**CETRA**2022 11-13 May 2022, Pula, Croatia
**7th International Conferenceon Road and Rail Infrastructure**

# REHABILITATION OF AN ACCIDENT SPOT WITH HUMAN FACTORS

**Sibylle Birth**[1], **Žiga Boh**[2], **Samo Krajnc**[2], **Jure Kukovič**[2]
[1] *Intelligenz System Transfer, Germany*
[2] *DRI Investment Management Ltd., Company for Development of Infrastructure, Slovenia*

## Abstract

The Ocizla roundabout was built in the first quarter of 2021 of prefabricated elements. Due to inadequate placement of the roundabout, traffic accidents began to occur in which motorcyclists were predominantly involved. When driving towards the Ocizla roundabout, drivers are not able to keep the lane. Instead of following a slight right curve to enter the roundabout they drive straight ahead until entering the opposite lane or crash on the curb stone of the roundabout. The accident data and the results for traffic monitoring give strong evidence that the cause of the accidents cannot be technically explained. It is rather a question of Human Factors of space perception that has to be investigated to solve the problem.A traffic monitoring between 6th and 8th October 2021 with a representative sample of 156 vehicle was conducted. We detected 23 % of vehicles that run near to the centreline or even crossed it. The Human Factor Evaluation Tool (PIARC) showed a high Human Factors Risk Score. According to that only 32 % of drivers demands were met.Consequently, Human Factors countermeasures have been planned and implemented. A first evaluation showed a significant improvement of the Human Factors Score: 76 % of drivers demands are fulfilled after implementation of countermeasures. This is a very good result – achieved only by low-cost optical measures without substantial building changes of the Oriza roundabout. The rehabilitation of an accident site with Human Factors is an effective way if accidents are not caused by technical issues but by wrong orientation, perception or even wrong expectations regarding the situation. It allows a pro-active approach to road safety.

*Keywords: human factors, road safety, low-cost measures to improve road safety*

## 1 Roundabout Ocizla

State road R2-409 connects regional centres with settlements and urban areas from central to southwest Slovenia with a length of 102,8 km. It is a two-lane road with an average road width of 6,5 m-7,5 m with clear boundary lines and centreline. The allowed speed in the rural areas is limited to 90km/h. The traffic share of cars is 75.9 %, the share of motorcycles is 1 % and the share of other vehicles is 14.1 % with a traffic volume of about 2,400 vehicles per day. The surveyed road section is section 0311 between Kozina and Kastelec. It has an intersection with the motorway A1 Ljubljana – Koper.
This section plays also an important role in the construction of one of the biggest infrastructural projects in Slovenia – the second track of the Divača-Koper railway line. With the start of the construction the number of trucks increased considerably and the traffic flow in the main direction was disturbed – especially for the vehicles from direction Ocizla. In order to let trucks join safely the R2-409 a prefabricated roundabout was installed in the first quarter of 2021.

DOI: https://doi.org/10.5592/CO/CETRA.2022.1389


**Figure 1** Location of the prefabricated roundabout in R2-409/0311 with signing [1]

## 1.1 Road situation before

From East to West the R2-409/0311 runs between hills in a wide left curve. 160 m ahead of the roundabout is an off-level crossing where the main road runs under the motorway (AC-A1) overpass. With the installation of the roundabout new signs were set to inform road users about the change: a speed limit (70 km/h) together with a danger sign "roundabout" was set 260 m ahead of the roundabout. A speed limit 50km/h was installed 110 m ahead. No other measures have been made to allow the detection of the roundabout.

## 1.2 Sight distance and visibility after

The visibility of the roundabout from East to West is limited as well as the overview about the course of the road. The roundabout is installed more at the right in the direction of the local road direction Ocizla and has a weak visibility. The colour of the prefabricated curbs (yellow - black) almost merge with the surrounding. That's why the stopping sight distance is not adequate.

