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CONCEPT OF LEVEL CROSSING SAFETY PERFORMANCE MONITORING

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Abstract: *Project SELCAT aims to collect, structure, cluster, analyse and disseminate existing world-wide research results and to stimulate new knowledge exchange in the area of level crossing safety. One its main aim is appraisal of the real risk of the level crossing operation on the international level. The paper presents a concept of level crossing safety performance monitoring based on an advanced* knowledge management system. First analysis results are shown.

Key words: *level crossing, risk analysis, accident statistics, safety performance*

1. INTRODUCTION

The Coordination Action "SELCAT" (Safer European Level Crossing Appraisal and Technology), is responding to the call of 6th Framework Programme of the European Commission in the area of "Sustainable Surface Transport Coordination Actions" towards the objective "Increasing road, rail and waterborne safety and avoiding traffic congestion". It aims actively to contribute to the reduction of level crossing accidents by the::

- collection, analysis and dissemination of existing research results and the stimulation of new knowledge exchange in the area of level crossing safety,
- creation of circumstances whereby European partners, in the rail and road sectors, can make a significant contribution to the reduction of accidents, injuries and fatalities at level crossings,
- understanding and codifying of existing and planned research,
- comparison and harmonisation of data sources,
- exploration of new technologies and harnessing appraisal techniques to optimise these.

The SELCAT consortium led by Institute for Traffic Safety and Automation Engineering of Technical University of Braunschweig, Germany, integrates 25 partners from 14 countries from Europe, Asia and Africa. Among them are universities, research institutes, road and railway organisations as well as railway infrastructure managers. The SELCAT consortium is closely collaborating with European Railway Agency.
The activities of SELCAT lead directly to the improvement and expansion of inter-modal collaboration between the road and rail sectors. The information collection, exchange and comparison is be provided by creation of a "Level Crossing Web portal". It should result in an effective and accessible Level Crossing Knowledge Management System (KMS) allowing also broad dissemination of safety and level crossing related research activities investigated by the SELCAT Project.

The paper presents preliminary results of the Work package 1 dealing with the Level Crossing Appraisal. One of the main aims of this work package is to estimate the global risk of different types of level crossings. As input for this task the accident statistics of countries of involved partners were considered.

2. MOTIVATION

Every year, more than 330 people are killed in more than 1200 accidents at road-rail level crossings in the European Union. Together with tunnels and specific road black spots, level crossings have been identified as being a particular weak point in road infrastructure, seriously affecting road safety [1]. In the case of railway transport level crossings can represent as much as 50% of all fatalities caused by railway operations. Up to now, the only effective solution appears to involve upgrading level crossing safety systems [2] even though in more then 90% of cases the primary accident cause is inadequate or improper human behaviour rather than any technical, rail-based issue.

High safety requirements for level crossing safety systems required by European railway sector standards create a high cost base which hinders the technological upgrade of existing systems. Railway standards [3] already include a risk based definition of safety, according to which only the unacceptable risk must be eliminated by the technical system. Nevertheless, the lack of approved safety methodology which would allow the industry to quantify the risk to be reduced still leads to the prescription of the highest safety integrity levels for technical solutions in most European countries

The Safety Directive 2004/49 EC [4] as well as the latest CENELEC standards for railway application expects application of risk based approaches when eliminating the negative statistics of occurred accidents. Thus the evaluation of operational risks plays the crucial role in any kind of decision making regarding the change of operational rules, legislation or technical systems.

From these reasons in the context of the SELCAT project a structure of safety performance database is to be designed and to be filled with data from available databases, especially from involved infrastructure managers. Attention should be paid to integration of detailed information on level crossing accidents (collisions with cars, cyclists, pedestrians etc.), their causes (safety system, human factors, etc.) taking into account the safety system (none, lights, barrier, etc.) and operational condition of the rail (single/double line, main/local line, average traffic flow, etc) and road traffic (infrastructure conditions, traffic flow, sight conditions, pedestrians flow, etc).

The aim is to find the level crossing types which posses the highest operational risk. This should be allowed to be carried out in general as well as taking into consideration the country specific operation condition (human behaviour, legislation, degree of technical development).

3. APPROACH

A detailed evaluation of the level crossing operational risk can be based only on the national statistics coming form different partners of the SELCAT project. The application of existing European statistics (e.g. EUROSTAT) has been shown as unusable as they do not posses the required level of information details. The same problem occurs when analysing the most of official national statistics sources.

