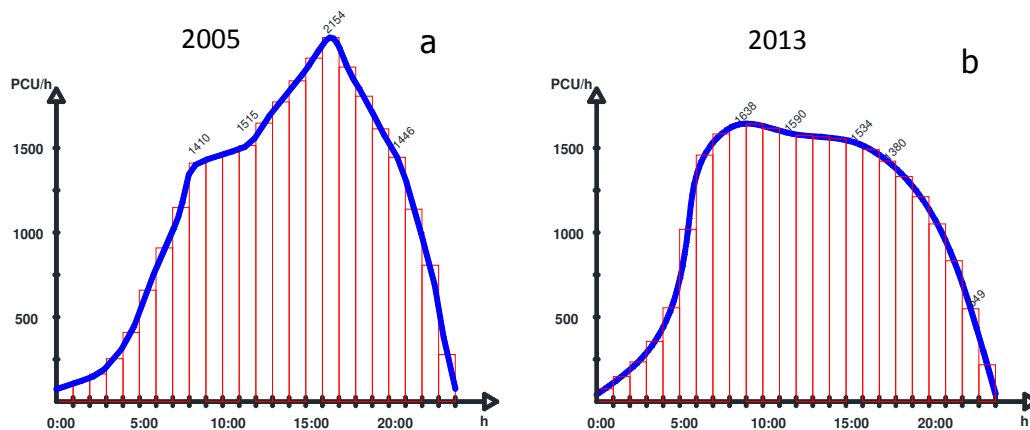


Figure 5: Daily load curve approximation for the Vinkovačka-Drinska roundabout and the data on the total number of vehicles stated in PCU/h

The new reconstruction of the reconstructed intersection has been done in 2009, when the tramway, guided over two access roads of the roundabout (Vinkovačka North and Drinska), was opened for traffic, thus affecting the functionality and safety of the whole roundabout. The total traffic load in current conditions is presented in Table 2, and the daily approximation of the traffic load in current conditions is shown in the Figure 5b.

3. Statistical indicators of the safety of the examined intersections

3.1 Absolute indicators

Objective insight into the safety of the roundabout is provided by statistics on the number and severity of traffic accidents, but the real picture takes longer period of monitoring. The Figure 6 shows the total number of accidents, number of severe traffic accidents and the number of minor traffic accidents causing only material damage at the Divatova-Huttlerova roundabout during the 12 years period of monitoring. During that time, there were no serious traffic accidents with fatalities. The influence of the reconstruction in 2003 can be seen in a slight decrease of the annual number of traffic accidents. This information should be considered in the context of continuous increase of traffic load (estimated DT in 2005 was 16,891 PCU/day, and in 2013 it was 19,123 PCU/day) and adverse shape of the roundabout.

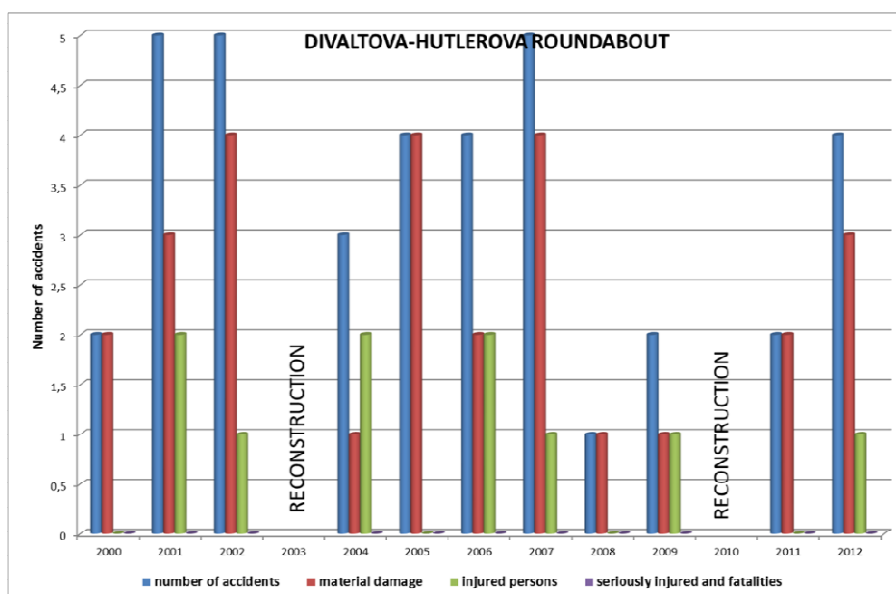


Figure 6: Absolute indicators of safety of the Divaltova – Huttlerova intersection