**Figure 2** Bad visibility of the roundabout and stopping sight distance [1]

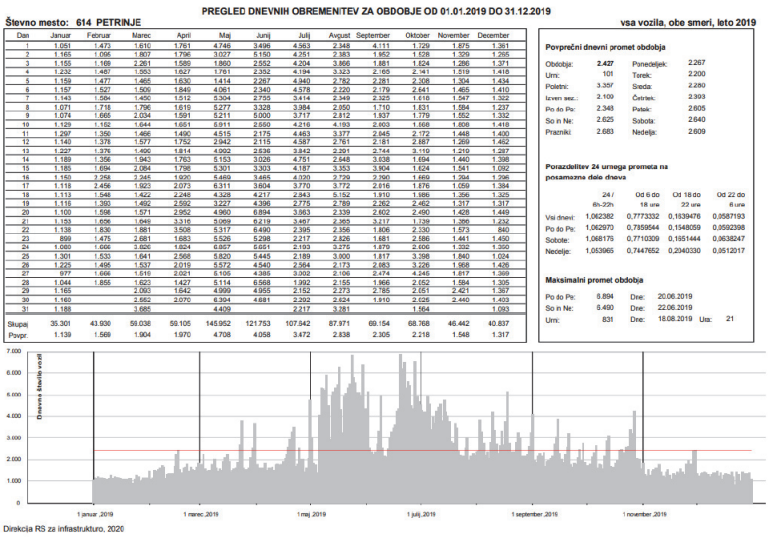
**Figure 3** Old misleading centerline [1]

The old centreline, running in the middle of the old left curve was not completely erased. So there is still a perceptible centreline which indicates a left curve instead a right turn entering the roundabout. It has a misleading effect.

# 2 Accident data

## 2.1 Traffic loads in the period from 1st January to 31st December 2019

Traffic loads come to its peak between May and August – which is a traditional time for motorized excursions in Slovenia. There is a considerable traffic increase of two-wheelers on Fridays, weekends and public holidays, provided the weather is clear. More than 1000 single-wheeled vehicles (two-way traffic) daily are recorded.