Any kind of statistics collection and comparison requires harmonisation of their sources. Therefore challenging aim of SELCAT became to design universal platform allowing integration of statistics from different partners related to different national specific level crossing types. The chosen approach took the functionality as the basic structuring element.

Structuring of the level crossing functionality is based on a generic approach [5] [6]. A Level crossing (LC) is generally seen as crossing of railway and road traffic flows (basic dynamic or functional LC aspects) which safety related physical interaction must be prohibited by the operation functions of the level crossing safety system (static or physical LC aspects) [7]. In order to describe the static LC aspects the generic approach identifies four basic operational functions (to detect, to inform, to warn and to protect) on both traffic sides (see figure 3). The basic functions are further refined e.g. the function “to warn” is further split according to its general way of realisation (audible, visual, physical).

A step to technological concretisation represents a further refinement of the basic structure of static operation aspects. The final refinement level is given by a particular technological solution given by the level crossing type and the way of operation (automatic, manual).

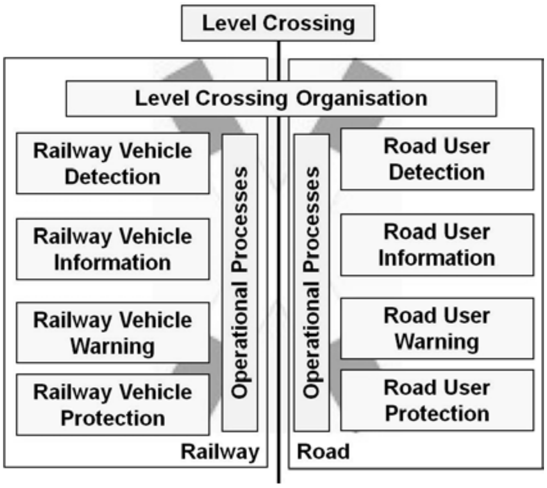

Figure 1: Functional decomposition of a level crossing system

The dynamical aspects of the level crossing are covered by the definition of operation condition of the traffic flows. Here can be integrated also temporal aspects of the safety procedure of a level crossing.

Beside the static and dynamic aspects big part of the domain knowledge concerns organisational aspects which also include construction laws and standards.

4. IMPLEMENTATION

4.1 LEVEL CROSSING TYPES

The implemented interface of the SELCAT KMS allows to the project partners specifying all national level crossing types using predefined functional structure. On this way is guaranteed the common specification language, necessary for the future risk analysis.

Figure 5 shows an example of a defined and classified LC type.

On this way has been up to now defined 68 national specific level crossing types. Apart of identification of level crossing functions each type definition contains also data about approximate acquisition and operation cost for the purposes of future cost benefit analysis. Included are also relevant data of national legislative e.g. maximal and minimal allowed traffic flows, speeds on railway and road side. Finally the existing population of particular level crossing type is included allowing normalization of future analysis results. Beside the level crossing type population also some further general information for normalization of the particular country are collected (length of railway network, train kilometres, human population per square kilometre, total number of road or railway accidents, etc.)

The KMS provides interactive possibility to search for level crossing types according to given functionality or technical implantation feature. The different searching parameters can be connected by AND or OR gate. Beside interactive search it is possible to define general level crossing types (basic types) on more abstract level of functionality definition. In the case of the abstract level crossing type the user to indicates the relevance of functions for his analysis (existing, not existing and irrelevant functions). Such abstract (meta) level crossing type can be used for search of groups of related particular types from different countries. As an example of such abstract level crossing types the categories of European Railway Agency have been defined.

4.2 ACCIDENT STATISTICS

The KMS allows to each defined Level crossing type to associate the related accident statistics. In particular it is possible to collected statistics about:

the accident severity (fatalities, serious and light injuries),

the kind of the accident (car, bus, bicycle, pedestrian, etc) and

the accident causes (external, internal, technical, human).

The figure 6 shows an example of level crossing statistics referring to two different level crossing types for reference years 2001 - 2005.

Accident statistics of each reference year can be refined specifying the kind of transport and accident causes. The figure 4 shows example of such a refinement of accident statistics for Automatic Half Barrier (AHB) level crossing from the year 2004.

