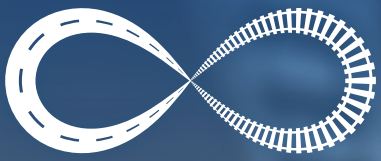

CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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CETRA 2018
5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

TITLE
Road and Rail Infrastructure V, Proceedings of the Conference CETRA 2018

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

ISBN
978-953-8168-25-3

DOI
10.5592/CO/CETRA.2018

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY
"Tiskara Zelina", May 2018

COPIES
500

Zagreb, May 2018.

Proceedings of the
5th International Conference on Road and Rail Infrastructures – CETRA 2018
17–19 May 2018, Zadar, Croatia

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CETRA 2018
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CETRA 2018 17–19 May 2018, Zadar, Croatia
5th International Conference on Road and Rail Infrastructure

THE COMPREHENSIVE ANALYSIS OF A HIGH RISK SITE: A CASE STUDY

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Abstract

Safe transport infrastructure is one of many factors that may help reduce the likelihood of traffic accidents or the severity of their consequences. Adjustments of transport infrastructure can thus significantly contribute to reducing losses from traffic accidents. The aim of technical alterations (i.e. roads and their accessories) is not only to increase traffic flow, but also to create a self-explaining and forgiving road environment. However, some safety adjustments or alternations may instead they may create a new critical point in transport infrastructure. The aim of this paper is to present and analyze a particular high-risk site, which was created by improper modification of the current traffic area and point out the importance of the driver perception of the traffic area. For assessing how drivers perceive traffic space at this critical point, the eyetracking method was used. This paper contains the comprehensive analysis of traffic accidents that occurred in this place, in relation to their formation and consequences. Traffic-engineering analysis of the critical place was conducted as well. A comprehensive analysis of this critical location, and especially the analysis of driver perception of the traffic area confirmed the unsuitability of the technical design of a specific transport area and the necessity of its comprehensive adjustment.

Keywords: accident, analysis, infrastructure, perception, driver, injury

1 Introduction

Road traffic is one of the most dangerous systems that people meet with daily. Road safety depends on numerous factors – human behaviour and skills, infrastructure, vehicle technical condition, weather, legal aspects, etc. Safe transport infrastructure is one of many factors that could effectively eliminate the possibility of traffic accidents occurrence or reduce the severity of their consequences. Roadway features such as roadway curvature, cross sections, traffic density, channelization, density of information and other various elements affect driver behaviour and performance. Consideration of driver performance is critical for driver safety. When roadways are designed to comply with driver expectation and limitation, the likelihood of accidents decrease [1].
Forgiving road has been defined as a road designed to block the development of driving errors and to avoid or mitigate negative consequences of driving errors. Forgiving roads shoud allow driver to regain control and either stop or return to the travel lane without injury or damage [2]. The concept of self-explaining roads on which the driver is encouraged to naturally adopt behaviour consistent with design and function originated in the Netherlands. Drivers would perceive the type of road and "instinctively" know how to behave. This concept has been de-

veloped in European countries to understand which design features modify driver behaviour. The road design as well as the behaviour of road users is more predictable on self-explaining roads [3], [4], [5]. Driver perception of the road was subject of many studies. Steyvers [6] developed the Road Environment Construct Scale to differentiate the perception of roads with different accident rates. Driver's subjective impression from photos analysed also Weller [7]. For the visual behaviour analysis of driver, eyetracking methods has been used [8]. As shown by the following case study, some structural modifications do not always improve road safety, but on the contrary, a new critical location in the road infrastructure can be created. Infrastructure should be transformed according to the principle of self-explanatory and forgiving road. Consistency in road design and cogitation of driver expectancy is important.

2 Critical accident location

In the Czech Republic, several different methods of identifying of critical accident site has been used. All these methods are based on traffic accident data analysis over the certain time period. These methods are also based on a police accident database, which contains data on all traffic accidents investigated by the police, including GPS coordinates of the accident scene location.
The principle of determining accident locations is based on the distribution of road infrastructure on sub-sections of the same length. Number of traffic accident has been assigned to these sections. For all methods, it is important to set the limit for the number of accidents over a certain time period. In the Czech Republic, according to the CDV methodology [9], the place of frequent traffic accidents is considered as a place (250 metres long) where at least 3 accidents with personal consequences have been occurred in 1 year or at least 3 accidents of the same type with personal consequences for 3 years or 5 accidents of the same type in 1 year.
The aim of this study is to introduce comprehensive analysis of frequent accident site, which was created by improper modification of the current traffic area. It is a section of D2 motorway. In order to improve the traffic accessibility of the shopping centre, the arrangement of the motorway lanes has been changed. This change resulted in the creation of crossing of the collector from the D1 motorway direction from Prague and arriving at the shopping centre direction from Brno. The motorway at the beginning of the split was a right curve, which at 150 metres before the split of lanes crossed the left-handed curve. In the lane of the motorway direction to Bratislava, a concrete barrier was installed to protect against impact to the bridge pillar. Concrete barriers were fitted with the crash cushion TP80.The crash cushion should reduce the vehicle kinetic energy and increase vehicle passenger safety in case of impact.