PREGLED DNEVNIH OBREMENITEV ZA OBDOBJE OD 01.01.2019 DO 31.12.2019

Števno mesto: 614 PETRINJE

vsa vozila, obe smeri, leto 2019

| Dan | Januar | Februar | Marec | April | Maj | Junij | Julij | Avgust | September | Oktober | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.051 | 1.473 | 1.610 | 1.761 | 4.746 | 3.496 | 4.563 | 2.348 | 4.111 | 1.729 | 1.875 | 1.361 |
| 2 | 1.165 | 1.095 | 1.807 | 1.796 | 3.027 | 5.150 | 4.251 | 2.383 | 1.952 | 1.528 | 1.329 | 1.265 |
| 3 | 1.155 | 1.169 | 2.261 | 1.586 | 1.860 | 2.552 | 4.204 | 3.866 | 1.881 | 1.824 | 1.286 | 1.371 |
| 4 | 1.232 | 1.467 | 1.553 | 1.627 | 1.761 | 2.352 | 4.194 | 3.323 | 2.165 | 2.141 | 1.519 | 1.418 |
| 5 | 1.159 | 1.477 | 1.465 | 1.630 | 1.414 | 2.267 | 4.340 | 2.762 | 2.281 | 2.308 | 1.304 | 1.434 |
| 6 | 1.157 | 1.527 | 1.500 | 1.849 | 4.061 | 2.340 | 4.578 | 2.220 | 2.179 | 2.641 | 1.465 | 1.410 |
| 7 | 1.143 | 1.584 | 1.490 | 1.512 | 5.304 | 2.755 | 3.414 | 2.349 | 2.325 | 1.618 | 1.547 | 1.322 |
| 8 | 1.071 | 1.718 | 1.796 | 1.619 | 5.277 | 3.328 | 3.984 | 2.650 | 1.710 | 1.831 | 1.584 | 1.237 |
| 9 | 1.074 | 1.665 | 2.034 | 1.591 | 5.211 | 5.000 | 3.717 | 2.812 | 1.937 | 1.779 | 1.552 | 1.332 |
| 10 | 1.129 | 1.152 | 1.644 | 1.651 | 5.911 | 2.550 | 4.216 | 4.193 | 2.603 | 1.668 | 1.608 | 1.418 |
| 11 | 1.297 | 1.360 | 1.466 | 1.490 | 4.515 | 2.175 | 4.463 | 3.377 | 2.945 | 2.172 | 1.448 | 1.400 |
| 12 | 1.140 | 1.378 | 1.577 | 1.752 | 2.942 | 2.115 | 4.587 | 2.761 | 2.181 | 2.887 | 1.269 | 1.462 |
| 13 | 1.227 | 1.376 | 1.490 | 1.814 | 4.992 | 2.636 | 3.842 | 2.291 | 2.744 | 3.119 | 1.210 | 1.287 |
| 14 | 1.189 | 1.356 | 1.943 | 1.763 | 5.153 | 3.026 | 4.751 | 2.448 | 3.638 | 1.694 | 1.440 | 1.398 |
| 15 | 1.185 | 1.694 | 2.084 | 1.798 | 5.301 | 3.303 | 4.187 | 3.353 | 3.904 | 1.624 | 1.541 | 1.092 |
| 16 | 1.160 | 2.258 | 2.345 | 1.920 | 5.469 | 3.485 | 4.100 | 2.729 | 2.390 | 1.469 | 1.394 | 1.096 |
| 17 | 1.118 | 2.456 | 1.923 | 2.073 | 6.311 | 3.604 | 3.770 | 3.772 | 2.816 | 1.876 | 1.059 | 1.384 |
| 18 | 1.113 | 1.548 | 1.422 | 2.248 | 4.328 | 4.217 | 2.943 | 5.152 | 1.910 | 1.986 | 1.356 | 1.325 |
| 19 | 1.116 | 1.393 | 1.462 | 2.592 | 3.227 | 4.396 | 2.775 | 2.769 | 2.262 | 2.462 | 1.317 | 1.317 |
| 20 | 1.100 | 1.598 | 1.571 | 2.952 | 4.960 | 6.894 | 3.983 | 2.339 | 2.602 | 2.490 | 1.428 | 1.449 |
| 21 | 1.153 | 1.656 | 1.649 | 3.316 | 5.069 | 6.219 | 3.467 | 2.365 | 3.217 | 1.739 | 1.395 | 1.232 |
| 22 | 1.138 | 1.830 | 1.881 | 3.508 | 5.317 | 6.490 | 2.395 | 2.356 | 1.806 | 2.330 | 1.573 | 840 |
| 23 | 899 | 1.475 | 2.681 | 1.683 | 5.526 | 5.298 | 2.217 | 2.826 | 1.681 | 2.586 | 1.441 | 1.450 |
| 24 | 1.060 | 1.666 | 1.826 | 1.824 | 6.857 | 5.651 | 2.103 | 3.276 | 1.879 | 2.606 | 1.332 | 1.350 |
| 25 | 1.301 | 1.533 | 1.641 | 2.568 | 5.820 | 5.445 | 2.189 | 3.900 | 1.817 | 3.398 | 1.840 | 1.024 |
| 26 | 1.225 | 1.495 | 1.537 | 2.019 | 5.572 | 4.540 | 2.564 | 2.173 | 2.883 | 3.226 | 1.568 | 1.426 |
| 27 | 977 | 1.666 | 1.516 | 2.021 | 5.106 | 4.385 | 3.002 | 2.106 | 2.474 | 4.245 | 1.817 | 1.369 |
| 28 | 1.044 | 1.855 | 1.623 | 1.427 | 5.114 | 6.568 | 1.992 | 2.155 | 1.966 | 2.652 | 1.584 | 1.305 |
| 29 | 1.165 | | 2.093 | 1.642 | 4.999 | 4.955 | 2.152 | 2.273 | 2.785 | 2.051 | 2.421 | 1.367 |
| 30 | 1.160 | | 2.552 | 2.070 | 6.394 | 4.681 | 2.292 | 2.624 | 1.910 | 2.626 | 2.440 | 1.403 |
| 31 | 1.188 | | 3.685 | | 4.409 | | 2.217 | 3.281 | | 1.564 | | 1.093 |
| Skupaj | 35.301 | 43.930 | 59.038 | 59.105 | 145.952 | 121.753 | 107.942 | 87.971 | 69.154 | 68.768 | 46.442 | 40.837 |
| Povpr. | 1.139 | 1.569 | 1.904 | 1.970 | 4.708 | 4.058 | 3.472 | 2.838 | 2.305 | 2.218 | 1.548 | 1.317 |

