International Journal of Integrated Engineering, Special Issue 2018: Civil & Environmental Engineering, Vol. 10 No. 2 (2018) p. 43-48
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DOI: https://doi.org/10.30880/ijie.2018.10.02.010

Findings of the safety inspections found on the TEN-T road network in the Czech Republic

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Received 01 January 2018; accepted 15 April 2018, available online 07 May 2018

Abstract: In 2015 the Czech Technical University in Prague carried out a safety inspection on the TEN-T road network in the Czech Republic and on the selected 1st class roads (in the future they are intended to replace the planned TEN-T network). This article is designed to provide a basic overview of the most common problems in terms of both the frequency with which these risks occur and their significance. This article will also present a newly developed web application, CEBASS, which gives road operators an effective and systematic tool to manage the process of solving these problems. The aim of this article is to describe the classification created and used during the safety inspection course, which is better for road operators than the existing methods for safety inspections.

Keywords: Safety Inspection, TEN-T, Czech Republic

1. Introduction

The TEN-T networks (Trans-European Transport Networks) are a planned set of road, rail, air and water transport networks in the European Union. TEN-T road network envisages coordinated improvements to primary roads and traffic management systems, providing integrated and intermodal long-distance high-speed routes. A decision to adopt TEN-T was made by the European Parliament and Council in 1996. The EU works to promote the networks by a combination of leadership, coordination, issuance of guidelines and funding aspects of development.

Last year there was carried out a safety inspection in the Czech Republic on the traffic roads of the TEN-T network and on the selected 1st class roads that are not classified as part of the TEN-T network and are intended to replace the TEN-T network in the future. This inspection analysed all sections of motorway network in the Czech Republic (approx. 780 km) as well as selected dual carriageways (approx. 430 km) and 1st class roads (approx. 890 km). The total length of the network analysed was 2,100 km. The majority of the inspection ("main inspection") was conducted from April to June 2015. The visibility and weather conditions were standard. The results of the safety inspection were evaluated using Czech Directive No. 317/2011 Special Report Section 7a and the methodology of 121/2013-520-TPV/1 "Safety inspection of traffic roads".

2. Road safety inspection procedure

The road safety problems were identified by driving round the network with an inspection vehicle that had been equipped with special data collection equipment. The traffic roads were also assessed in terms of their comprehensibility and safety for road users (drivers). In principle, safety inspections are about tracing the two basic principles behind routes – "self explaining" and "forgiving" – with the aim to obtain a safe road. Forgiving road means a concept that is designed to "forgive" mistakes made on the road. Self explaining road means that the infrastructure and its environment can be easily understood in order to adjust their behaviour accordingly.

Selected routes were tested in both directions. Drivers, pedestrians and cyclists perceive the environment around a traffic road differently in every direction. Something that is harmless in one direction can become dangerous in the other direction. The inspector focused on description of each problem in detail. Suggestions for improvement, however, are general in nature and recommendations can be considered. There are two exceptions to this, both are related to systematic measures and are described in detail in the following sections of this paper. These two specific measures are linked to the safety inspection audit team's desire to draw attention to current, unresolved problems in the road safety situation with regard to exits / separate exits / parking (see Subsection 4.1.) and bus stops on rural roads (see Subsection 4.2.). On rural roads, the biggest importance was placed on the safety of road users driving motor vehicles. When investigating urban

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Fig. 1 Form with additional information about every road safety problem.

roads, the inspector focused on safety of road users who could be injured (pedestrians, cyclists) as well.

Every road safety problem was noted in the form in Figure 1. The form contains additional information (e. g. remarks, local speed limit) in addition to basic information (e. g. number and type of traffic road, photographs, nature of the problem, GPS location, permitted severity, suggestion for improvement and outlay for the measure).

The result of usage of this form is the information that demonstrates the difficulty to implement recommended measure and severity of the risk identified. For ease of understanding, the difficulty involved in implementing each solution has been traffic light colour coded (red, yellow or green). A description of what each colour means can be found in Table 1.

As the next innovative step following the completion of the inspection, the CEBASS (Centrální Evidence Bezpečnostních Analýz Silniční Sítě – Centre of Evidence for Traffic Network Safety Analysis) web application database was created. This application provides a means for identifying road safety problems on traffic roads effectively and systematically, while also enabling road managers to implement solution management in the network that is monitored. The application went live on 1st March 2016.

