OPTIMIZING THE CHOICE OF LEVEL CROSSINGS IN A TECHNICAL AS WELL AS ECONOMICAL WAY

Christoph Lackhove[1], Markus Pelz[2]

Summary: The planning of level crossings is so far mainly determined by operational rules and regulations. Economic aspects are often not part of a structured decision. This gap will be closed during the development of a method for the identification of a suitable safety and securing system for level crossings. With the method, it will be possible to optimize safety and securing systems for level crossings under technical and economical aspects during the planning phase. Elements of the method are a cost analysis as well as a value analysis. Aspects like the use of legacy components are taken into account. The structure and procedure of the decision-making of this new method are presented in this paper.

1. Introduction

The railway companies are committed to build their asset and their vehicles in a safe manner and maintain that status [1]. To fulfill this task, hazardous events have always been examined to find the weaknesses in the railway system and to eliminate them.

Due to the systems character, the railway traffic has the higher priority compared to street traffic at level crossings [2]. To avoid a crash, it has to be ensured that railway and street traffic never use the level crossing at the same time. It is the main task of the railway infrastructure companies to guarantee the safety of all participants in the traffic system.

The maintenance activities carried out are not enough to keep up with the aging of the facilities. It is not possible to modernize the needed amount of level crossings. This leads to disturbance and delays in traffic operations due to a sinking technical availability. To avoid cost intense maintenance activities the line speed is often reduced. The sinking performance of the line leads to a loss of attractiveness and profitability.

Accordingly, the main challenges to improve the situation are actions to [3]:

– increase the level of safety, if necessary;

[1] Dipl.-Wirtsch.-Ing. Christoph Lackhove, German Aerospace Center (DLR), Institute of Transportation Systems (ITS), Lilienthalplatz 7, 38108 Braunschweig, Germany, phone: +49 531 295 3505, fax: +49 531 295 3402, e-mail: christoph.lackhove@dlr.de

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

– speed up acceptance procedures, if necessary;

– improve operational characteristics;

– find cost efficient solutions;

– reduce the number of accidents.

The identification of cost efficient solution led to a method for a structured planning of level crossing facilities. The goal of the method is to find the technical and operational optimum among criteria that have been identified beforehand.

Some of the criteria are interdependent in means of operations or regulations. With the developed decision support these interdependencies are visualized for the planner. They determine the optimal choice for the level crossing safety system.

A further approach has been added to this method. This approach delivers a structured and reproducible way to additionally identify the economical and technical optimum of level crossings. Hence, it is possible to reduce the time needed to plan the level crossing and to reduce its costs.

The method of how to choose the optimal level crossing consists of three phases, also shown in Fig. 1:

– evaluation of the technical and operational optimum

– evaluation of the occuring costs

– evaluation of the value

This paper deals with the evaluation of the occurring costs and the value.

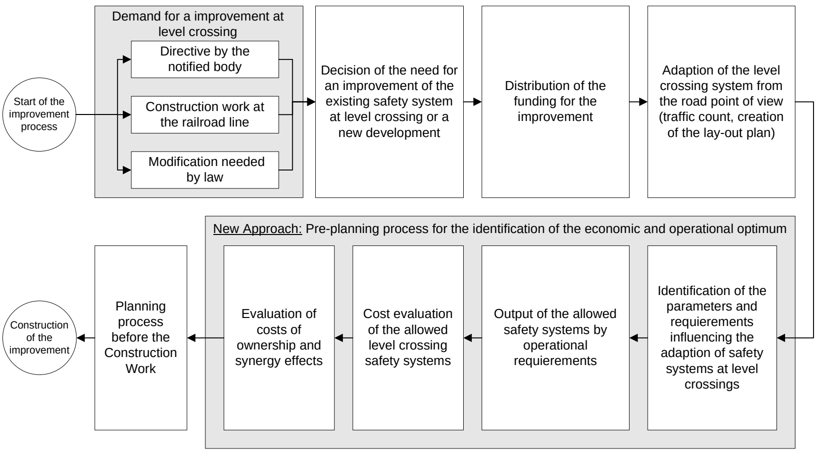

Fig. 1. New approach for the planning of level crossings

2. Cost evaluation of level crossings

The decision on new safety and control systems for level crossings so far mainly refers to technical and regulatory aspects. Economic aspects are not part of the decision. If more than one safety system is allowed for a level crossing by technical and regulatory means, there does no guideline exist for the planner to support his decision. This method picks up the missing link and adds it to the decision support. The planner does benefit from:

- guided choice of optimal level crossing safety system, and
- identification of potentials for optimization.