**Povprečni dnevni promet obdobja**

| | | | |
|---|---|---|---|
| Obdobja: | 2.427 | Ponedeljek: | 2.267 |
| Urn: | 101 | Torek: | 2.200 |
| Poletni: | 3.357 | Sreda: | 2.280 |
| Izven sez.: | 2.109 | Četrtek: | 2.393 |
| Po do Pe: | 2.348 | Petek: | 2.605 |
| So in Ne: | 2.625 | Sobota: | 2.640 |
| Praznki: | 2.683 | Nedelja: | 2.609 |

**Porazdelitev 24 urnega prometa na posamezna dela dneva**

| | 24 / | Od 6 do | Od 18 do | Od 22 do |
|---|---|---|---|---|
| | 6h-22h | 18 ure | 22 ure | 6 ure |
| Vsi dnevi: | 1,062382 | 0,7773332 | 0,1539476 | 0,0587193 |
| Po do Pe: | 1,062970 | 0,7595644 | 0,1548059 | 0,0592398 |
| Sobote: | 1,068175 | 0,7710309 | 0,1551444 | 0,0638247 |
| Nedelje: | 1,053965 | 0,7447652 | 0,2040330 | 0,0512017 |

**Maksimalni promet obdobja**

| | | | | | |
|---|---|---|---|---|---|
| Po do Pe: | 5.894 | Dne: | 20.06.2019 | | |
| So in Ne: | 5.490 | Dne: | 22.06.2019 | | |
| Urn: | 831 | Dne: | 18.08.2019 | Ura: | 21 |



**Figure 4** Overview of traffic loads [16]

## 2.2 Typical accidents and accident data

Before the installation of the roundabout no accidents were reported from 2015 – 2020. After the roundabout was built there were 5 accidents, all of which involved only motorcyclists. In three cases, the drivers were seriously injured. Police reports revealed several traces of tire braking in front of and at the curb stones of the roundabout. This indicates additional accidents (collisions with curbs) which were not even reported. At the end of 2021 a heavy truck break through the roundabout causing major damage of the traffic facility. Based on the accident data the typical characteristics of the accidents are:

- unadjusted speed
- collision with the prefabricated curbs
- the participants were motorcyclists.

That's why a traffic monitoring was conducted.

## 2.3 Traffic monitoring

From 6th to 8th October 2021 a traffic monitoring with a video camera was conducted with a statistical analysis of the driving position, the braking and irregularities in the trajectory (156 vehicles). While approaching the roundabout from the direction of Kozina we observed that 42 cars (27 %) are driving too close to the centreline. Additionally 22 cars (14 %) drifting

dangerously close to the centreline and even 14 cars crossed it (9 %). 96 cars (62 %) started breaking very early because their speed was too high to cope with the unexpected situation. This is a clear hint that the bad visibility of the roundabout and the misguiding effect of the centreline works in general and leads to misperception and driving mistakes. It causes for field-dependent drivers a heavy misorientation. So 50 % of drivers interfere with the traffic of the opposite lane. This is completely inacceptable from the point of view of traffic safety.


**Figure 5** Driving across the center line [17]

The accident data and the results for traffic monitoring give strong evidence that the cause of the accidents cannot be technically explained. It is rather a question of Human Factors that has to be considered to solve the problem.

# 3 Human factors evaluation

## 3.1 What are human factors and their role in accidents

Human Factors (HF) are defined as those psychological and physiological threshold limit values which are verified as contributing to operational mistakes in machine and vehicle handling [4]. In the case of road safety, the Human Factors concept considers these certain road characteristics which pre-program the driver's expectations how to drive. The Human Factors approach traces accidents back to their actual root-causes. The overall impression of the road and its surrounding is able to guide or irritate the driver, to stabilise or destabilise his driving performance and finally to pre-program the expectations about the roads course and the appropriate speed level. This overall impression is the basis of a self-explaining road design that uses design elements, marking, equipment, landscaping and signing to pre-program right expectations how to drive and to avoid accidents from the root of its causation [10, 11, 12].

