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Working Party on Road Traffic Safety

Group of Experts on Improving Safety at Level Crossings

Sixth session
Geneva, 5-6 November 2015
Item 2 (e) of the provisional agenda
Programme of Work:
Identification of the key causes and possible solutions related to human factors contributing to unsafe conditions at level crossings

This document, submitted by Austria, German Aerospace Center and Cognito Ltd summarizes the work undertaken by the human factors subgroup of the Group of Experts.

This document summarizes the following actions undertaken by the human factors subgroup of the Group of Experts:

- an analysis of the questionnaire on human factors at level crossings answered by participating countries of the UN ECE Level Crossing Expert Group;
- the development of a unique tool for level crossings ('toolbox') by using a cognitive, psychological model as a theoretical framework;
- the initial version of the toolbox that has been developed to date
- references to gaps in the research on human factors
- the summary of the findings of the subgroup to date
- Recommendations

I. Background

It is a common knowledge – proven by numerous studies and statistics from all over the world – that accidents at level crossings are primarily due to faulty or maladaptive behavioural patterns of road users, both motorists and pedestrians. Nevertheless level crossing accidents are largely perceived as a rail problem by the public and media which indicate also in these areas an incorrect perception of the situation.

In 2011 the Inland Transport Committee recommended establishing a “Group of Experts of limited duration to work on enhancing safety at level crossings. […] The Expert Group, in general, will aim at bringing together safety specialists from the road and rail sectors so as to better understand the issues at this intermodal interface.” (ECE-TRANS-WP.1-2011-6-Rev.1.pdf)
The Terms of Reference of the Group of Experts on Safety at Level Crossings states the overall aim of work is to “describe, assess and better understand the safety issues at a road/rail interface as well as to develop a multidisciplinary strategic plan aimed at reducing the risk of death and/or injury at level crossings.”
In its first session the Group of Experts decided on the programme of work. One subgroup was dedicated to “The identification of the key causes and possible solutions related to human factors contributing to unsafe conditions at level crossings” (ECE-TRANS-WP1-GE1-2e.pdf).
Participants of the subgroup are Mr Günter DINHOBL, Austrian Federal Railways-Infrastructure Company, Austria, Mr Jan GRIPPENKOVEN, German Aerospace Center (DLR), Gemany, and Dr.rer.nat. Michael CALE, Cognito Ltd., Israel.

II. Findings

a. Analysis of the questionnaire on human factors at LC-accidents

In 2014, the subgroup on ‘human factors’ created a questionnaire on the topic of human factors in level crossing accidents, which was handed out to 24 individuals out of 22 participating UNECE countries. A broad international overview about key problems related to human factors at level crossings could be obtained.
The results of the questionnaire clearly points to the direction that human factors are a major issue in level crossing safety in all of the participating countries that has to be addressed seriously. The consensus in the expert group was that important topics in the field of human factors are the underlying factors that lead to misbehaviour of road users, how to record these factors and what can be done, based on the analysis of human factors to achieve enduring changes in road user behaviour in order to get closer to “vision zero”. Especially in the way accidents are reported in most countries, potential for improvement was recognized by the group. It was also noted that existing recording tools as well as solutions to reduce level crossing are usually developed in a kind of 'trial & error‘-fashion and not based on a systematic accidents are usually not or theory driven evaluation. In most cases, their effectiveness is not proven. The countermeasures, tools and solutions to increase level crossing safety most often are developed with a strong technological focus and do rarely consider human factors in an appropriate manner.

The main causes behind level crossing accidents reported by the respondents of the questionnaire were attentional failure and a lack of risk awareness of driver/pedestrians, followed by a lack of care/distraction. Education and legal issues were also named a few times. Two-thirds of the countries which sent replies stated that they had solutions and/or innovative countermeasures to solve these problems; whilst one-third of the countries stated they did not have solutions. Examples for countermeasures that were given quite often were awareness campaigns as well as the removal of level crossings through closure and/or building an over or underpass were often mentioned. Additionally, the long term effect many awareness campaigns have in terms of a behavioural change is not documented. It should be noted that the awareness campaigns referred to were often general awareness raising campaigns that have a wider scope and do not exclusively address level crossing issues.

Besides questions about human factors approaches to level crossings, UNECE members were also asked to provide the human factors subgroup with documented study results or research papers around the topic. It turned out that most member countries either no research in the field of human factors at level crossing exists, or that the justified experts were not aware of the existing research. More than three-quarters of the replies stated that there is no research on this topic in their countries.

Regarding educational programmes that focus on the awareness of the road users concerning level crossings safety, around two-thirds of the responses declared that no such programmes exist, while most of the positive responses declared that such programmes were included as part of general awareness raising campaigns on safety in rail transport (e.g. behaviour on platforms; not to cross tracks; not to climb on wagons; etc.).

The responses to the question on ‘actions undertaken to improve safety at level crossings on the basis of causative human factors’ revealed the following: one third is dedicated to ‘no actions taken’, one third to ‘included into general awareness campaigns’, and the remaining one third divided up between different measures to enhance visibility and to strengthen (police) enforcement.