3 Accident analysis

Accident analysis has been completed on this place. After the implementation of mentioned construction modifications (time period since 1st August 2016 to 30th September 2017), there were 8 traffic accidents of the same type – driver did not respond on the traffic situation in time and hit the crash cushion. Four of these cases were without personal injury, two with minor injuries of participants, one was with fatal injury and other accidents cases participants suffered serious injuries.
Compared to this period, accident analysis in period before modification of this place has been completed. According to the CDV methodology [9], the 250 metres long road section has been analysed. In time period 2013 – 2015, 6 accidents were reported on this place – 2 with minor injuries and 4 with property damage only. In 2014 there were 4 accidents – 3 without personal injuries, one with minor injuries. These accidents were mostly caused by distraction, one of these was caused by speeding. In 2015 there were just 1 accident with minor injury.

This place was not critical accident site before modification. The significant increase of the accident number motivated the following in-depth accident analysis. In the following paragraphs the three most serious will be described.

3.1 Traffic accident No. 1.

The driver of small truck was distracted or fell asleep and hit the fixed obstacle. There were 7 people injured. The crash cushion was in contact with the middle part of the vehicle front mask. After the impact, the vehicle was rapidly decelerated, the passengers were thrown forward during a sudden deceleration. The engine of the vehicle was pressed into the interior on the front passenger seat. Five people had minor injuries, two were injured seriously.
The passenger on the front seat did not use the seat belt, so she was thrown forward through the windscreen of the vehicle due to the impact. Paradoxically, the fact that she did not use safety belts and left the vehicle through the windscreen most likely saved her life, as she would have suffered devastating injuries of her lower limbs and lower part of her torso of the body by the engine compression.

3.2 Traffic accident No. 2.

The next serious traffic accident appeared on the October 2016. The accident had a similar scenario as previous accident: frontal collision of the small truck and the fixed obstacle –contact of the right side of the vehicle front mask (the side opposite to the driver, the deformation on the driver´s side was minor) and the crash cushion. The crash cushion was not fixed after the previous one. The driver has been thrown forward through a rapid deceleration. Despite the seat belt fastened, driver suffered serious injuries. Due to the interview with the driver, he did not sufficiently control the vehicle and was not able to react in a sudden direction change.

3.3 Traffic accident No. 3.

The most serious was the traffic accident from December 2016. The scenario was also very similar. Frontal collision of the right front part of the vehicle and fixed obstacle – crash cushion, which was still not fixed after previous accidents. After the impact, the vehicle was turned over to the left side and sliding on the road about 50 metres until stopped. The passengers of the vehicle were thrown forward through a rapid deceleration, then they were thrown on the left against to the vehicle interior after rollover. The airbag was not operational, according to the photo documentation it was removed. The trunk of the vehicle was not separated by a divider from the rest of the vehicle. Six people were injured – 4 seriously, 1 fatally. The driver had minor injuries, because the impact was mainly directed to the right side of the vehicle.
The older woman suffered fatal injuries. She was sitting on a chair in the trunk of the vehicle. Apparently, she hit the rear surface of the last row seats, and then the left side of the interior of the vehicle. Massive blunt violence operated on the front trunk caused multiple chest injuries. When the vehicle turned over and the uncoordinated movement of the body, passenger was damaged in the interior of the vehicle, the head has struck a strong obstacle, thus breaking the connection between the skull and the cervical spine, with injuries to the cervical spinal cord and the brain stem. She died on scene immediately.

3.4 Conclusion from accident analysis

As can be seen from the analysis of accidents, accidents with injuries occurred when the driver was affected by impaired conditions (rain, glare) or reduced visibility by darkness. Vehicle driver interviews indicate that accidents occurred with insufficient driver performance and respond failure to a sudden change of direction.

The detailed accident analysis also showed the inadequacy of the installed crash cushion. As illustrated by Figure 1, this type of crash cushion was plugged between the longitudinal beams during frontal collision with small truck. The vehicle engine was pressed into the interior on the front passenger compartment.

Figure 1 Crash cushion (left) [10] and traffic accident of the small truck on the D2 on October 2016 (right)

4 Road safety inspection

4.1 Analysis of driver perception using eyetracking

For the analysis of driver perception of roadway design, eyetracking techniques has been used. Eye-tracking method is used to measure motion of an eye relative to a head and allows eye fixations analysis. For this purpose, video-based eyetracker ASL mobile eye XG unit has been used.

