# METHOD FOR A STRUCTURED IDENTIFICATION OF SUITABLE SAFETY AND SECURING SYSTEMS FOR LEVEL CROSSINGS

Thomas Böhm[1], Markus Pelz[2], Hartwig Asbrock[3]

Summary: Safety and securing systems for level crossing have a long life time. Once a system reaches a life time when it is no longer conform to applicable regulations, it has to be modernized or replaced. The planner of the level crossing system alongside the road and railroad has to adapt the system to various local conditions and rules. He has to choose a suitable system by the use of his individual expert knowledge. The decisions he made are often hard to understand or to trace for the operating company. This paper presents a structured method, which was developed as a basis for the decision making. It helps to trace the decisions of the engineer and even enables the engineer to identify a suitable level crossing system.

## 1. Introduction

Current prospects say that the traffic performance in the year 2025 will be much higher than today. Compared to the year 2004 the passenger rail transport will increase by 25.6 % and the freight rail transport will increase by 34 % [1]. The future transport demand causes a high pressure on railway companies to provide an efficient service, which requires also a capable railway infrastructure.

The Institute of Transportation Systems (ITS) of the German Aerospace Center (DLR), in cooperation with the German infrastructure operator DB Netz AG, has analysed the planning procedure of level crossings. The main question was how to determine the optimal technical equipment in the early planning phase to ensure an efficient railway operation. The result of this analysis is a method for a structured identification of suitable safety systems for level crossings.

[1] Dipl.-Ing.-Inf. Thomas Böhm, German Aerospace Center (DLR), Institute of Transportation Systems (ITS), Lilienthalplatz 7, 38108 Braunschweig, Germany,
e-mail: thomas.boehm@dlr.de, phone: +49 531 295 3504; fax: +49 531 295 3402;

[2] Dipl.-Ing. Markus Pelz, DLR-ITS,
e-mail: markus.pelz@dlr.de, phone: +49 531 295 3483; fax: +49 531 295 3402

[3] Dipl.-Ing. Hartwig Asbrock, DB Netz AG, Mainzer Landstraße 201-203, 6060326 Frankfurt/M, e-mail: hartwig.asbrock@dbnetze.com, phone: +49 69 265 30441; fax: +49 69 265 30402

## 2. Safety Systems for Level Crossing

Level crossings in Germany are basically divided into those which are technically secured and those which are not technically secured. The German body of rules and regulations for railway construction and operation (EBO) defines when a technically secured level crossing is required [2]. Therein the minimal criteria for a technical securing system of the level crossing are determined depending on the conditions alongside the road and the railway (see Fig.1).

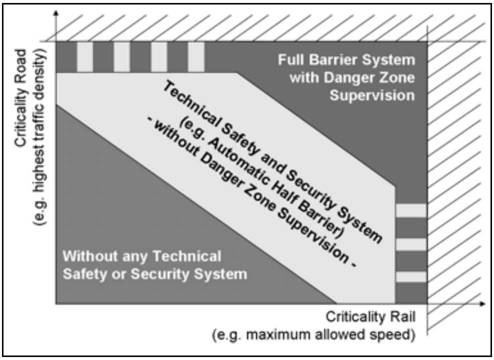


Fig.1. Criteria for securing Level Crossings according to the EBO [3]

The technical securing of level crossings is a task involving various means of transport and thus a complex manner for all involved organisations (authorities and companies). The common goal is to install the most efficient technologies in terms of economy and operation. Thereby it has to be distinguished between the safety system alongside the railroad and the securing system alongside the road. Both systems have to be planned by an engineer (planner). While the system alongside the road is strictly bound to the directive KoRil 815 with little scope for interpretation, the system alongside the railroad is open to choose different technical equipment. Hence it is much more difficult to determine a suitable system. The study focuses on a method to identify the suitable safety system alongside the railroad.

The current state of activation of the level crossings in Germany is mainly characterised by three main types of level crossing control systems [4]:

- Signal controlled (Interlock through a main signal) (Hp): Activating level crossing through interlocking system. To set signals level crossing must be safe.
- Control through signaller (Fü): Activating level crossing through train by trackside elements. Control of the status of level crossing at interlocking system through signaller.

- Control through train driver (ÜS): Activating level crossing through train by trackside elements. Control status of level crossing at surveillance signal by train driver.