5. ANALYSIS

The first analysis of operational level crossing risk has been carried out on the base of the abstract level crossing types defined by European Railway Agency for the purpose of definition of Common Safety Indicators [8]. The figure 5 shows schematically this categorisation. The principal differentiation defines an active level crossing as a level crossing where the crossing users are protected from or warned of, the approaching train by the activation of devices, when it is unsafe for the user to traverse the crossing. In the case of Automatic active level crossings (A.1) are these devices activated by the approaching train. The devices of Manual active level crossings (A.2) are activated by humans, whereby there is no there is not interlocked railway signal showing to the train a running aspect only where protection and/or warning of level crossing are activated. In the case of passive level crossings (B) there isn't any form of warning system and/or protection activated when it is unsafe for the user to traverse the crossing.

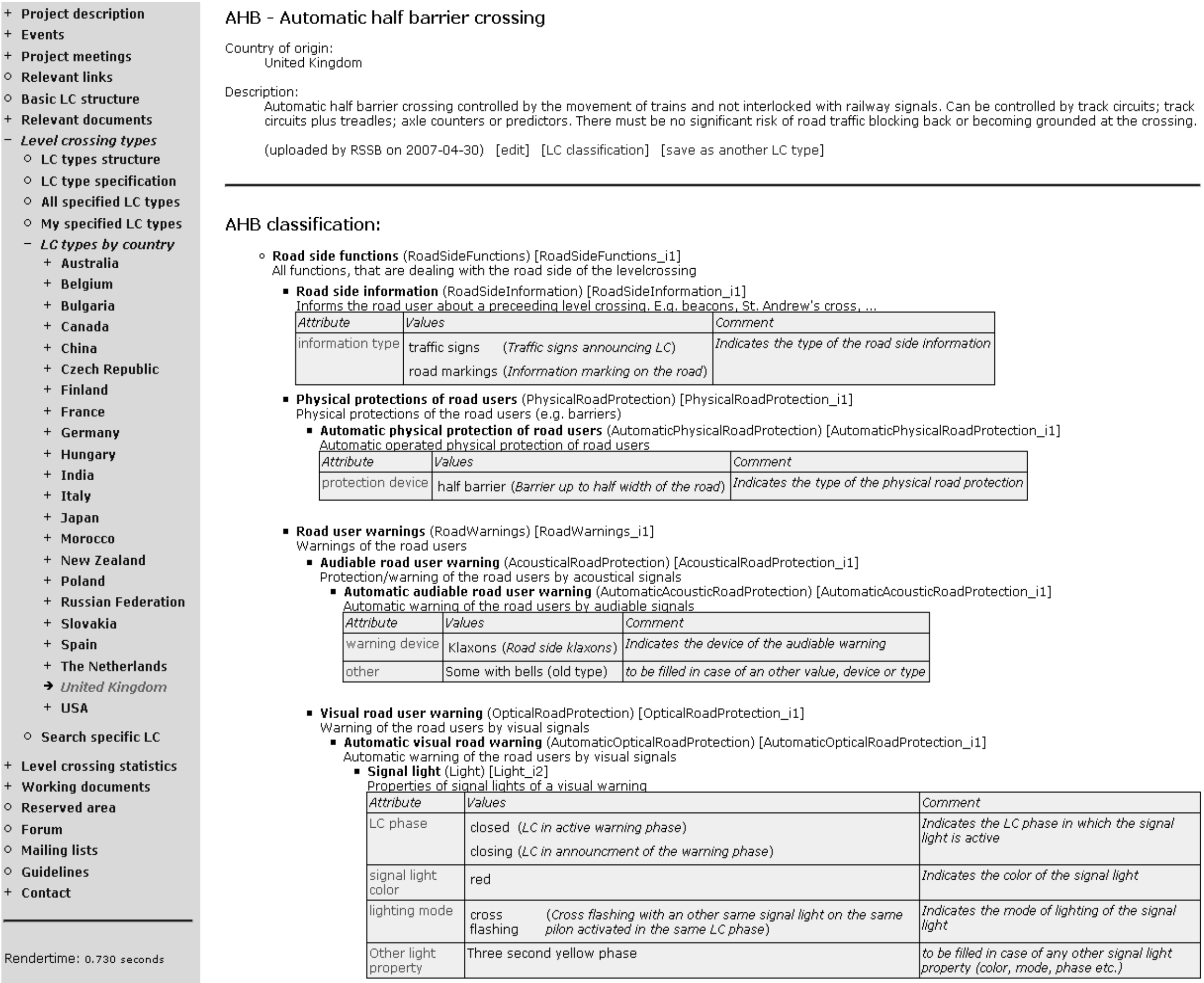

Figure 2: Example of a LC type in the SELCAT KMS (source: Railway Safety & Standard Board (RSSB), UK)