Statistics for traffic accidents at Vinkovačka-Drinska roundabout is presented in the Figure 7, for the 12 years long monitoring period. The diagram shows a significant impact of reconstruction on a reduction of accidents at the intersection. Besides, it is necessary to note that there was also a small traffic relief at the roundabout compared to 2005 (Table 2). The change in the traffic image, compared to the traffic load prior to reconstruction, is caused by the construction of a new street as an extension of Divaltova Street in 2009.

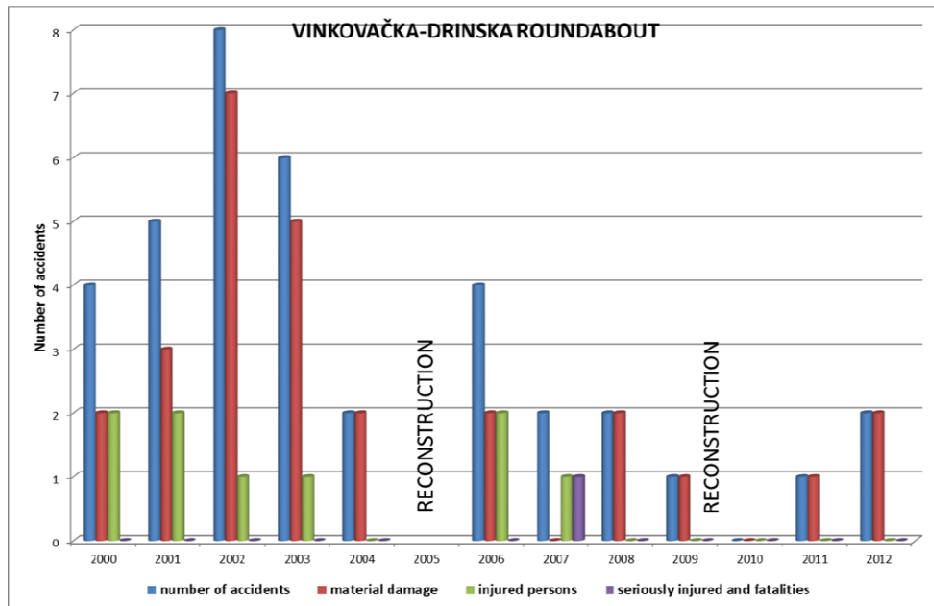


Figure 7: Absolute indicators of safety of the Vinkovačka – Drinska

3.2 Relative indicators

Absolute indicators of traffic safety at a roundabout, before and after a reconstruction, are comparable only if the traffic load remains the same. In order to be able to compare two intersections, and, more commonly, an intersection before and after a reconstruction, it is necessary to observe the number of accidents per year in relation to the traffic load. The Figure 8 shows the total number of accidents per million vehicles annually for both examined intersections.