If a level crossing is rebuilt or a new level crossing safety system is used, the elementary control systems for level crossings are completed through combinations of the three basic control systems. All in all it is possible to install the following six control systems [5]:

- *ÜS*, *Hp*, *Fü* and
- Control by train driver by optimized activation ($ÜS_{OE}$): The idea is to combine an ÜS (surveillance signal) with the Fü-logic (optimized activation point).
- Combination of the basic control systems: *Hp/ÜS*, *Hp/Fü*

During the planning procedure of the particular level crossings, it is identified and determined which control system is used and when it is used.

## 3. Practice in Planning Level Crossings Today

The realisation of level crossing projects, as it is practiced today, has the following steps (see also Fig. 2):

- Identifying the need (e.g. judicial reasons, building measures at the road or at the rail track)
- Determining if an existing technical securing system has to be revised or a new technical securing system has to be installed
- Planning by experience of the designer or consulting
- Clearing of the financing
- Planning of the system alongside the road
- Planning of the system alongside the railroad
- Building

As mentioned above, the system alongside the road is simple to choose and to plan, because the corresponding directive is comparatively straight. The difficulty lies within the identification of a suitable system alongside the railroad. The decision depends on or is at least influenced by various given parameters. Some of those parameters, mainly judicial and technical ones, exclude or require a certain system, while others only point to a preferred system. The designing engineer has also to consider the interdependencies between some of the parameters. Thus, the engineer often finds himself in a situation when he has to decide between optional systems which all fit the requirements but differ in their operational efficiency.

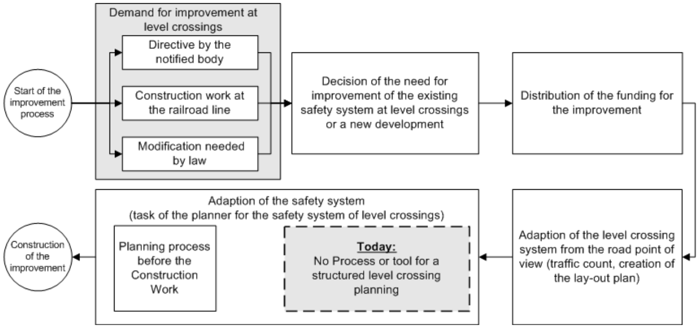


Fig.2. Today's practice in planning level crossings

The engineer's decision is based on his individual expert knowledge, which makes it hard to understand for other involved instances, e.g. the operating company. Additionally, the lack of a structured method which allows for all relevant criteria in the decision leads to results strongly depending on the individual planner. Thus, it is not guaranteed that the chosen system is the technically and operationally best solution.

## 4. The Structured Approach

A method for a structured identification of suitable safety systems for level crossings, not only enables others to understand the decision process, but also helps the planning engineer to consider all relevant criteria. The decision per criteria can be successively processed and documented (see Fig. 3). It also fasten the process, hence saves money.

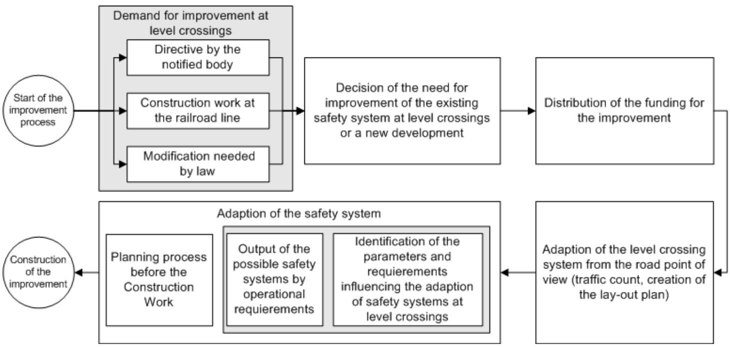


Fig.3. Adapted process with the new structured approach

It is essential to completely cover all parameters and their interdependencies, so that certain systems can be removed from the set of solutions. Three types of parameters have been identified:

– Non-influenceable basic parameters: These are mainly operational or judicial or technical conditions, which result from the circumstances of the surroundings of the regarding level crossing, e.g. immediate vicinity of main traffic road, interface to a corresponding interlocking, etc.

– Influenceable basic parameters: These are technical or operational parameters with different options. The designing engineer has to decide which option is needed or wanted for the regarding level crossing, e.g. including of the level crossing in the regional operation control centre, autonomously operating level crossing, etc.