AHB [edit]

	accidents	fatalities	serious injuries	light injuries	add/change
2001	11	4	4	1	[change means of transport] [change accident causes]
2002	9	1		6	[change means of transport] [change accident causes]
2003	8	3	1	5	[change means of transport] [change accident causes]
2004	5	9	10	28	[change means of transport] [change accident causes]
2005	7	5		3	[change means of transport] [change accident causes]
	[add year for means of transport]		[add year for accident causes]		

AOCL [edit]

	accidents	fatalities	serious injuries	light injuries	add/change
2001	5		2	15	[change means of transport] [change accident causes]
2002	7		4	3	[change means of transport] [change accident causes]
2003	11		2	4	[change means of transport] [change accident causes]
2004	8		1	5	[change means of transport] [change accident causes]
2005	3				[change means of transport] [change accident causes]
	[add year for means of transport]		[add year for accident causes]		

Figure 3: Example of level crossing accident statistics entered in the SELCAT KMS (source: RSSB, UK)

LC types:	AHB			
Year:	2004			
Means of transport				
	accidents	**fatalities**	**serious injuries**	**light injuries**
all:	5	9	10	28
cars:	3	8	10	27
buses:				
heavy vehicles:				
cyclists:	1			1
motorcyclists:				
pedestrians:	1	1		
agriculture vehicles:				
animals:				
Accident causes				
	accidents	**fatalities**	**serious injuries**	**light injuries**
technical causes railside:	1			1
technical causes roadside:				
human causes railside:				
human causes roadside:	4	9	10	27
others:				

Figure 4: Refinement of entered level crossing accident statistics (source: RSSB, UK)

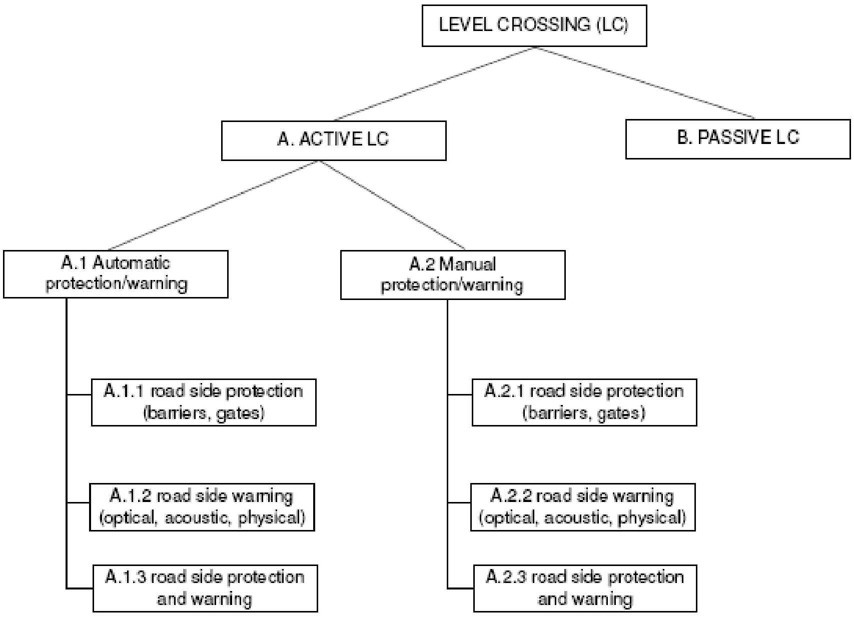

Figure 5: Proposal of European Railway Agency for the level crossing classification

Figure 6 shows the time related accident statistics of all types of national passive level crossings find by the KMS according to the specification of European Railway Agency. As normalisation factor of the data the effort of train kilometres for the corresponding country has been applied (value in millions indicated in brackets).
The chart allows identifying the most risky level crossing types and using the link in the legend it makes it is possible to exanimate in detail the corresponding level crossing type specifications. The chosen normalisation factor and the level crossing type specification support the interpretation of the graphical analysis results. Table 1 shows in numerical form the results of the analysis of level crossing accident statistics related to all abstract level crossing types defined by ERA with reference year 2005. The numerical values represent the average number of accidents of involved countries from and outside European Union (marked as EU and NonEU respectively). The number of level crossing types with available statistics is indicated always below the number of average accidents. For the purpose of comparability four different normalisation factors have been applied:

- Population of the particular level crossing type in the country
- Length of railway network of the country
- Train operation volume given in millions of train kilometres
- Number of inhabitants per square kilometres of the country

The graphical visualisation of the table 1 is shown on figure 7 in form of 3D bar diagram (the z-axis has logarithmic scaling).