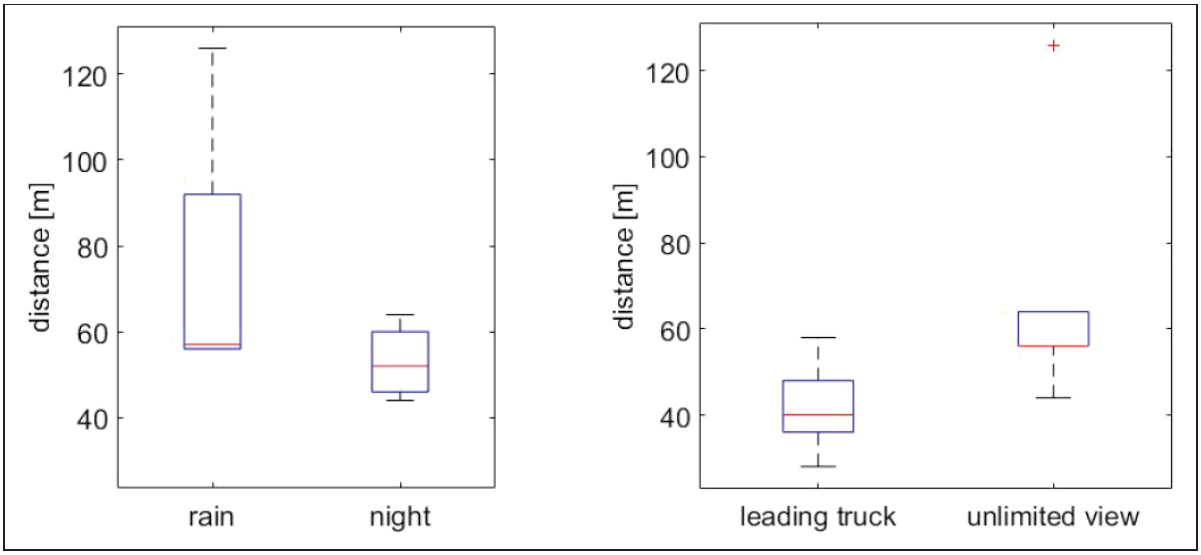

Figure 2 Distance of crash cushion perception beginning

Ten drivers aged from 24 to 47 participated in this study. The speed of vehicles at this location ranged from 72 to 86 km/h (mean 80 km/h). The subjective visual perception of drivers was analysed, especially the distance from which the crash cushion starts to be perceived by the driver (Figure 2). Measurements were carried on an impaired visibility conditions – rain and night. Unfortunately, the night measurement could not be realized before the site was modified. Due to the high volume of truck traffic at this location, analysed situation was also divided into 2 groups – view limited because of the leading truck and without limitation.

Visual behaviour of drivers was analysed 10 sec. before crash cushion. Drivers visually scan central area in front of the vehicle most often (mean value of central area perception was 64 %) and left side of the lane – road marking and barriers (mean value 20 % of total time). The right side of the lane was mostly observed closely before crash cushion (mean time of visual perception 13 %). Traffic sign showing the direction was perceived for 0.5 s on average.
Analysis of the visual perception demonstrated that drivers began to perceive crash cushion mostly 2 seconds before passing through it. Driver´s attention was not distracted at the time of measurement. For forensic examination, the value of 2 seconds is the upper limit of reaction time [11]. Whereas the crash cushion has been in the direct trajectory of the vehicle, critical situation may have occurred, especially for distracted driver. The questionnaire survey shows that the majority (9 from 10) of drivers marked design of the transport area as unclear.

4.2 Road safety inspection

From the provided road safety inspection several serious safety hazards has been identified: primarily unfavourable traffic lane course, the absence of vertical traffic signs damaged after previous accidents and advertising in the vicinity of the road which can influence driver attention. Low-cost recommendation has been proposed for improving road safety (Figure 3 and 4): mainly creation of a longer manoeuvring space before the fixed obstacle (A), road marking of smoother lane course (B), the addition of more salient vertical traffic signs (especially before the lanes split) (C), using the audio-tactile road marking (D), also advertisement removing.