– Depending parameters: These are parameters that always depend on basic parameters. They may also influence each other, e.g. the closing time as little as possible.

Some of the parameters of each type exclude or require a certain safety and securing system. These are so called exclusive parameters.

The structured approach lists all parameters and their options (currently 20 parameters with the total amount of 48 options) in a way that the designing engineer only has to select the option where applicable. As mentioned before, selecting an option of a parameter will eliminate or at least favours one or more systems from the set of solutions. This is realised with a score value expressing the benefit of the corresponding securing system. The integer score ranges from 0 to 2, with:

– 0 meaning the system is inapplicable hence has to be excluded,

– 1 the system is applicable,

– 2 the system is favourable regarding the option

| Nr. | Parameter N | | Option M | Selection S | System I | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ÜS | Fü | Hp | ÜSOE | Hp/ÜS | Hp/Fü |
| | **non-influencable basic parameters** | | | | | | | | | |
| 1 | line equiped with technical securing system | a | Yes | | 1 | 1 | 1 | 1 | 1 | 1 |
| | | b | No | | 1 | 1 | 0 | 1 | 0 | 0 |
| 2 | Interface to interlocking exsisting | a | Yes | | 1 | 2 | 2 | 1 | 1 | 1 |
| | | b | No | | 1 | 1 | 1 | 1 | 1 | 1 |
| | **influencable basic paramters** | | | | | | | | | |
| 13 | including in the regional control center possible | a | Yes | | 1 | 0 | 1 | 1 | 1 | 0 |
| | | b | No | | 1 | 1 | 1 | 1 | 1 | 1 |
| 14 | autonomous oparation wanted | a | Yes | | 1 | 0 | 0 | 1 | 0 | 0 |
| | | b | No | | 1 | 1 | 1 | 1 | 1 | 1 |
| | **depending parameters** | | | | | | | | | |
| 20 | closing time | a | as little as possible | | 1 | 1 | 0 | 1 | 1 | 1 |
| | | b | irrelevant | | 1 | 1 | 1 | 1 | 1 | 1 |
| | **(preliminary) result of the suitable system** | | | **X (i):** | 1 | 1 | 1 | 1 | 1 | 1 |

Fig.4. Section of structured identification

Figure 4 shows a section of the structured identification approach. Therein the designing engineer has to set “1” or “0” in the column “Selection”. A “0” marks an incorrect option, whereas “1” marks a correct option of the parameter in the corresponding line. It also prohibits another entry of “1” for the same parameter. The use of numbers is part of the method, because it enables the mathematical calculation of decisions regarding a single parameter and the overall decision. The columns and lines of “System I” contain the information on the score value $x_i$ of a system. For all safety and securing systems *i* applies:

$$X(i) = \prod_{n=1}^{N} \sum_{m=1}^{M_n} s_{nm} * x_{inm} \tag{1}$$

with $s \in \{0;1\}$ and $n \in N$ as the set of all parameters and $m \in M_n$ as the set of all options of parameter *n*. Once the engineer has checked off and marked the options the result is shown in the last line. The field with the highest value indicates the most suitable system regarding the conditions and choices. A field containing a Zero means this system is not applicable in this situation.

The description above is first part of the method. It supports a structured quantification of the most suitable system, but does not automatically make the process easier or prevents faults. This is achieved with the second part of the method which takes into account the interdependencies between the parameters and their options. Therefore, all options of a parameter are associated with each other via a matrix structure, similar to the principles of an adjacency matrix. The matrix contains the status of an association, so that it documents which influence a certain option has on other options. For example, a parameter A is “YES” which requires parameter B with “No”. The matrix forces the engineer to follow conditions or prohibits conflicting options. Thus, it prevents faults. Additionally, the matrix tells which parameter(s) should be checked off next after a parameter has been checked off. It is a kind of guiding the engineer through the decision process and avoiding unnecessary parameters. It works like a decision tree but it is more flexible. Another advantage of the method is that the deciding person does not necessarily have to start with the first parameter listed. It is possible to start checking any favourable parameter and still get the result quickly.