## 3.2 The method of human factors Assessment: The human factors evaluation tool (HFET, PIARC)

The Human Factors Evaluation Tool is based on the analysis of about 1.800 accidents that are technically unexplainable. It contains about 100 validated and reliable items that are proven to be the root-cause of accidents [5] and violate the principles of a self-explaining road design. It was developed by road safety experts of the World Road Association (PIARC, 2004-2019, [3,4].
This tool predicts accidents with a consistency of over 75 % between predicted and real accident locations [6], and a consistency of 56 % - 78 % between Human Factors Risk Score and actual accidents in a network wide road safety assessment [7]. The Human Factors Risk

Score represents the percentage rate of fulfilled Human Factors demands. It is showing the accident probability of a road situation as well as the priority of countermeasures:

- If the percentage is ‹ 39 %, accident probability is high and it is mandatory to take efficient countermeasures. The results are marked red:
- If the percentage is 40 - 60 %, accident probability is middle and it is desirable to take efficient countermeasures. The results are marked yellow.
- If the percentage is 61 – 99 % accident probability is low. Some desirable improvements could be made. The results are marked green.

## 3.3 Human factors requirements for safe roundabout

Reaction time: If a driver has to cope with an unexpected, new build roundabout/intersection he needs not only fractions of a second to react (simple "stimulus–reaction time). The average driver needs at least 4-6 seconds to adapt to a surprising new intersection ("perception–decision time"). So the new roundabout should be visible and understandable about 4-6 seconds ahead.

Field of view: The overall impression of the road pre-programmes expectations about course and speed level. To ensure a safe slowdown in speed while approaching a new roundabout, it should be placed directly as an eye-catching hindrance in the view axis of the driving lane. Additionally the view to other roads entering the roundabout should be obstructed. Not any other eye-catchers in the periphery or depth of the field of view should distract the driver.

Expectation logic: A new junction always disturbs the habitual driving pattern. The change of roads' function must be recognized and newly learned. That's why the approaching section and the roundabout itself must be optically so designed, that the optical clues catch attention automatically and instruct road users how to drive.

## 3.4 Results of human factors assessment

The accident spot was inspected with videos and street view to compare the programming of drivers before and after the installation of the roundabout. The following results show that the situation misguides drivers and their expectations.

Reaction time: The new intersection is located about 300 m after the exit of Kozina in a left curve. It can only be recognized from a distance of about 60 m. Several speed and warning signs try to inform the driver. But it is not installed as an eye-catcher directly in the view axis of the driver. It is rather arranged at the right in the periphery. So the bad visibility provides not enough perception-decision-time to cope with the situation. Only 29 % of the Human Factors requirements are met. The accident probability is high and it is mandatory to take efficient countermeasures.

Field of view: The old far visible left curve has additionally a dominant eye-catching mountain which increases misorientation. The old centre marking of the road catches the fixations and reinforces the wrong orientation to drive in a left curve. There are no optical clues that reinforce an orientation reaction to slow down and turn to the right to enter the entrance to the roundabout. The Risk Score of subdivision "risks in the depth of the field of view" meets only 33 % of the Human Factors requirements. The accident probability in the subdivision "depth of the field of view" is high and it is mandatory to take efficient countermeasures.

Expectation logic: Neither the change of road's function nor the change of driving direction to the right can be understood early enough. Old habitual driving patterns (speedy left curve) compete with new requirements (break down and turn to the right to enter the roundabout).

From a legal point of view, the signage is fine, but cannot really prepare the driver for the new situation. The Risk Score for drivers' expectations meets only 20 % of the requirements. The accident probability is high and it is mandatory to take efficient countermeasures.