To carry out the economic evaluation, decision criteria have to be identified and defined first. These decision criteria stem from cost drivers, which make the different level crossing safety systems comparable. It is possible to create two different scenarios to compare strategies. Scenario 1 deals with the complete modernization of the level crossing. Scenario 2 takes into account that there could be reusable components from the legacy level crossing. The following cost categories are regarded:

- required elements for the level crossing safety system (type and amount);
- re-usable elements from the legacy level crossing facility (type and amount);
- investments, derived from the two categories above;
- costs for cable wiring, depending on the maximum speed and the number of tracks,

For each required element j, the costs per piece k_j are identified. The amount of each element j required for the level crossing safety system i is represented by m_{ij}. The amount and type of elements for each safety system m_{ij} multiplied with the costs per piece k_j sum up for the overall costs.

Opposed to the number of required elements m_{ij} is the number of reusable elements v_{ij} of the component j for the safety system i.

To distinguish between scenarios, the decision variable Y is used. It is assigned with the value 1 or 0, depending on whether the scenario is relevant or not.

The equation (1) below shows how the estimated investments for a level crossing safety system in a certain scenario are generated:

$$K_i = \sum_j k_j ((m_{ij} - v_{ij}) Y_{Scenario} + m_{ij} (1 - Y_{Scenario})) \qquad (1)$$

– K_i – Cumulated investments of the level crossing safety system i

– k_j – Cost per piece of the component j

– m_{ij} – Amount of the component j required for the level crossing safety system i

– v_{ij} – Amount of the component j re-usable from the legacy level crossing for the safety system i

– $Y_{Scenario}$ – Value 1 assigned, if the scenario of reusing elements from the legacy level crossing facility is relevant, otherwise value 0 assigned

– i – Index of level crossing safety systems

– j – Index of components

		Level crossing safety systems i	Cost drivers
Required elements	j	m_{ij}	k_j
Re-usable legacy elements	j	v_{ij}	k_j
Scenario 1	Y=0	$\sum_j k_i m_{ij}$	
Scenario 2	Y=1	$\sum_j k_i (m_{ij} - v_{ij})$	
Investments		K_i	

Fig. 2. Evaluation scheme for the investments in level crossings

3. Value evaluation of level crossings

Even for smaller projects non-monetary factors can have a huge impact on the decision for the most suitable level crossing safety system. To make such a decision comprehensive and systematical, the instrument of the Value Benefit Analysis can be used [4]. It enables the user to combine monetary and non-monetary aspects for the decision [5].

In this case, the Value Benefit Analysis is used to evaluate the costs of ownership and possible synergy effects if neighboring level crossings are taken into account. It is possible to gain the monetary data instead, but it is obvious that this would make a lot of effort. To keep the approach simple and easy to use the monetary evaluation is dismissed at this point.

The first step of the Value Benefit Analysis is the identification and definition of a value system and the decisive criteria. The decisive criteria are the basis for the evaluation of the alternative investments. The evaluation itself has to be carried out with a distinct measuring scale [6]. It is also important to identify the main goals, which have to be further detailed. There should be no interferences or interdependencies among those goals. This leads to a defined goal hierarchy [7][8].

The main goals are mutually put into a preference order by the weighting factor G. Therefore, it is possible to compare the criteria of the height of the investments, the costs of ownership, and the synergy effects regarding neighboring level crossings. The more detailed criteria within each main goal are weighed with the factor g_j. The factor represents the importance, i.e. the influence on the result, of a criterion compared to others.

The economic evaluation of a level crossing safety system only becomes relevant, if the evaluation of the technical optimum yields more than one allowed system. In this case, the decision variable X_i of the level crossing safety system i is assigned to the value 1, otherwise its value is 0.