As it can bee seen from the table 1 and figure 7 the abstract level crossing types A 1.1 and A 2.2 do not have representative level crossing types in countries involved in SELCAT project. In the first case it is the active automatic level crossing with barriers without any kind of road user warnings (e.g. visual or audible). The second case refers to active manually operated level crossings equipped only with warnings without physical protection in form of a barrier or gate. The missing of data can be caused by contemporary incompleteness of database of level crossing types in relation to all member states of the European Union.

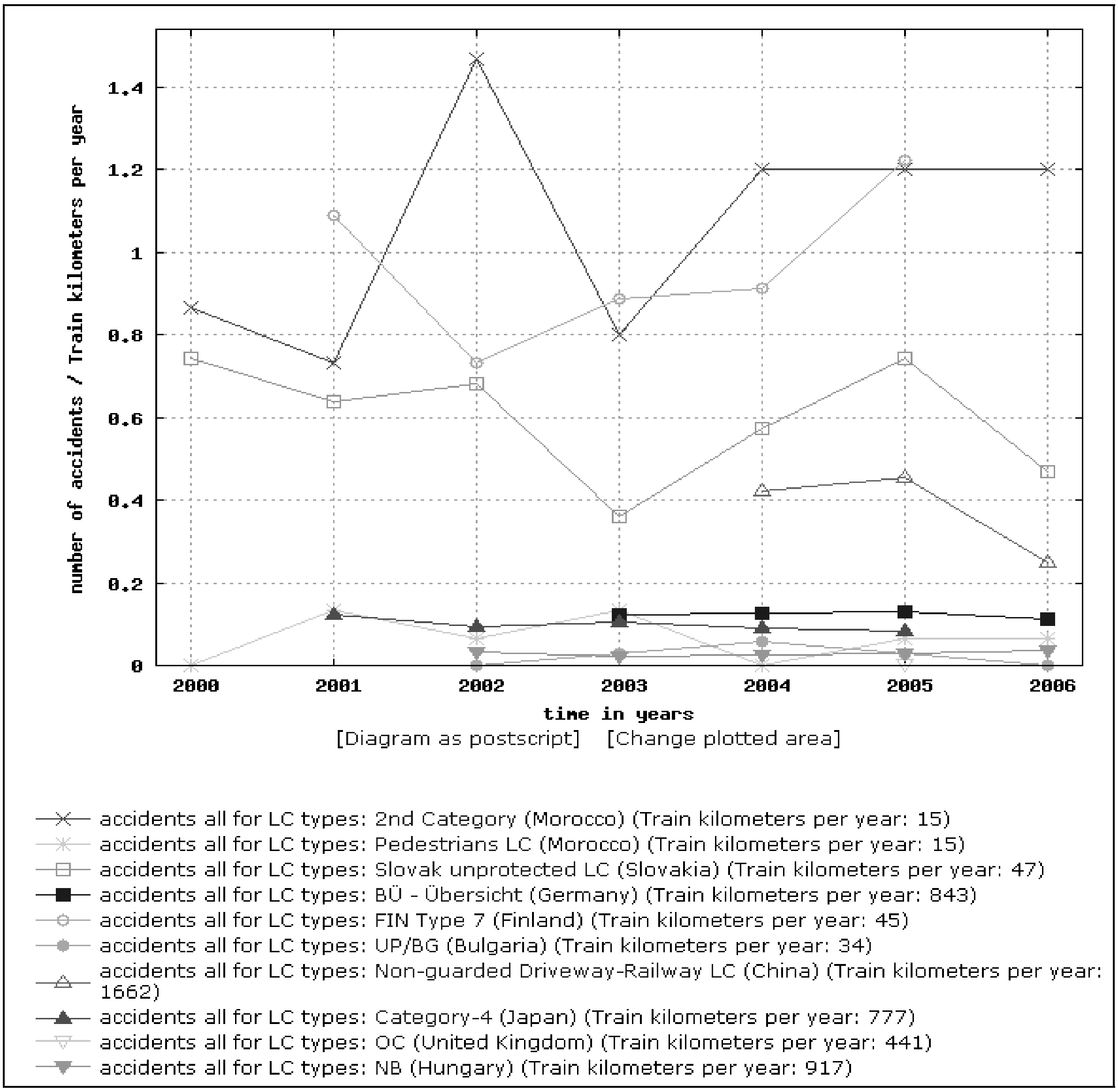

Figure 6: Accident statistics of passive level crossings normalized by the volume of train traffic (in illions train kilometers)

		Acc / (LCLype x LC)		Acc / (LCLype x km)		Acc / (LCLype x Tkm 10^6)		Acc / (LCLype x Pers/km^2)	
	ERA LCtype	EU	NonEU	EU	NonEU	EU	NonEU	EU	NonEU
	B	0,01783333	0,05375	0,00428333	0,005625	0,36133333	0,44975	0,64383333	1,54125
Nr. of LCtypes		6	4	6	4	6	4	6	4
	A 1.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Nr. of LCtypes		n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	A 1.2	0,03716667	0,015	0,0022	0,0006	0,19433333	0,02	0,17866667	0,05
Nr. of LCtypes		6	1	6	1	6	1	6	1
	A 1.3	0,01328571	0,0095	0,00074286	0,00665	0,07431142	0,44	0,10514286	1,7
Nr. of LCtypes		7	2	7	2	7	1	7	2
	A 2.1	0,003125	0,12	0,0002	0,0032	0,009175	0,4	0,0104	0,086
Nr. of LCtypes		4	1	4	1	4	1	4	1
	A 2.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Nr. of LCtypes		n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	A 2.3	0,135	n.d.	0,0023	n.d.	0,077	n.d.	0,136	n.d.
Nr. of LCtypes		1	n.d.	1	n.d.	1	n.d.	1	n.d.

Table 1: Level crossing accident statistics related to different types and normalisation factors (for 2005)

The analysis results show that the choice of the normalisation factor significantly changes the risk apportionment among different types of level crossings. When referring to the population of level crossing types it seems to be that the type A 2.3 has the main risk proportion. Detailed analysis shows that it is a guarded level crossing equipped with red steady signal light and gates closing either road or rail communication. According to the data collected coming from EU member states, the second highest risk is associated with the LC type A.1.2 – active automatic road user warning (without barriers). However, if taking any other normalisation factor the most risky level crossing type is the type B – passive level crossing. This trend is clearly confirmed also in non EU countries, even if the difference to other types is in some cases not at all significant.