<u>Summary:</u>

1. there is high consensus relating the importance of human factors as key reason for level crossing accidents
2. there is no pool of common knowledge available which would require specific intervention
3. the measures which have been taken to enhance safety at Level Crossings are neither theory driven nor evidence based – and finally not evaluated
4. in order to offer a scientifically based alternative the human factors subgroup of the expert group decided to develop ‘ASAP’ (Analytic System for Accident Prevention’)

b. Previous research on human factors at level crossings – an excerpt

Despite signs and signals announcing level crossings, road users often do not perceive, recognize or respect the train’s right of way respectively the requirement of a level crossing. Accidents at level crossings remain an ongoing international problem. Most level crossing accidents involve a road user who collides with a train. In most countries, more than 90% of all collisions at level crossings originate from inappropriate behaviour of a road user. Accidents are most often blamed on human errors like ‘inattentive driving’ on the part of the road user or a ‘lack of knowledge’ about level crossing regulations. Since this description of the human error is rather unspecific and often not verified, some research has been done in the past to analyse human information processing at level crossings more detailed. Research on this subject has for example been conducted by Rudin-Brown, French-St. George and Stuart (2014), who describe human factors that can lead to unsafe situations at rural level crossings (detection of a train / understanding the need to stop / sightlines / train conspicuity / speed illusion due to the unchanged retinal image of an approaching train / train horn audibility / “looked-but-failed-to-see error” / learned misbehavior / wrong expectations / distraction / driver impairment information processing). In several studies, aspects of driving behavior and attention during the approach towards level crossings have been investigated in different settings and countries (Åberg, 1988, Rudin-Brown, Lenné, Wigglesworth, 1978). Wigglesworth (1978) observed driver’s behavior at level crossings. He focused on head movements that served as an indicator of the searching behavior of the drivers during the approach. his results reveal that a majority of drivers did not search and look for a train. In the case of level crossings with flashing lights, 72% of the drivers paid attention to neither the tracks to the left nor the tracks to the right. At passive level crossings, 40% of the drivers did not show any head movements at all.

In a comparable study, Åberg (1988) observed drivers at 16 different level crossings in Sweden. Of the drivers, 24.8% checked both sides of the level crossing for a train, whereas 59.8% displayed no head movements to either side. 15.4% looked either at the rails to the left or right at the level crossing, but did not search for a train on the other side.

Grippenkoven & Dietsch (2015) conducted a study on driver behaviour and gaze direction of drivers at level crossings. Based on an empirical field study with a high fidelity eye tracking system, it was found that almost all of the drivers in the study visually fixated at least parts of the signs that belong to a (passive) level crossings. Nevertheless, two thirds of the drivers in the study subsequently did not derive and engage in the right actions: Searching for a potentially approaching train in the periphery of the level crossing, slowing down and being ready to break.

Rudin-Brown, Lenné, Edquist, & Navarro (2012) analyzed the driving behavior of 25 participants during their approach towards three different level crossings within a simulator setup. The driving performance and attention of the drivers was analyzed by comparing the number of violations, reviewing speed profiles and evaluating visual scanning patterns. 14 out of 25 participants committed a violation in the case of the passive protection with stop sign. Five violations were recorded in the case of the level crossing with light signals. Seven were recorded for the level crossing with half-barriers. Speed profiles of the approach towards each of the crossings were compared for the share of participants in the study that did not commit a violation. Speed profile results revel that in case of the level crossing with stop signs, drivers slowed down earlier on approach compared to the two other level crossings. Concerning the visual scanning patterns of the participants no significant difference could be found with regard to the time spent looking at the peripheral regions of the visual scene at the three level crossings. These results are in conflict with the data presented by Wigglesworth (1978), who found a significant difference in the number of drivers that direct their attention to peripheral locations at active level crossings (with flashing red lights) compared to passive level crossings. A possible explanation is the small sample size and the different setup (simulation) in the study of Rudin-Brown, Lenné, Edquist, & Navarro (2012).

More research has been conducted on human factors at level crossings, the overview in the previous just represents a selection in order to form an impression of research in the field of information processing.

In addition to the research concerning attentional processes of drivers at level crossings, a lot of possible countermeasures are discussed in the literature, as well as expert groups. Some examples are rumble strips, various lighting systems that highlight sign, coloured streets around level crossings, different marking patterns on the ground that lead to speed illusions or an increased enforcement by speed cameras. Examples for effective measures to change the behaviour of drivers at level crossings were conducted for example by Cale, Gallert, Katz & Sommer (2012) and Grippenkoven, Thomas & Lemmer (2015). Cale et.al. showed the usefulness of visual illusions in slowing drivers down during their approach towards the level crossing in a simulator study. Especially the use of parallel white lines across the road, beginning 100 m in front of the level crossing with a steadily decreasing interspace between the lines, turned out to be very useful in decreasing the speed of drivers.
Grippenkoven et.al. (2015) investigated pulsating LED strobe lights (PeriLight) that were placed in the periphery of a passive level crossing. In an in field driving study, these lights were place 50 metres besides the roads, on the left and right side close to the tracks, when a car approached the lights were automatically activated. The system turned out to be very effective in leading car drivers to direct their attention to the peripheral regions of a level crossing, the area a train could be coming from. It can be assumed that this system increases the likelihood of an early detection of an oncoming train. The effectiveness of Cale et.al.'s as well as Grippenkoven et.al.'s approach is based on simple and cheap concepts, which make use of automatic processes of human perception.
In future research, more effort should be spent on alternative, human centred countermeasures like the ones described, in order to increase safety at level crossings. These countermeasures should especially address the topics visual attention, speeding and risk taking.