The evaluation of the investments carried out above is the basis for the first main goal of the Benefit Value Analysis. From these data, a corresponding value is derived in a way that growing investments result in a sinking value. This leads to the following transformation (2):

$$N \sim \frac{1}{1+K} \Rightarrow \begin{cases} N \underset{\lim K \to \infty}{=} 0 \\ N \underset{\lim K \to 0}{=} 1 \end{cases} \qquad (2)$$

As stated above, the value has to be measured with a distinct scale. To ensure such a scale, e.g. with 0 for the lowest and 5 for the highest value N_{max}, equation (2) is normalized with the factor E according to the following transformation (3):

$$N_{\max} = \frac{1}{1+K_{\min}} E \Leftrightarrow E = N_{\max}(1+K_{\min}) \qquad (3)$$

To gain a preference order, the value factors are multiplied with the corresponding weighting factors and summed up for each alternative. This sum represents the value of each alternative.

Similar to Life Cycle Costing, the Life Cycle Value derived from the investments and the costs of ownership yield the value of equation (4) for the level crossing safety system i:

$$N_{i,LCV} = X_i \left[G_{Invest} \frac{1}{1+K_i} E + G_{CoO} \sum_j g_{j,CoO} \frac{1}{1+k_{ij}} e \right] \qquad (4)$$

– X_i – Decision variable, value 1 assigned if level crossing safety system i is allowed, otherwise value 0 is assigned

– G_{Invest} – Weighting factor for the criterion of height of investments

– G_{CoO} – Weighting factor for the criterion of costs of ownership

– $g_{j,CoO}$ – Weighting factor of the criterion j within the criterion of costs of ownership

– k_{ij} – Costs of ownership in the category j for the level crossing safety system i

– E – Normalizing factor for the value derived from the cumulated costs of level crossing safety system i

– e – Normalizing factor for the value derived from the costs of ownership of the level crossing safety system i

– i – Index of level crossing safety systems

– j – Index of criteria

	Level crossing safety systems i	Weighting factors	
Investments	K_i		G_{Invest}
Costs of ownership Human resources Maintenance Operational	k_{ij}	g_j	G_{LCV}
Life Cycle Value	$N_{i,LCV}$		

Fig. 3. Life Cycle Value evaluation scheme of level crossings

Furthermore, possible synergy effects of taking neighboring level crossings into account shall also be regarded. This is done by the value factor n_{ijl}. It represents the benefit when modernizing level crossing safety system i together with the neighboring level crossing j. If there are many similarities between those two level crossing, e.g. if they both use the same safety system, the benefit will be high. If the level crossings have nothing in common, the benefit could be 0.

This is also a fact which could be expressed in monetary figures, but the effort could probably be too high. That is why a non-monetary evaluation is preferred, as shown in equation (5):

$$N_{i,LC-LC} = N_{i,LCV} + X_i G_{LC-LC} \sum_j \sum_l g_{l,LC-LC} n_{ijl} Y_{j,LC-LC} \quad (5)$$

- G_{LC-LC} – Weighting factor for the criterion of synergy effects between neighboring level crossings
- $g_{l,LC-LC}$ – Weighting factor for the criterion l of synergy effects between two neighboring level crossings
- n_{ijl} – Value factor for the synergy effects of criterion l between the level crossing safety systems i and j
- $Y_{j,LC-LC}$ – Decision variable, value 1 assigned, if the neighboring level crossing uses the safety system j, otherwise value 0 is assigned
- i – Index of level crossing safety sytems
- l – Index of criteria
- j – Index of the neighboring level crossing safety systems

		Level crossing safety systems i	Weighting factors	
Life Cycle Value		$N_{i,LCV}$		
Synergy effects				G_{LC-LC}
Planning effort	j	n_{ijl}	g_l	
Compatibility	j	n_{ijl}	g_l	
Construction activity	j	n_{ijl}	g_l	
Total value		$N_{i,LC-LC}$		

Fig. 4. Total value evaluation scheme of level crossings

4. Conclusions

The method enables the planner of level crossings to systematically make comprehensive decisions. If there is more than one safety system allowed for the level crossing, due to technical and regulatory standards, the planner is able to compare the height of investments, the costs of ownership, and possible synergy effects with neighboring level crossings. To keep the method easy to use and to reduce the necessary effort for the data collection, a non-monetary evaluation of the value has been applied for the costs of ownership and the synergy effects.

If combined with a method to evaluate the technical and operational optimum of level crossings, the method delivers to carry out a full cost-benefit-analysis. Furthermore, this approach could be expanded with the perspective of the street traffic. This finally would take all aspects into account and thus help to improve the economic, safety, and operational situation of level crossings.

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