## 5. Example

The previous chapter explained the method. An example of its application is given in this chapter. Entering the planning process where the adaptation of the safety system starts (see Fig. 3). The planner takes the list of parameters and compares the options with the circumstances and condition of his level crossing project. He can start with whichever parameter he prefers, but it is recommended and reasonable to start with one of the non-influenceable parameters. In this example (see Fig. 5) he starts with parameter number 3. The level crossing is integrated in the interlocking hence he marks option “Yes” with “1”. The result is that the systems ÜS and $ÜS_{OE}$ are excluded, because they are not applicable here. In conformity with the documented dependency of options (not shown in the figure due to the complexity of the matrix), the checked option requires parameters number 1 and 2 both to be checked with “Yes” too. Otherwise there would emerge a conflict.

| Nr. | Parameter N | | Option M | Selection S | System I ÜS | Fü | Hp | ÜSOE | Hp/ÜS | Hp/Fü |
|---|---|---|---|---|---|---|---|---|---|---|
| **non-influencable basic parameters** | | | | | | | | | | |
| 1 | line equiped with technical securing system | a | Yes | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | b | No | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 2 | Interface to interlocking exsisting | a | Yes | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| | | b | No | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | level crossing integrated in the interlocking: | a | Ja | 1 | 0 | 1 | 2 | 0 | 1 | 2 |
| | | b | Nein | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **influencable basic paramters** | | | | | | | | | | |
| 13 | including in the regional control center possible | a | Yes | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| | | b | No | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 14 | autonomous oparation wanted | a | Yes | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| | | b | No | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **depending parameters** | | | | | | | | | | |
| 20 | closing time | a | as little as possible | | 1 | 1 | 0 | 1 | 1 | 1 |
| | | b | irrelevant | | 1 | 1 | 1 | 1 | 1 | 1 |
| **(preliminary) result of the suitable system** | | | | **X (i):** | 0 | 0 | 4 | 0 | 1 | 0 |

Fig.5. Section of an example of the method

Additionally, the matrix guides the engineer to other parameters. In this example he wants the system to be included in the regional control centre and it shall not operate autonomously, thus he checks parameter 13 with “Yes” and 14 with “No”. The decision eliminates the systems Fü and HP/Fü from the set of solutions. If the engineer would have chosen number 14 with “Yes” no system would be left and he must have revised his choice.

At this point the engineer can read from the result line that only systems Hp/ÜS and Hp are suitable, with Hp favoured. The engineer might be satisfied with the result or check off some more parameters (may be number 20) until the result is only a single system.

## 6. Conclusions

This paper explains a method for a structured identification of suitable safety and securing systems for level crossings. The method starts with the listing of all relevant environmental, technical, operational, and judicial parameters and their options regarding the decision for operationally and technically efficient system. It reflects the current technical standards and the German body of rules and regulations. The parameters had been sorted into three types of parameters (non-influenceable, influenceable, and depending). For each option of every parameter the effect on a system had been defined pointing out whether a system is favourable or just suitable or inapplicable. The associations between parameters had also been taken into account via a matrix structure. It provided a guide through the decision process. The planning engineer simply has to check off the parameter‘s options applying his knowledge.

The advantages of this approach are summarised as follows:

- Decisions are less individual
- Decisions are understandable respectively traceable
- Makes it easier for the engineer to consider all relevant criteria
- Prevents from faults
- Identifies the technically and operationally efficient system
- Saves time and money

Although, the presented method is supporting the design and planning process it can be improved. The goal is an integrated method which not only considers the systems alongside the railroad but also the systems alongside the road. Additionally, the identification of the operationally and economically efficient system is an import goal. This is done in another study and will be published in the near future.

## 7. References


1 BMVBS- Bundesministerium für Verkehr, Bau und Stadtentwicklung (Hg.) (2007): Prognose der deutschlandweiten Verkehrsverflechtungen 2025, Unter Mitarbeit von INTRAPLAN Consult GmbH und Beratergruppe Verkehr + Umwelt GmbH, München/Freiburg. (FE-Nr. 96.0857/2005).

2 Eisenbahn Bau- und Betriebsordnung (EBO).

3 Pelz, Markus et. al: Innovative Sicherungstechnik mit optischen Systemen. VDEI: EI - Der Eisenbahningenieur, 59 (8/2008), DVV Media Group / Eurailpress, S. 11 - 17, ISSN 0013-2810

4 Pelz, Markus et. al: Generic Operational Requirements for Video based Applications at Level Crossings. In: El-Koursi et. al: Safer European Level Crossing Appraisal and Technology SELCAT, 2nd SELCAT Workshop, Marrakesch, 2007.

5 Konzernrichtlinie 815 der Deutschen Bahn Netz AG (KoRil815) „Bahnübergangsanlagen planen und instand halten“.