# 4 Human factors countermeasures and their effectiveness

## 4.1 Goal of countermeasures

The goal of HF countermeasures is to provide drivers with the relevant information how to approach the roundabout with low-cost solutions. They should improve traffic safety and reduce the accident probability. If this is reduced, also the number of driving mistakes decrease. With this, also accidents will go down. Main goals are:

- to provide more perception-decision-time by setting speed limits. This must be combined with improvement of the visibility of the roundabout.
- to guide orientation and attention away from the left curve to the entrance of the new roundabout. This could be done by attention-guiding elements.
- to pre-program new expectations and to overcome the habit of unhindered driving through a left curve.

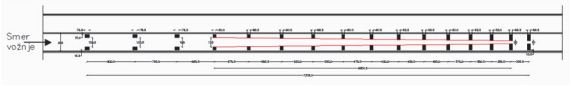
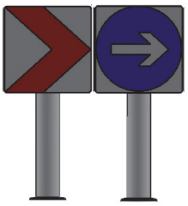
## 4.2 Description of Countermeasures

Countermeasures to improve road safety were identified on the basis of shortcomings in the results of the Human Factors Evaluation Tool. As traffic accidents occur at the entrance of the roundabout (from East to West), the following Countermeasures to improve traffic safety are in the approaching section and the entrance to the roundabout are explained in table 1 below.

**Table 1** Countermeasures to improve traffic safety

| Countermeasure | Illustration |
|---|---|
| Drivers will be informed 250 m ahead of the roundabout that they are approaching a new intersection. A pre-intersection sign is placed showing the course of the roundabout and the settlements that can be reached from it. There is also added a table "250 m" to inform the driver about the distance. |  |
| In order to slow down there will be set up a speed limit 70 km/h 370 m ahead of the roundabout. |  |
| The existing lanes are currently 2 x 3,6 m wide, which means that the width of the road contributes to an increased speed. In order to comply with the speed limit the existing centreline is changed into a double divided line – filled inside with a green field. This limits the width of the lane to 2 x 2,75 m. This adapted lane marking starts 270 m ahead of the roundabout and ends at its entrance. |  |

**Table 1** Countermeasures to improve traffic safety - continuation

| Countermeasure | Illustration |
|---|---|
| For the appropriate approach to the roundabout, 110 m ahead a highlighted traffic sign with flashing lights is added. It contains a roundabout sign, the distance and a speed limit of 50 km/h. It is mounted on an attention-guiding yellow frame.<br>From this point on, a 75 m long optical break appears on the road, which help drivers to slow down unconsciously and to cope with the speed limit.<br>  |  |
| 50 m ahead of the roundabout a speed limit of 30 km/h is set. In order to guide the drivers to the right and break the orientation to drive in a left curve, passive safety posts (1,2 m high) are placed on the green field in the centre line with a distance of 4 m. |   |
| To prevent a view to the other side of the roundabout and guide drivers, passive safety posts for motorcyclists are placed on the left side of the road (in the direction of the roundabout) at a distance of 6 m and a height of 1,2 m. |  |
| To ensure the visibility of the roundabout and to guide the driver's attention passive safety posts with a height of 1,32 m are placed in the inner part of the roundabout. |  |
| Low hight delineators with reflectors are placed on the top of the existing curbs of the middle island in the approaching lane. They will guide the driver properly to the entrance of the roundabout. |  |
| The misguiding centre line of the left curve will be completely removed. | |