Thanks to the CEBASS application described above, road operators can submit comments on all the road safety problems identified and update the measures being taken to resolve them at the same time (see Figure 1).

The application works in real time, meaning that multiple specialists can work on a suggestion to solve a particular problem each from their own PC. The application makes it possible to allocate the current phase from the three solution statuses to each problem; this can be expanded with text comments. The app user can select whether the solution to the problem is "in progress" or whether the problem has been "removed". They can also state that they do not agree that a particular problem exists using the "risk

Table 1 Explanation of the colours used to indicate the effort involved in each solution [1].

Colour	Description
red = complex solution	Expensive and time-consuming solution (e. g. improving a roundabout). This includes negotiations and approval processes, document creation, safety audits, etc.
yellow = administrative solution	Greater administration needed – suggestion for putting up suitable traffic signs and / or minor construction work.
green = simple solution	Simple solution (e. g. pruning trees, road marking, highlighting or replacing traffic signs, putting up reflector posts).

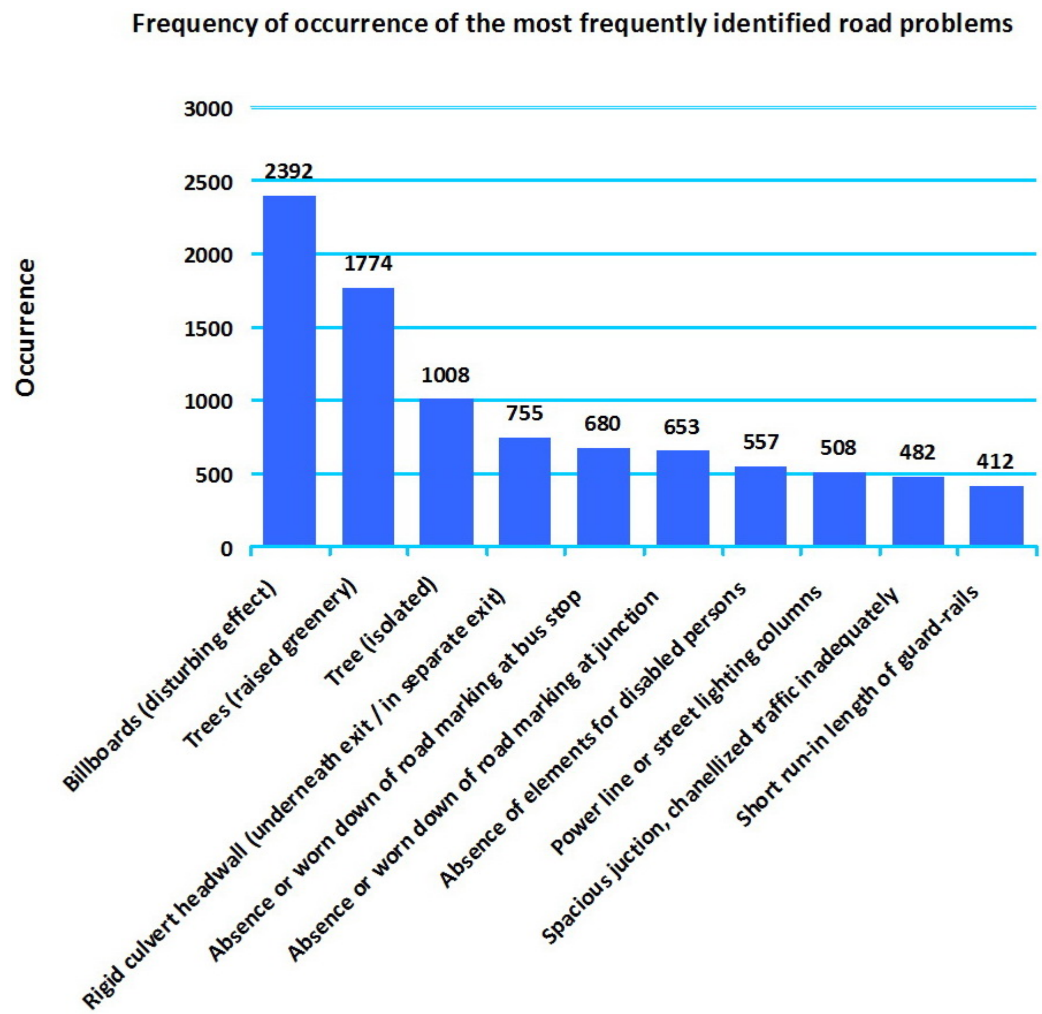

Fig. 2 Frequency of occurrence of the most frequently identified road problems.

not accepted" status. Various statistical analyses are created using this data (see Figure 2). The most interesting medium is most likely to be the set of three pie charts: "Problem divided by time / cost", "Problem divided by danger" and the current "Status of work" in the road operator area (see Figure 3).