<u>Summary:</u>

- Internationally, road traffic participants are responsible for over 90% of all level crossing accidents and should be targeted in countermeasures.
- Existing research shows that key problems in terms of human factors are inattention, a lack of understanding and deliberate misbehaviour.
- Some measures have been developed during the last years, that turned out to be effective in making drivers redirect their attention or slow down in front of a level crossing.
- More effort should be spent in developing cheap, human centred solutions to increase safety at level crossings. Existing research has shown that this approach has the potential to lead to the development of original and effective countermeasures.

III. Analysis

The findings show that in general an appropriate awareness of the opportunities that are offered by human factors approaches to safety at level crossing (accidents) is still missing within most railway companies. In order to help railway companies, regulatory bodies and other institutions who deal with level crossing safety to understand the root causes for accidents at different level crossings, the Group of Experts decided to develop of a unique analytical tool ('toolbox') based on a cognitive, psychological model as a theoretical framework. Only a step-by-step working process makes it possible to identify key causes in required detail and finally possible solutions related to human factors contributing to unsafe conditions at level crossing.

a. Development of a unique tool for analysing human factors at level crossings as part of accident reports

The outcome of (a) indicated the lack of both data and knowledge on **human factor causes at level crossing accidents (HF@LC)**. Accordingly and as a first step a theoretical framework of accidents at level crossings was developed, which based on a five step model of human information processing. Using this model, a significant number of accident reports provided on the website of ERA, as well as some accident reports from Austria, Belgium, Germany, the European data base (recorded by ERA) and Canada were analyzed. The focus of the accident reports is in most cases on the examination of the required functionality of protection devices of the railways and of the correct behaviour of the train driver. In the analysis of the accident reports, the subgroup members noted that their main purpose of these reports is to serve as a legal documentation of the responsibility and guiltiness of the involved parties of level crossing accidents. While factors relating to the railway company responsibilities are investigated in detail, factors relating to human behaviour including errors of other road traffic participants were neither analysed in depth, nor even documented in a way that could enable an expert from the human factors domain to draw conclusions or derive tailored measures to increase the safety in general of or the area around a particular LC. In other words, these kind of accident reports show that the main causes of level crossing accidents are not because of wrong behaviour resp. performance of the railway (technology) system and therefore these reports document in an indirect way the (mis)behaviour of road users.

The human factors subgroup wishes to emphasize the fact that currently available tools were not, are not and will not be able to analyze human factors at level crossing-accidents and to offer information that can be used to develop improved and safer solutions for the future. Therefore, it is essential to ask intelligent questions to analyse human factors at level crossing accidents, because otherwise one cannot expect to receive useful answers why level crossing accidents happen.

Basing itself on a five step model of information processing the human factors subgroup feels confident that an in depth human factors analysis of accidents in general and at level crossings in particular can provide insight and comprehension and thus forms the necessary groundwork to prevent future accidents.

Starting from existing level crossing accident report tools the subgroup decided to start the development of a tool for a human factors at level crossing accident reporting, finally named **'Analytic System for Accident Prevention' (ASAP)**. The main categories of the toolbox are listed in the table below next to examples for analytical questions within the tool.

1	*Attention*	*Is there evidence of cell phone use or SMS? Were there small children in the car? Was there something visually tempting in the surroundings?*
2	*Perception*	*How far ahead can you recognize the LC. Was there fog or overgrowth disturbing? Were the windshields dirty? Were opposing vehicles blinding the driver?*
3	*Cognition*	*Is the driver familiar or used to such level crossings ? Do average drivers comprehend the setting including speed requirements and looking out for indications of danger ?*
4.	*Motivation*	*Was the driver under time or social pressure? What driving norms are standard in the area around the level crossing and social class? Are there signs of depression?*
5.	*Performance*	*When as the driver trained re level crossings. Did he overtake*

	traffic build up on the rails? Did driver try to get in in the last second and overestimate his control of the situation?

The toolbox enables authorities and experts to evaluate level crossings accidents in a more elaborate way that facilitates learning from it.
The human factors subgroup suggests using the level crossings human factors recording toolbox with more than 150 items included which is based on the five function model of human factors.

b. HF@LC-toolbox: structure of 'ASAP'

Remark
Unfortunately no offer of funding to refine and finalize the proposed toolbox has been given up to the date of the formal document.

Description
The scope of the toolbox has been enlarged by separation into two questionnaire-tables: the first one (HFA – Human Factors Analysis) is dedicated solely to the human factors aspects while the second one (LCA – Level Crossing Analysis) is a summary of the most necessary structure of 'conventional' level crossing accident investigation reports. In other words, the first table shall be used when analysing human factors causes at level crossing accidents, while the second table may be used, e.g. when there are no sufficient national level crossing accident investigation reports available.