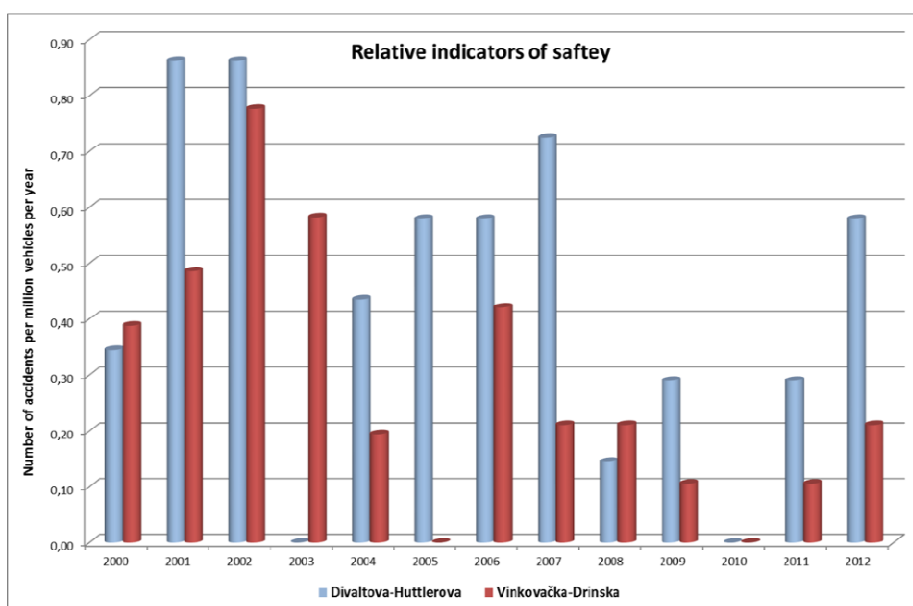


Figure 8: Relative indicators of the safety of the examined intersections

The diagram in the Figure 8 clearly shows that the reconstruction of the intersection achieved better effects at the Vinkovačka-Drinska roundabout. Relative indicators show greater overall safety at the Vinkovačka-Drinska roundabout, although that intersection has a larger traffic load than Divaltova – Huttlerova roundabout (Tables 1 and 2 from 2013).

4. Results of the survey

4.1 Population of surveyed drivers

Subjective emotionally and cognitively based estimation of safety at the roundabout was examined by means of a survey, described in references [9]. Safety assessment of the examined intersections yielded 200 respondents – drivers involved in the traffic of the local network. Out of the total number of respondents, 60% were male, and 40% female. Also, 74% of respondents were from the urban environment, and 26% from rural (Figure 9). The surveyed population contained 13% of professional drivers. Average age of respondents was 37, while 5% were younger than 20 and 5% were older than 60 years of age (Figure 10). Average driving experience of the whole surveyed population was 19 years. Educational structure is such that 51% of respondents have a college degree or more, 41% of respondents have a high school diploma, and 7% of respondents have a Ph.D. (Figure 10).

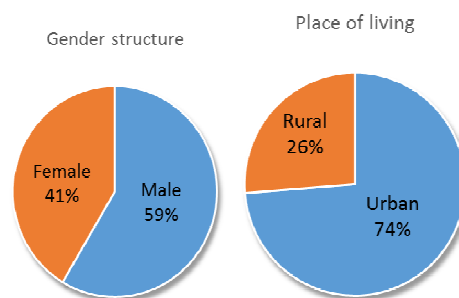


Figure 9: Surveyed drivers

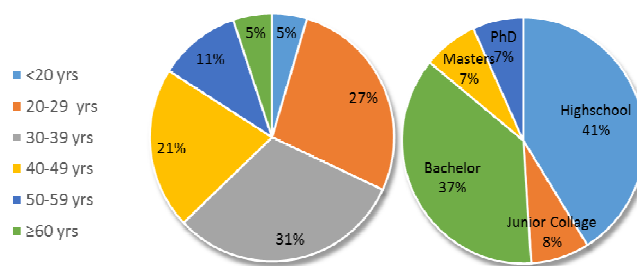


Figure 10: Age and educational structure of the drivers

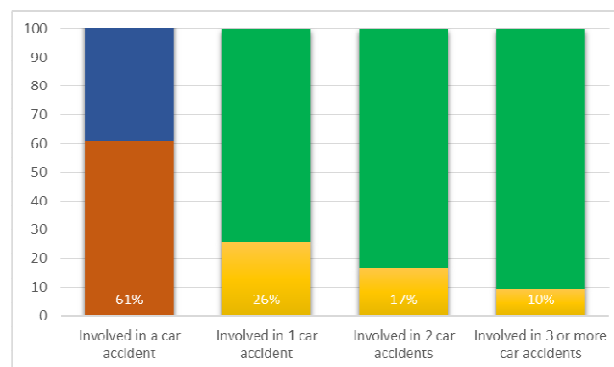


Figure 11: Involvement in traffic accidents

Involvement in traffic accidents shows that 61% of surveyed drivers have participated in traffic accidents. 10% of all respondents had 3 or more accidents, and 26% participated in one traffic accident (Figure 11). Not a single respondent was involved in an accident with fatal consequences for accident participants, and 11% participated in serious car accidents with injured people.