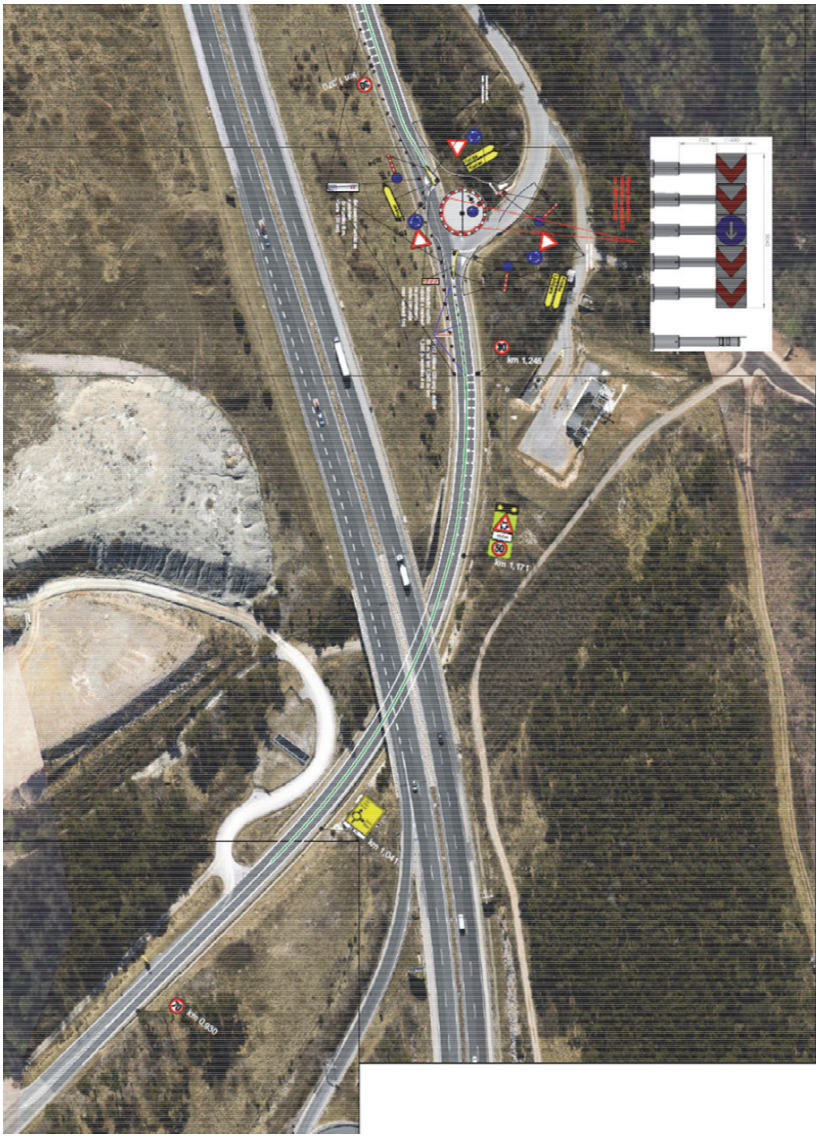


**Figure 6** Planned Human Factors countermeasures in the approaching section [1]

## 4.3 Results of human factors assessment

For the planned countermeasures the Human Factors Risk Scores were calculated. The results show clearly that the Human Factors countermeasures grant a maximum benefit with the above-mentioned low-cost measures.

**Table 2** Risk Scores in the Human Factors Evaluation before and after improvement

| | Before | After |
|---|---|---|
| Human Factors requirement | HF Risk Score | HF Risk Score |
| I. Reaction time: Give driver enough time! | 29 % | 65 % |
| I.1 Transition with sufficient perception-decision time? | 25 % | 100 % |
| I.2 Perception, Visibility, Understanding is sufficient? | 31 % | 54 % |
| II. Field of View: Give reliable optical guidance! | 48 % | 76 % |
| II.1 Monotony and risk of speeding up is avoided? | 80 % | 100 % |
| II.2 Lane keeping is stabilized or disturbed? | 43 % | 57 % |
| II.3 Optical guidance prepares users for new changes? | 33 % | 100 % |
| III. Expectation logic | 19 % | 84 % |
| III.1 Visibility of roundabout enhanced by optical clues? | 0 % | 80 % |
| III.2 Change of direction reinforced by eye-catchers? | 0 % | 75 % |
| III.3 Habits/Expectations compete with new requirements? | 33 % | 91 % |
| III.4 Signing pre-programs expectations consistently? | 20 % | 80 % |
| Total Human Factors-Score | 32 % | 76 % |

### 4.4 First results of the effectiveness and validity

The described countermeasures will be implemented at the beginning of May 2022 when the weather conditions improve. Before and after the implementation speed measurements and a video-observation of the traffic will be conducted. We expect that the drivers' approaching of the roundabout will be smoother with less surprising breaking manoeuvrers. We expect also a lower speed level due to signing, optical breaks/countermeasures. With a clear and unambiguous guidance and signing it will be possible to pre-program right expectations and an improved driving trajectory. This is really needed to diminish the number of road users that drift dangerously close to the centreline or even cross it.
The first evaluation of the effectiveness of Human Factors countermeasures will start immediately after the implementation. After one year the effect of countermeasures will be evaluated again to draw conclusions regarding a final adjustment. The last monitoring will be carried out in 2023 to evaluate the final state of implementation.