The questionnaire-table LCA which is very similar to existing tools is structured by the following four sections:

- accident
- LC condition
- local conditions at time of accident
- drivers

The section on 'accident' collects information of the position of the LC, the people involved in the accident on road and rail and their state of health, the types of vehicles (both road and rail).
The section on 'LC condition' gives information on the setting of the LC, like type, road and rail parameters like gradient and/or curves, speed limits at the LC and before the LC.
The section on 'local conditions at time of accident' is dedicated to conditions like e.g. weather, visibility, temperature which were given at the time of the accident.
The section on 'drivers' collects information on the drivers, most important information on the road driver like e.g. age and gender of driver, nationality of road driver licence, licence expiry date.

The questionnaire-table HFA is dedicated to collect in-depth human factors related information on existing level crossings after accidents. Some of the information can be acquired from (1) questions to the participant(s) with – in most cases - yes/no-statements; (2) observations by the reporter; (3) objective information which can be measured like e.g. use of alcohol or drugs, average closing time of technical LC-safety device; (4) Testing (if applicable), e.g. of driver or of traffic behaviour at specific LC responses from psychological questionnaires, scores from testing procedures, virtual reality tools, interviews etc..
The table is structured by five areas which reflect scientific theory mentioned above:

> attention
> perception and perceivability
> cognition
> motivation
> performance

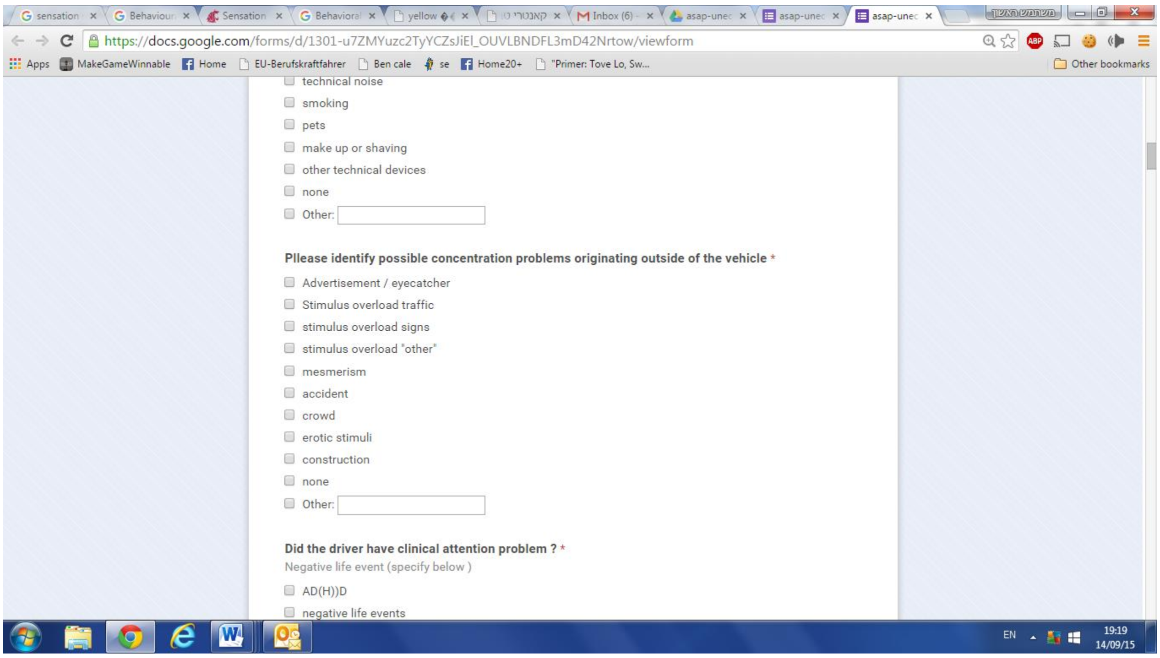
The area ‘attention’ contains a listing of information on potential attention problems like sources of distraction inside and/or outside the vehicle, and also on specific internal attentional problems of the road traffic participant.

The area ‘perception and perceivability’ contains a listing of information on the environment and the surrounding of the LC in terms of general perception conditions. “Did the accident occur because the LC or elements of it were not or could not be perceived in time?”

The area ‘cognition’ contains a listing of information on the environment and the surrounding of the LC in terms of general cognition conditions, including indirect observations like average behaviour at the specific LC, and also cognition aspects of the accident (road) driver. “Did the accident driver have problems interpreting or comprehending the situation or did he fail to choose an adequate reaction in time?”

The area ‘motivation’ contains a listing of information on the (road) driver, like e.g. his/her experience, reason for the ride, behaviour, stress or depression situations. “Were psychological or social factors active which led road user(s) to choose dangerous or unsuitable interpretations or reactions?”

The area ‘performance’ contains a listing of information on roadside issues like average and permitted speed before and at LC, up to information on the (road) vehicle. ”Was the motivated, knowledgeable and attentive driver actually unable to do whatever was required to prevent the accident?”