Safety inspectors primarily monitored the problems that may affect road traffic safety in terms of its component parts, additional factors behind it and its spatial dimension.

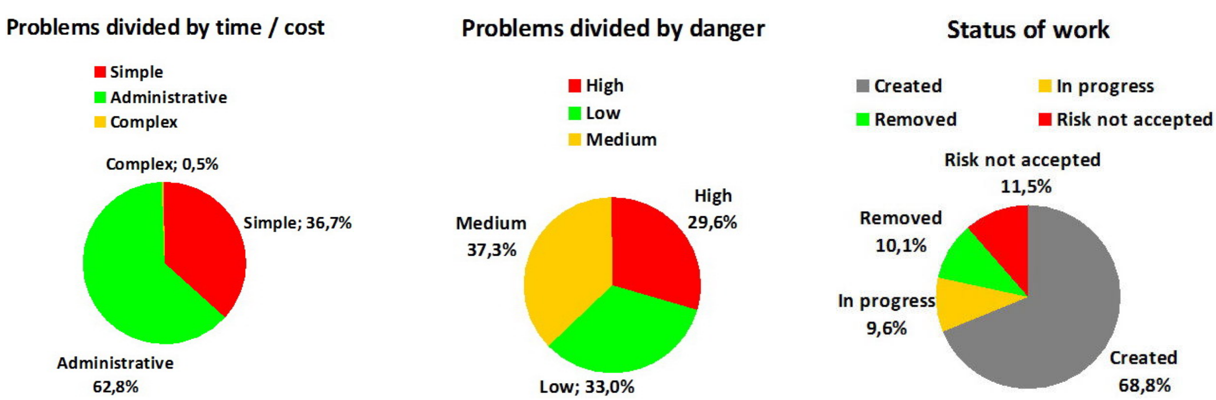

Fig. 3 Identified problems divided by time / cost, by danger and the current "Status of work".

2.1 Basic groups of identified problems

To clarify the risks and facilitate understanding of them, the identified problems were grouped into different categories. This categorisation (sorting into groups) takes into account not just the overall nature of the problem (construction and transport parameters) but also the type of improvement expected. On this basis we can sort the problems into the 14 following basic groups:

- fixed obstructions (e. g. traffic signs (TS), vegetation, rigid culvert headwalls or noise barrier walls, supports in the road area, electric cable ducts, street lighting, etc.);
- restraint systems (e. g. missing guard-rails, type / working width of guard-rails inadequate, insufficient passage between the guard-rails, short run-in length, short guard-rails in front of supports, TS, fixed obstructions, SOS boxes, trees, bridge structures, etc.);
- junctions (e. g. missing TS / transport facilities, worn down road markings on or defective design of TS / transport facilities, visibility and perceptibility, condition / traffic control, etc.);
- link (section) between junctions (e. g. incorrect / missing / poor-quality TS, transport facilities, missing / worn down / poor TS, insufficient visibility for stopping / overtaking, condition, traffic control, routing, etc.);
- exit / separate exit / parking (e. g. missing / poorly design TS or transport facilities, missing or worn down road markings, incorrectly designated parking space, visibility and perceptibility, etc.);
- level crossing (e. g. missing TS / transport facilities, defective road marking, visibility and perceptibility, condition, etc.);
- bus stops (e. g. missing TS / transport facilities, missing / worn down road markings, unsuitable arrangement of stops and types of stops, poor conditions for pedestrians, etc.);
- pedestrian crossings (e. g. condition and position of TS / transport facilities, missing / worn down road markings, visibility and perceptibility, condition with regard to length of crossing, missing elements for disabled persons, defective or incorrectly executed lighting, etc.);
- pedestrian access (e. g. missing pedestrian crossings, missing pavements, discontinuous paths, flawed design of pedestrian crossings, etc.);
- technical condition of the road (e. g. roadside, damage to the road, etc.);
- roadways (e. g. deep / steep ditches, steep sloping roadways, etc.);
- transition from rural road to urban road (e. g. missing or flawed traffic control, etc.);
- measures for improving the flow of traffic (e. g. increase speed limit, improve possibilities for overtaking, etc.);
- billboards (e. g. fixed obstruction, disruptive, etc.).