## References


[1] DRI: Videos and photgrafies produced in the process of rehabilitation of Roundabout Ocizla, Ljubljana, 2022.

[2] Goldstein, B.: Wahrnehmungspsychologie, Heidelberg, 1997.

[3] Birth, S., Pflaumbaum, M., Sieber, G.: IST-Checklist 2004, Potsdam, 2004.

[4] Birth, S., Staadt, H., Sieber, S.: Planen und Bauen mit Human Factors, Ministerium für Infrastruktur und Raumordnung, Brandenburg, Potsdam, 2004.

[5] Birth, S., Pflaumbaum, M.: Human Factors in Road Design: a way to self-explaining roads, Validation of the „IST-Checklist 2005, Project Report of Work Package 3: Expert Assistance for Safety Review of Rural and Urban Roads (single carriageway roads), Ranking for European Road Safety (RANKERS) Research Project funded under the 6th Framework Program of the European Community, Valladoid, 2006.

[6] Birth, S., Demgensky, B., Sieber, G.: Relationship between Human Factors and the likelihood of single-vehicle crashes on Dutch motorways, Report for Rijkswaterstaat Dienst Verkeer en Scheepvaart, Delft, 2015.

[7] Paliotto, A.: Development of a Human Factors Evaluation Procedure for Network-wide Road Safety Assessments, doctoral thesis, University of Florence and University Darmstadt, 2022.

[8] PIARC Technical Committee C.1 "Safer Road Infrastructure", editor: "Human Factors in Road Design. Review of Design Standards in Nine countries", PIARC-publication Ref.: 2012R36EN. ISBN: 978-2-84060-306-1. Paris, 2012.

[9] PIARC, Technical Committee C.3.2 "Risk Management for roads", Editor: "Human Factors Guidelines for a safer Man-Road Interface", PIARC, publ. 2016R20EN. ISBN: 2-84060-408-2. Paris, 2016

[10] Theeuwes, J.: Self-explaining roads: What does visual cognition tell us about designing safer roads?, Cogn. Research, 6 (2021) 15, DOI: https://doi.org/10.1186/s41235-021-00281-6

[11] Theeuwes, J., Horst, R.V.D., Kuiken, M.: Self-Explaining Roads and Traffic System, Designing Safe Road Systems - A Human Factors Perspective. London, CRC Press. E-Book ISBN 9781315576732. 2012, DOI: https://doi.org/10.1201/9781315576732

[12] Theeuwes, J., Diks, G.: Subjective road categorization and speed choice, Human Factors Research Institute, Soesterberg, 1995.

[13] Warren, W.H., Hannon, D.J.: Eye movements and optical flow. Journal of Optical Society of Amerika, 1990, pp. 160-169, DOI: https://opg.optica.org/josaa/abstract.cfm?URI=josaa-7-1-160

[14] Weller, G., Schlag, B., Friedel, T., Rammin, C.: Behaviourally relevant road categorisation: A step towards self-explaining rural roads, Accident Analysis & Prevention, 40 (2008) 4, pp. 1581-1588, DOI: https://doi.org/10.1016/j.aap.2008.04.009.

[15] Weller, G.: The Psychology of Driving on Rural Roads, The Psychology of Driving on Rural Roads, 2010, DOI: https://doi.org/10.1007/978-3-531-92414-4

[16] Slovenian Infrastructure Agency, Road System Records, IT and Archives Division, Ljubljana, February 2022, https://www.gov.si/teme/cestna-infrastruktura/#e71137

[17] Omega consult Ltd, Video traffic monitoring of roundabout Ocizla, Ljubljana, 2022.