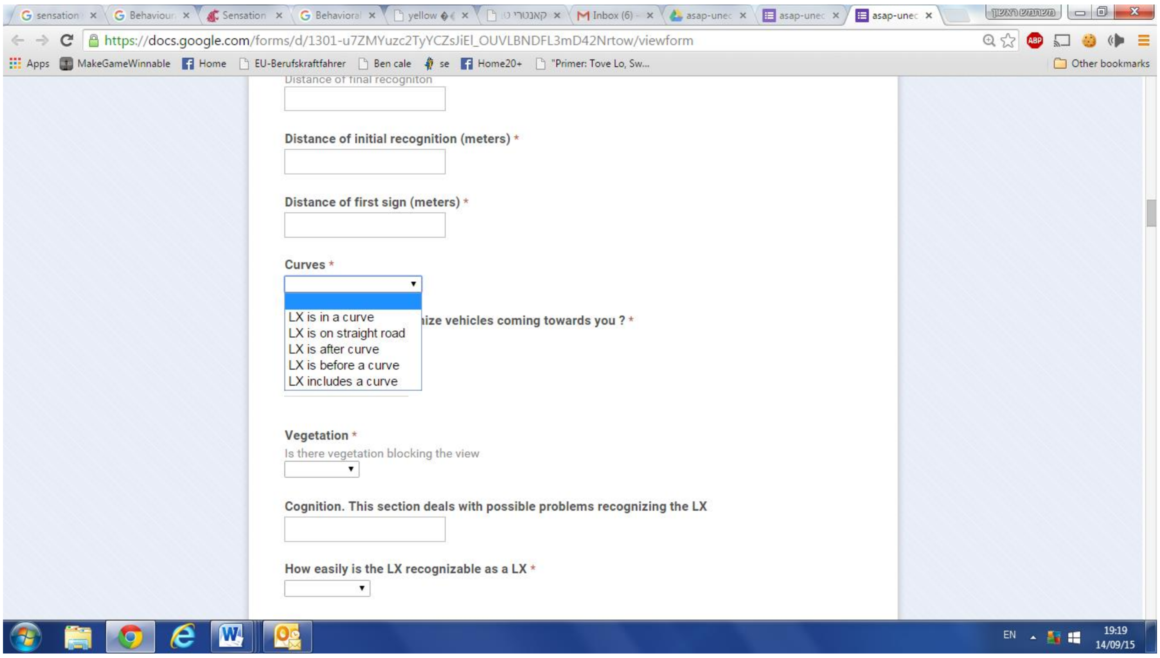


technical noise
smoking
pets
make up or shaving
other technical devices
none
Other:

Pllease identify possible concentration problems originating outside of the vehicle *

Advertisement / eyecatcher
Stimulus overload traffic
stimulus overload signs
stimulus overload "other"
mesmerism
accident
crowd
erotic stimuli
construction
none
Other:

Did the driver have clinical attention problem ? *
Negative life event (specify below)
AD(H))D
negative life events



Screenshots of draft toolbox

~~Results of~~ discussion with AT accident investigation body and ÖBB-internal departments

The two questionnaire-tables of the toolbox ~~were~~ are in discussion ~~discussed~~ with the head of the Austrian Accident Investigation Body (VERSA - Bundesanstalt für Verkehr - Sicherheitsuntersuchungsstelle des Bundes). The Austrian Accident Investigation Body makes level crossing accident reports of approx. 15% of all level crossing accidents in Austria; these are often the accidents with the most hazardous impact. VERSA is also working on a questionnaire on human factors which is in preparation at the moment and will include the draft findings of the human-factors subgroup of UN-ECE Group of Experts on Improving Safety at Level Crossings.

Outcome of discussion to be submitted later, after meeting (delay since End of September because of workload, holidays and illness…)

Use of the toolbox

The toolbox contains two questionnaire-tables

(a) How to use the toolbox: on one hand as questionnaire-tables for a standardized level crossing accident analysis of human-factors; on the other hand – when numerous of such human-factors level crossing accident analysis is available – to investigate characteristic accident-structures which are depending e.g. on level crossing type.

(b) Who shall use the toolbox: every institution who makes level crossing accident analysis, carried out by extensive trained human factors experts

Open points

Before the toolbox can be used as standardized level crossing accident analysis of human-factors the following steps have to be done:

(a) first testing: Real-time testing and analysis of toolbox; outcome: experience and usability of toolbox, including recommendations for detail improvement

(b) first loop: to improve toolbox in detail by critical analysis of the results of first testing; outcome: (a) final toolbox (structure), and (b) first set of analysis (for multi-analysis)
(c) application: recommendation for (European-wide) use when making accident analysis
(d) setup: single data/information collecting point and setup of (virtual) center of excellence for multi-analysis on HF@LC

c. actual gaps in the research on HF@LC

While a lot of research has been conducted on road users perception and some countermeasures have been developed, a relatively black spot in research in the field of level crossing safety is the development and especially the **evaluation of a systematic template for human factors issues in level crossing accident investigation**. Most accident reports focus on rather technical details, e.g. if the train driver tried to brake, or give a location plan of the area around the level crossing. Items in investigation templates concerning underlying causes on the side of the road user are scarce, therefore oversimplifications of causalities / human error can be found often.
A systematic accident investigation toolbox like the one named “ASAP” (‘Analytic System for Accident Prevention’), proposed by the subgroup is needed in order to get a deeper understanding of the real accident causes. Only if a greater degree of detail concerning human factors that lead to accidents can be reached, tailored countermeasures for different kinds of level crossings can be developed. Each new system or idea concerning designed to increase safety should be evaluated in a prototypical version, before a larger scale role out can take place.