The basic categories given above contain roughly 220 subcategories that define the specific type and nature of the localized problem.

3. Statistical analysis – frequency and seriousness of problems on monitored roads

The safety inspection carried out on the monitored road network identified in total 22,927 road safety problems, of which nearly 37% were classified with high risk. Almost a quarter of the problems, by contrast, came under the low-risk category. A general overview of the risks identified throughout the TEN-T network and the selected 1st class roads that will replace the planned TEN-T is shown in Table 2. As expected, the basic category of "fixed obstruction" occurred the majority in the negative assessment. The second basic category that appeared in the evaluation more than once is "Junctions". This problem has more specifically to do with missing road markings, worn down road markings

Table 2 Frequency of problems and risks associated with each basic problem group.

Category of problem	Number of problems	Risk High	Risk Medium	Risk Low
Fixed obstruction	7,161	4,116	2,602	443
Billboards	3,191	180	591	2,420
Restraint systems	3,031	1,691	1,009	331
Junctions	2,155	263	1,373	519
Pedestrian crossings	1,724	828	803	93
Bus stops	1,523	830	435	258
Exit / separate exit / parking	1,477	27	702	748
Link (section) between junctions	1,329	87	843	699
Pedestrian access	765	315	398	52
Transition from rural road to urban road	203	0	199	4
Roadways	192	124	57	11
Technical condition of the road	111	3	79	29
Measures for improving the flow of traffic	44	0	2	42
Level crossings	21	6	13	2
Total	22,927	8,470	8,806	5,651

and insufficient traffic control. The highest number of problems is caused by the type of billboards that are not considered as permanent barriers, but do have a disruptive effect on road users. Billboards presenting permanent barriers lie just outside the top ten most frequent problems. This happens, because they can be further subdivided into "billboards on a malleable frame" and "billboards on a non-malleable frame". These two problems were found 780 times in total.

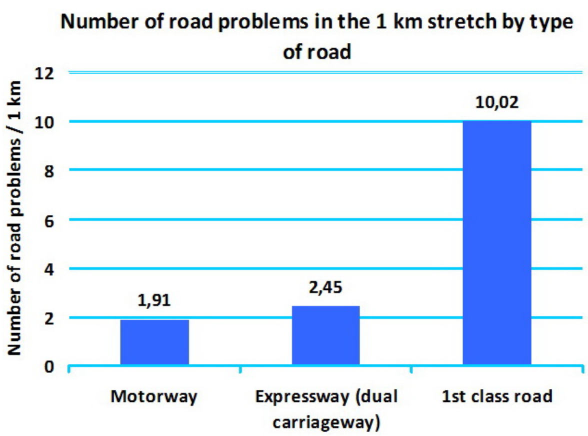

Fig. 4 Number of road problems in the 1 km stretch by type of road.

As a result of the safety inspection, a total of 2,984 problems were found on motorways and 2,111 problems were found on dual carriageways. The remaining 17,832 problems were identified on other 1st class roads. Table 3 shows the above-mentioned frequency of problems and their relative severity (see Table 3). If the frequency of identified problems is applied to the length of the monitored roads, this produces the frequency of problems per kilometre on the individual sections of the road. This comparison can be seen in Figure 4. This figure clearly shows the original hypothesis that the fewest problems occur on direction-specific roads – these problems can be found mostly on motorways and dual carriageways. Problems on 1st class roads, by contrast, occur up to four or five times more than problems on dual carriageways and / or motorways. The first inspections were carried out in 2010 on roads in the TEN-T network only (in accordance with legal regulations) and the majority of problems have already been resolved.

4. Systematic measures

4.1 Rigid culvert headwalls

Figure 2 shows that the fourth most common problem (occurring 755 times) is culvert headwall located underneath an exit or in a separate exit. The group of authors has drawn attention to this problem. Using the knowledge and experience gained from previous research [4], systematic solutions to this problem are available. Examination and evaluation of individual exits shows that some exits no longer fit for its purpose and they have been neither maintained or repaired (structural defects were found in 35% of all exits, e. g. portals are still damaged several years after an accident). When regenerating roads, the non-functioning and non-authorised exits ought to be removed. Example of water drains can be found in Figure 5.