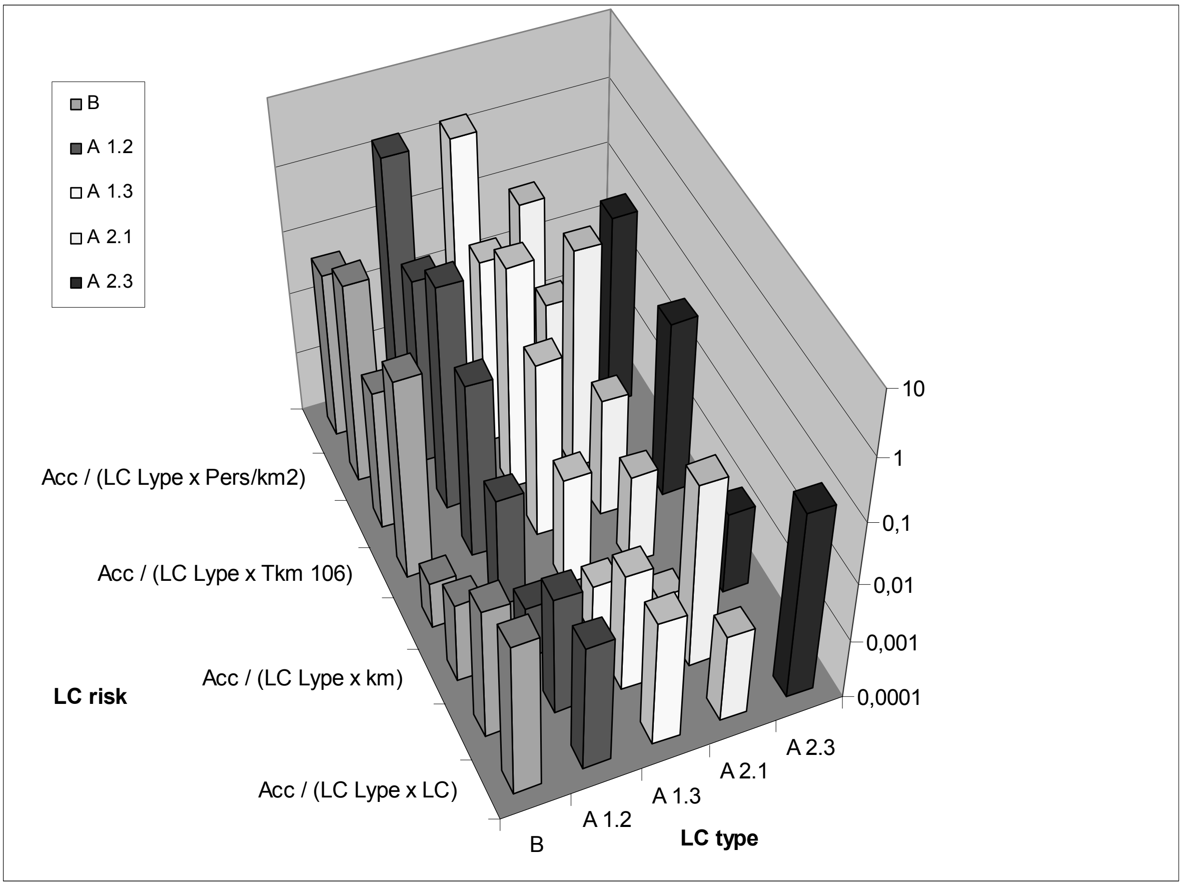

Figure 7: Graphical representation of level crossing accident analysis results from table 1

6. CONCLUSIONS

In the management of railway safety learning lessons from accidents is key to understanding of risk, regulation and the implementation of new safety initiatives. The described functionality of the SELCAT Knowledge Management System has been designed according to the requirements of the safety performance monitoring necessary for practical application risk based safety philosophy declared in the Safety Directive 2004/49. It allows collecting national level crossing accident statistics coming from different statistic sources related mostly to the typical national level crossing types. The common level crossing functional model is building base for harmonized information structure making possible comparisons and global evaluations. These are crucial for determination of Commons Safety Targets which are to be defined and to be used for risk assessment of future European railway control and protection systems according to the mentioned Safety Directive.

The Level crossing is a suitable example of a railway protection system for application of new safety regulations. The statistics shows that it possesses significant part of the railway risk. Its effective reduction will bring direct benefits in saved human lives and human health. Further completion of the statistic database of SELCAT KMS will allow more precise evaluations and comparisons planned in the project. These result represents input for further working areas of

SELCAT, particularly the level crossing technology and methodology.

The contemporary SELCAT KMS is designed for collection of national statistics evaluated on the base of accident reports (e.g. by railway infrastructure managers, national safety authorities etc.). These statistics often do not contain data of necessary level of detail about the occurred accidents, e.g. the causes, the severity, operational conditions or technical composition of particular protection system etc. However these play a significant role at identification and quantification of relevant hazards leading to the operational risk. Therefore the design concept of SELCAT KMS considers the future possibility of direct collecting of accident reports based on a common level crossing accident reporting protocol. Its specification is one of outstanding aims of the SELCAT project.

Acknowledgment

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КОНЦЕПЦИЯ ЗА МОНИТОРИНГ НА БЕЗОПАСНОТО ДЕЙСТВИЕ НА ПРЕЛЕЗИ

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Резюме: *Проектът SELCAT има за цел да събере, структурира, групира, анализира и разпространи съществуващите световни резултати и да стимулира обмена на знания в областта на безопасността на прелезите. Една от главните цели е оценката на реалния риск при действието на прелезите в международен аспект. Докладът представя концепция за мониторинг на безопасното действие на прелезите на основата на модерна система за управление на знанията. Показани са резултатите от първите анализи.*

Ключови думи: прелез, анализ на риска, статистика на катастрофите, безопасно действие.

Тази разработка е направена като част от дейностите по европейския проект SELCAT. За повече подробности вижте http://www.levelcrossing.net/