In-field validation of the effectiveness of countermeasures is a second gap in human factors research around level crossings. Accident numbers are often used to judge the effectiveness of a certain measure. Nevertheless, since accident numbers are usually not high for a single level crossing, they are no appropriate metric in order to judge the effectiveness of a given concept. A long-term surveillance (e.g. video) of the natural driving behavior of road users (e.g. speeding behavior; amount of violations that do not lead to an accident) at a level crossing before and after the implementation of a countermeasure would be a more suitable approach. The mobile multisensory system called “research level crossing” by the German Aerospace Center (DLR) is an example of a system designed for this purpose. It is a long-term surveillance tool that is capable of automatically categorizing human behavior and atypical trajectories at all kinds of level crossings, in order to evaluate the effect of changes in the infrastructure of the level crossing.

Besides the validation of technical countermeasures, the **validation of the effectiveness of awareness campaigns** is often not existent or unspecific. Often the reduction in deaths or accidents is ascribed to certain campaigns, but this practice is questionable, since it is often biased by the effect of the continuous reduction of the overall number of level crossings. Better methods to evaluate the effectiveness of awareness campaigns should be developed.

IV. Recommendations

The members of the subgroup recommend:

Recalling that 90-98% of accidents at level crossings are due to road users like motorists and pedestrians incorrectly using level crossings

Recognizing that level crossing accidents are largely perceived as a rail problem by the public and media which indicate an incorrect perception of the situation

Noting that a focus on human factors at level crossings to improve a correct use and behaviour will have the highest safety leverage

Noting that the findings show that (1) failure and a lack of attention of drivers/pedestrians and (2) lack of risk awareness and understanding are recognised as key human factors for level crossing accidents

Noting that the findings show also a lack of systematic, proven and scientific proven knowledge on in-depth-analysis of key causes of level crossing accidents

Noting that at the moment level crossing accident reports and –data/information collection exclude human factors issues

Noting that the most efficient task to identify possible solutions to improve safety at Level Crossings are with the help of in-depth human-factors-analysis

Encourages not to build new level crossings

Encourages to merge several nearby level crossings to reduce the number of level crossings

Encourages to identify possible solutions for the improvement of safety at Level Crossings are with the help of in-depth human-factors-analysis, both for design and for a well-founded evaluation of the effectiveness

Encourages to elaborate a standardised toolbox for human-factors-analysis for level crossing (use & accident) analysis (development & validation)

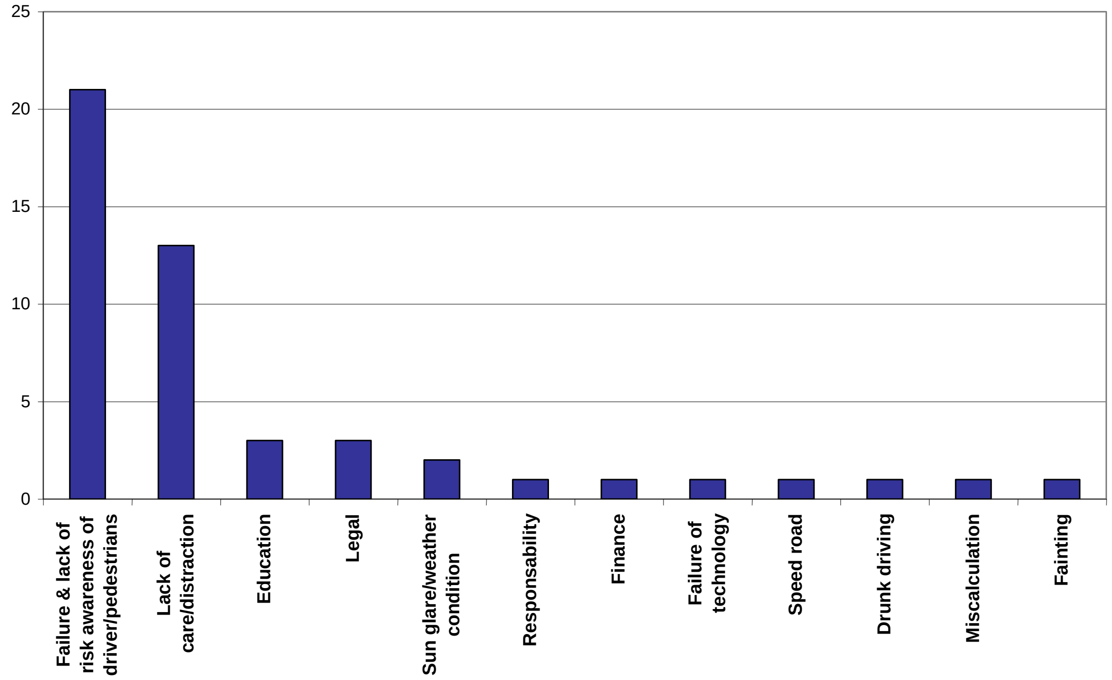
Encourages to strengthen research on human-factors-analysis at level crossing, in particular for level crossing accident analysis

Encourages to focus on a human centred perspective in the development of future countermeasures, in addition to the technological solutions