Fig. 5 Rigid culvert headwall (1st class road I/52, km 34 - 35).

From the point of view of construction work, the embankment crown retainers should also be optimized. This is one of the ways in which the biomechanical injuries of passengers can be minimized. This likelihood, which is closely associated with a front-on impact (the headwall), can be minimized by changing the gradient of the culvert headwall. This innovative solution has been implemented even though experts have no valid studies on the effect of these sloping culvert headwalls on the way in which a vehicle moves during and after an accident. This is an empirically established potential solution for improving safety. It would be advisable to undertake a study to verify the positive contribution this change brings. Any potential research should not focus just on traffic accidents

Table 3 The total number of problems on reference roads.

Category of problem	Number of problems	Risk		
		High	Medium	Low
Motorways	2,984	864	939	1181
Expressways (dual carriageways)	2,111	865	605	641
1st class roads	17,832	6741	7262	3829

analyses where embankment crown retainers are already in place – it should also aim to find out the optimum materials for and optimum gradient of the portal.

The second new solution is integrated shock absorbers. The idea would be to have separate exits that already contain individual deformation blocks. The deformation blocks are able to withstand load transmission from vehicles (in a vertical direction) and are designed to deform in the event of side-on impact. Last but not least, it goes without saying that other more – or less – conventional solutions can also be investigated, such as preceding the shock absorbers (to absorb the mechanical energy of a crashing vehicle) or restraint systems (concrete or steel guard-rails).

4.2 Bus stops on rural roads

Just like permanent embankment crown retainers, bus stops on rural roads (i. e. not in an enclosed built-up area) present another road safety problem that cannot be solved conceptually even though it causes overarching social damage in the localities every year. A total of 367 problems with suggested system solutions were found. One of the aims in this case was to convince experts to resolve this problem by using complex solutions.

Low-floor buses are used as standard (not just in cities). This improves (in conjunction with correct and modern bus stops) access to public transport for physically handicapped people (barrier-free access), which has obviously a positive effect on the comfort of travelers.

Four basic problems were found at bus stops:

- missing traffic signs;
- missing / worn down road markings;
- unsuitable arrangement of stops and types of stops;
- poor conditions for pedestrians, i. e. poor access to the bus stop.

The last two subcategories are essentially the most risky. The following figures show the standard bus stop designed on rural roads in the primary road network of the Czech Republic. Figure 6 shows example of bus stop.

Fig. 6 Bus stop (1st class road I/16, km 189 – 188).

4.3 Results of systematic measures

The safety inspection reveals the main development issues among bus stops on rural roads. The authors therefore suggest the following:

- develop bus stops that encourage people to use public transport, improve comfort and increase road safety;
- avoid upgrading bus stops on the traffic lane and use this solution as a special option in justifiable cases only;
- carry out a detailed assessment of the location of bus stops on rural roads from the point of view of routing; compare this with the routes for road users not driving motor vehicles who could be injured.

5. Summary

On the roughly 2,100 km of roads that were monitored in the Czech Republic, a total of 22,927 road safety problems were identified. Almost 37% of these problems carry a high risk. The results were sorted out into 14 basic groups and the "fixed obstruction" group occurred the most. The most frequent problem were billboards. These do not present a barrier as such, but they do disturb road users driving motor vehicles. Second and third place were taken by various different types of vegetation (bushes, individual trees, etc.).

When the frequency of problems was applied to the length of the individual road types (motorways, expressways, 1st class roads), it was discovered that most frequent problems occur on 1st class roads (10 problems per kilometre in one direction). Problems on 1st class roads occur up to four or five times more than problems on dual carriageways and / or motorways.

In order to effectively and systematically resolve these problems, a team of safety inspectors at the Czech Technical University in Prague developed a new web application called CEBASS. This application was used to analyse the data from the inspection. It was then given to road operators (ŘSD ČR) to enable them to exercise effective problem resolution management.

In their assessment report about the safety inspection, authors focused mainly on the unresolved issues affecting roads in the Czech Republic, particularly on permanent water drains in exits and on the problems associated with bus stops on rural roads. Potential solutions based primarily on the results obtained from theoretical research and on empirically acquired knowledge were put forward. Future research projects could potentially focus on this area.

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