4.2 Subjective perception of risks

Surveyed drivers first gave an emotional and cognitive assessment of risks for the entire traffic network in Osijek, and 11% of drivers said they feel emotionally based insecurity for themselves as drivers, 28% felt concern for other traffic participants, and 38% of the drivers were concerned about children as traffic participants. 13% of respondents stated that they fear serious traffic accidents, 22% were afraid that someone else might get hurt in a serious accident, and 36% of drivers frightened that a child may have a serious car accident in the network of Osijek. Cognitive-based uncertainty shows that 13% of drivers estimated to be likely to experience a car accident, 27% of them estimated that there is a chance that someone else is experiencing the accident, and 36% that it could be a child. Cognitive-based fear from a serious traffic accident, 8% of drivers feel for themselves, 18% for others and 29% for children. Survey results show that most drivers feel insecurity, both emotionally and cognitively based, about children as participants in the traffic of the entire urban network of Osijek.

Out of the total number of respondents, 81% believes that, according to the traffic safety criterion, roundabouts are better solutions than classic intersections as they were before the reconstruction, and 53% perceives roundabouts as safer than intersections equipped with traffic lights. 91% of surveyed drivers feel capable of driving in one-lane roundabouts, and 76% in all roundabouts. When it comes to two-lane roundabouts, 52% of respondents highlights that changing lanes inside the roundabout is problematic. 10% of respondents perceive roundabouts as slow, 30% believes that roundabouts are not safe for pedestrians, 46% that they are not safe for cyclists, and 38% believes that roundabouts are not safe for children.

When it comes to the examined roundabout Vinkovačka-Drinska, 15% of respondents feel emotionally based insecurity, 11% is worried that they might experience a severe car accident, and 20% estimate that it is likely (cognitive-based) that a traffic accident occurs at that particular intersection (Figure 12). Regarding Divaltova-Hutlerova roundabout, emotionally based insecurity also feels 15% of respondents, fear from serious traffic accident feels 12%, and cognitive-based insecurity feels 25% of surveyed drivers (Figure 12).

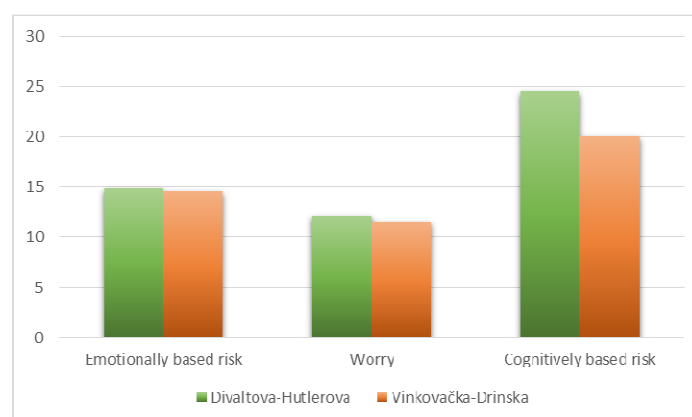


Figure 12: Risk perception at the examined intersections

Comparative analysis of the reasons why respondents considered the examined roundabouts unsafe is shown in the diagram in the Figure 13. For each intersection the biggest problem is the tramway through the intersection, followed by an inappropriate speed, visibility and geometry of the intersection.