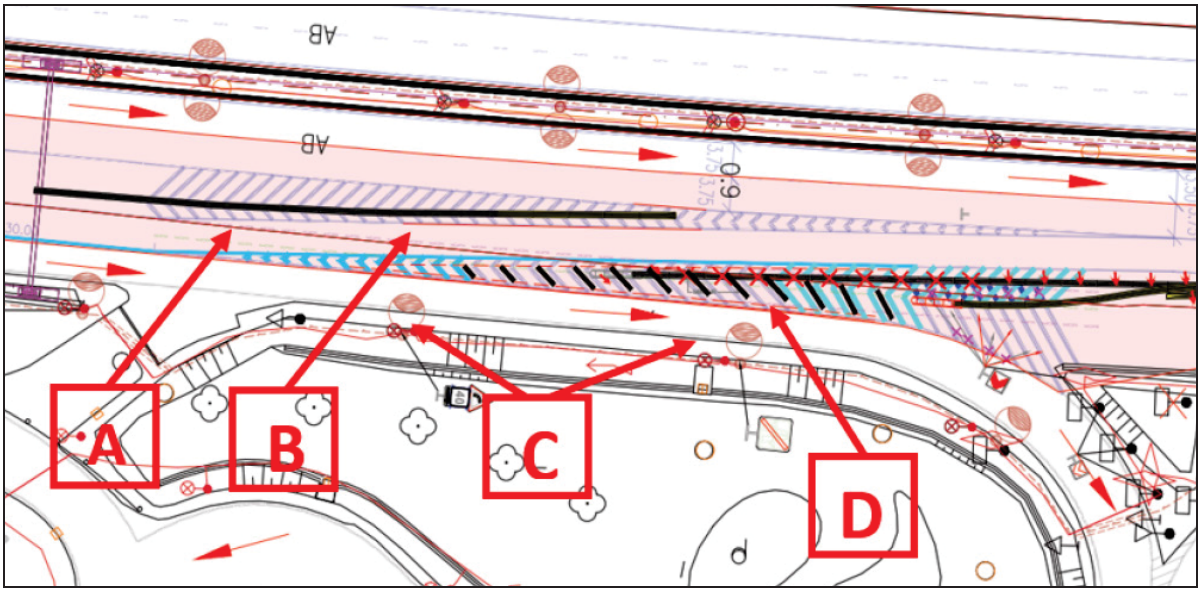

Figure 3 Recommended adjustments

Figure 4 Situation before adjustments (left) and after adjustments (right)

5 Socio-economic losses caused by traffic accidents

Transport and its consequences are evaluated from different points of view of safety, road, vehicle and human factor. However, it is very important to assess the transport impacts also from the economic viewpoint. The methodical procedure of loss calculation of traffic accident rate was defined under conditions of the Czech Republic in [12]. This calculation includes the cost of Integrated Rescue System work, eliminating the consequences of a traffic accident; costs of police, administrative and judicial activities; health and social security of the injured person; material damages, including costs of insurers, as well as lost economic benefits, which the state comes to the inability of the injured to work. Total road traffic casualties are then determined by multiplying the unit cost according to the severity of the injury with the number of deaths, injuries and accidents involving only property damage, [13].

Table 1 Economic loss from accidents

Accident fatality	count	Total cost [CZK]
Fatal injuries	1	19 411 000
Serious injuries	7	35 659 400
Minor injuries	7	4 679 500
Without personal injuries	4	1 458 000

According to this methodology, the amount of economic loss from accidents (Table 1) is 61.207.900 Czech crowns (2 404 553 Euros). The crash cushion was installed four times (360 000 Czech crowns per one crash cushion Tau Tube P120 and 40 000 Czech crowns transport and installation), which means 1 600 000 Czech crowns (62 856 Euros) in sum.

6 Conclusion

As a result of the traffic-engineering accident analysis taking account to the medical consequences of the traffic accident, installed crash cushion has been assessed as inappropriate. A crash cushion with the higher retention rate should be installed (at least 110 km/h).
Results from the road safety inspection and analysis of driver perception and accident analysis also showed that the current design of the traffic area is unsuitable. The concrete barrier with a crash cushion has been placed in the straight-ahead lane direction. As evident from driver´s interviews, the lane direction change could be perceived as unexpected, and sudden. In accordance with the creation of self-explanatory roads, the adjustment of lane directional with emphasis on fluency of the change should be realized.
Conducted accident analysis also shows critical problem of existing after accidents unrepaired equipment. It could be also assumed, that collision with the fixed crash cushion could led to the less tragic consequences.
During September 2017, the recommended adjustments has been implemented. The adjustment consisted in the barriers modification, crash cushion displacement, adjusting the horizontal and vertical road marking, installing the transverse thresholds and sounding horizontally marking, the manoeuvring space before crash cushion extending including the lane extension. These adjustments have made the site more comprehensible. The audio-tactile road marking sufficiently alert the driver to the change of direction especially in situations where is driver attention distracted. The crash cushion has been no longer in the straight-ahead direction. There has been no traffic accident since the adjustments have been realized. Compared to the socio-economic losses caused by traffic accidents (2 404 553 Euros), the adjustments realization cost was 406 595 Czech crowns (15 973 Euros)

Acknowledgement

The paper was produced with the financial support of the Ministry of Education, Youth and Sports within the National Sustainability Programme I, project of Transport R&D Centre (LO1610), on the research infrastructure acquired from the Operation Programme Research and Development for Innovations (CZ.1.05/2.1.00/03.0064).

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