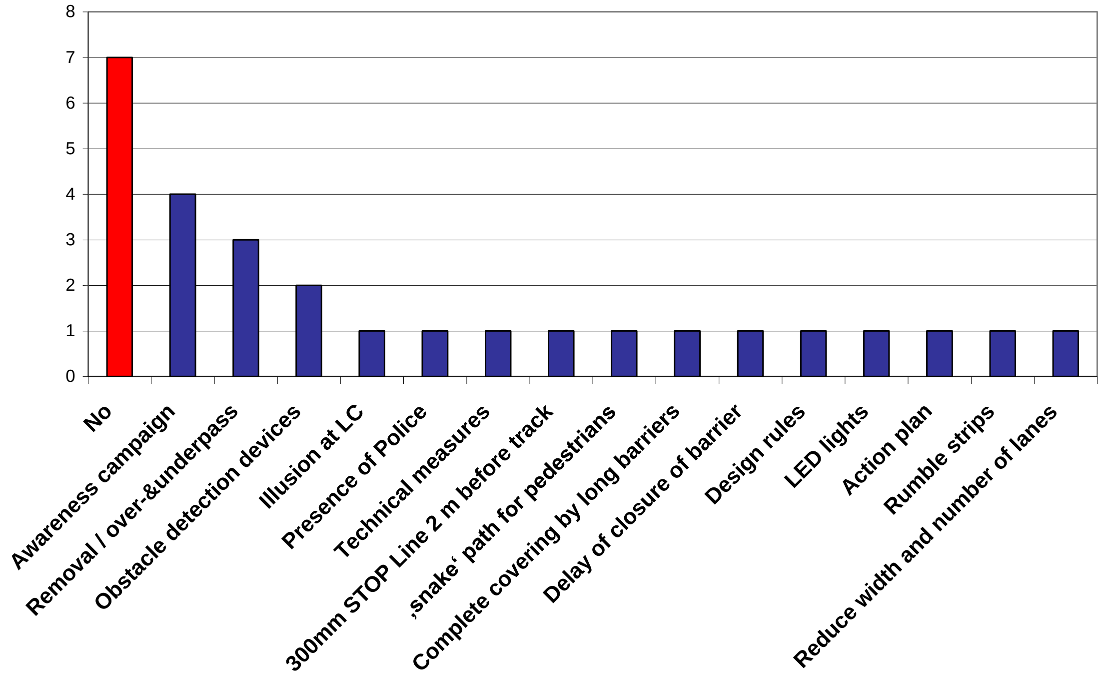
V. Annex

A: Questionnaire responses

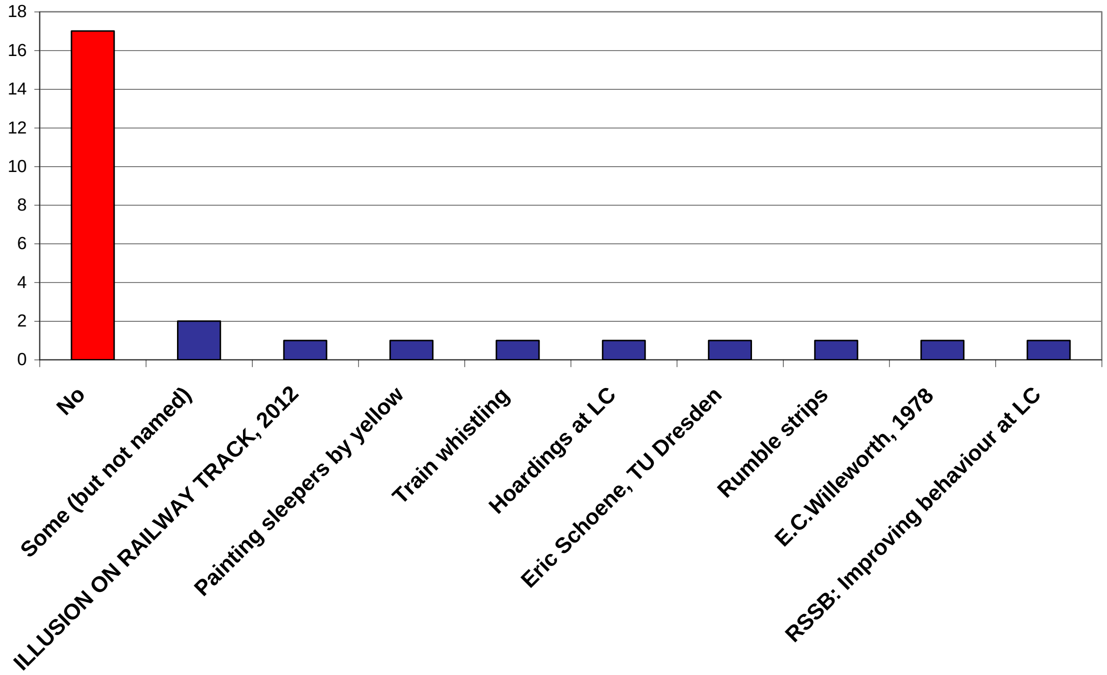
Q1:
What are the three main causes behind level crossing accidents in your country?