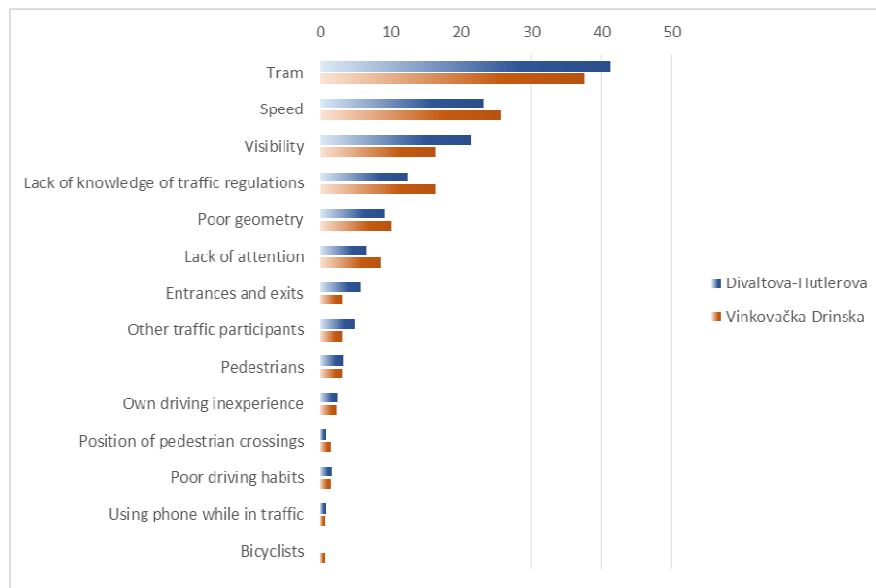


Figure 13: Reasons why the tested drivers feel unsafe

5. Discussion

Population of surveyed drivers does not constitute a representative sample for the traffic network of the town of Osijek (e.g. surveyed population is more educated than the representative sample), but it provides a basic insight into the subjective perception of risks of the surveyed drivers.

It is indicative that the biggest concern, both emotionally and cognitively based, is expressed for children as traffic participants. On one hand, it indicates that expert teams of planners and designers, as well as decision makers, have to choose those design solutions that incorporate the protection of the most vulnerable traffic participants. On the other hand, results of the survey show an increased sensibility of drivers towards children as traffic participants, and it influenced increase in child pedestrian safety. This fits with statistical indicators for child casualties on the roads obtained by traffic police on the national level of the Republic of Croatia. Approximately fifteen years ago, most of the children became casualties as pedestrians, and nowadays as passengers in vehicles [11].

Survey results for the roundabouts in Osijek show that a significant number of respondents (81%) believe that roundabouts are safer than classic intersections, such as the examined intersection were before the reconstruction. Respondents also evaluate roundabouts as positive according to other traffic safety indicators, such as indicators showing that 70% do not experience roundabouts less safe than other solutions for pedestrians, 54% for cyclists and 62% for children as traffic participants.

Surveyed drivers have singled out the two examined roundabouts as, subjectively, the least safe one-lane roundabouts in the traffic network of Osijek. Comparison of the examined intersections by the number of accidents per year shows that the roundabout Vinkovačka-Drinska is safer, as it can be, especially, seen in the diagram of relative safety indicators, since this particular intersection has a larger traffic load than the Divaltova-Hutlerova intersection. Emotionally based insecurity at both intersections is similar, although slightly higher at the Divaltova-Hutlerova intersection (Figure 12). Cognitive-based insecurity is significantly bigger at the Divaltova-Hutlerova intersection (Figure 12), which coincides with objective indicators of safety and statistics of accidents on the examined intersections. Respondents' answers about the reasons why they feel unsafe at the examined intersections were compared at these intersections. It turned out that the biggest problem is the way the tram is running through the intersection, followed by an inappropriate speed, visibility and geometry of the intersection. As the reasons, respondents cited insecurity in interactions with other traffic participants (drivers, pedestrians and cyclists), lack of knowledge of driving rules, lack of attention, etc.

6. Conclusion

According to the results of the survey on perception of risks in the entire traffic network of the town of Osijek, drivers express the biggest concern, both emotionally and cognitively based, for children as traffic participants, indicating that they are sensitized to that sort of issues.

The surveyed population of drivers in Osijek expresses generally positive attitude towards reconstruction of classic intersections into roundabouts according to traffic safety criteria. Respondents perceive them as safer for all traffic participants, not just drivers. The poll tested emotionally and cognitively based perceptions of risk and the results show very good agreement with the statistical indicators of intersection safety, especially in case of cognitive-based risk perception. Numerous studies around the world also show the connection between perception of risk and insecurity [3, 4 and 10]. Perception of risk is correlated with the behaviour of a driver [2, 5 and 7], as indicators of insecurity in local conditions confirm. Intersection Divaltova – Huttlerova, which has a greater cognitive-based perception of risk, also has a larger number of accidents, according to statistical indicators, during 12 years long monitoring. This survey on the perception of risks in local conditions has confirmed that the intersections perceived as unsafe by traffic participants are positively correlated with a greater number of errors and conflicts, which ultimately lead to more accidents.

7. References

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