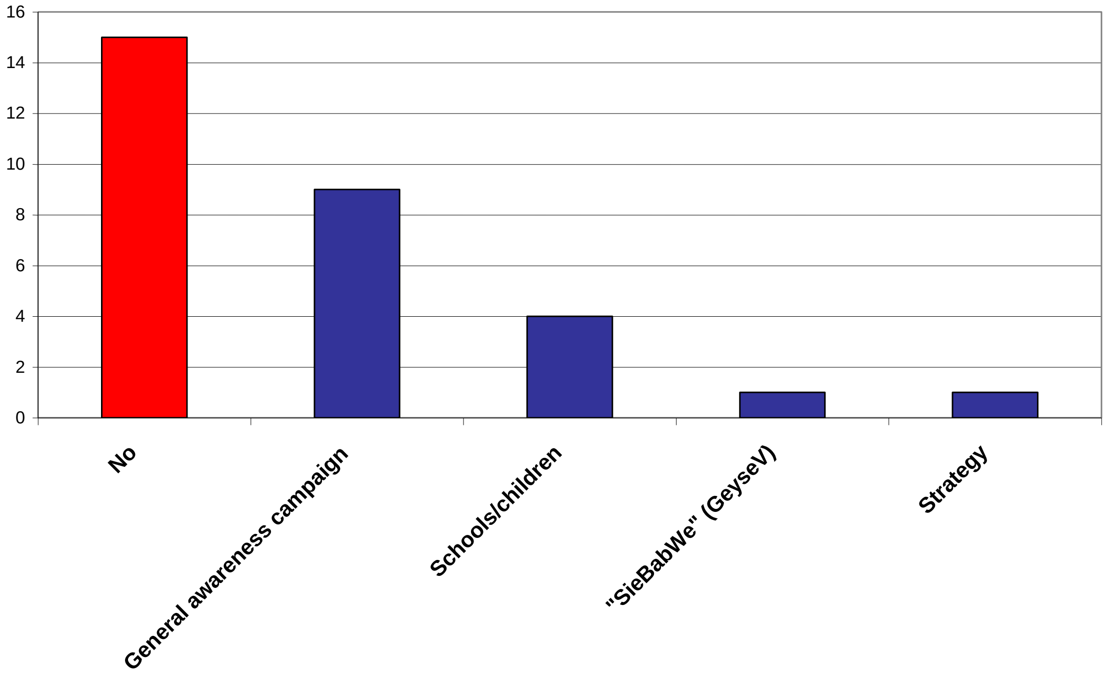
Q2:
Does your country have any solutions and/or creative and innovative countermeasures to solve these problems?



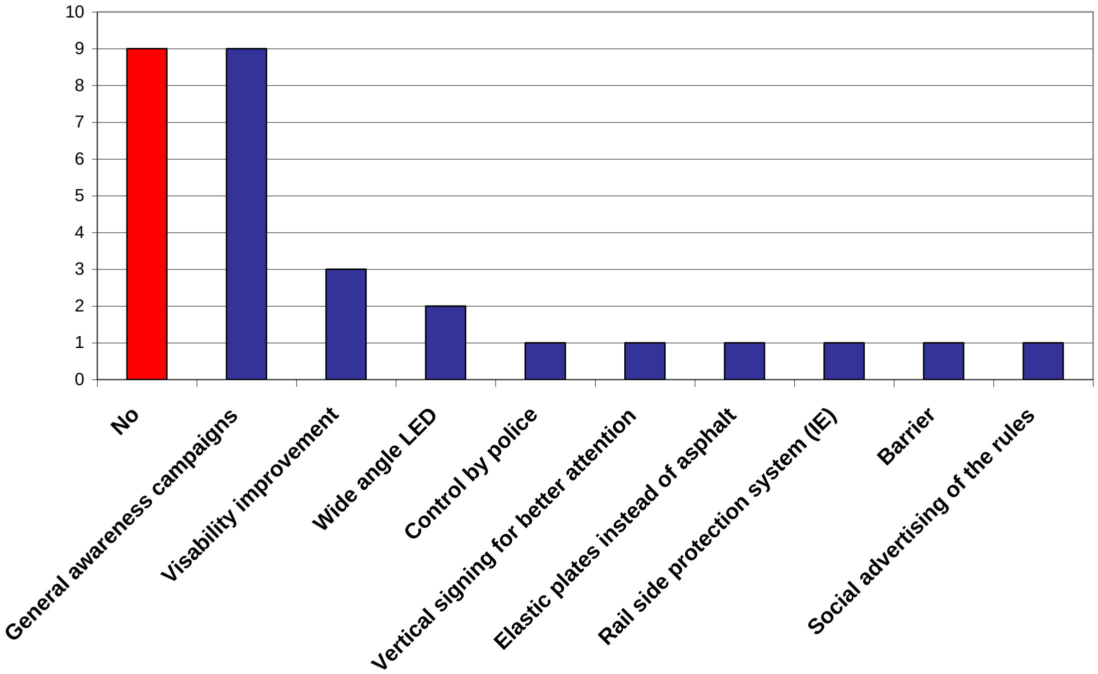
Q3:
Do you have any research studies or papers on human factors relating to the behaviour of road users around level crossings which you could share?



Q4:
Are there any educational programmes in your country that focus on the awareness of the road users concerning level crossings safety?



Q5:
Referring to the list of human factors at the start of this section E, has your country taken any action to improve safety at level crossings on the basis of these causative factors?



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