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Influence of Railway Control and Signaling Equipment on Reduction of Occurrences in the State Railway Network of Czech Republic

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Abstract

The paper develops the issue of the evaluation of investment projects in the area of the national railway infrastructure solved within the research project. The research projects is focused on the evaluation of benefits connected with the increasing of the safety and the reliability of the railway infrastructure due to the realization of projects including investments into managing and security equipment. The paper is focused on the identification of the relation between the change of the level of security on the railway and the change of the number of occurrences on the railway. The methodology of the research consists in the analysis of the database of occurrences obtained from the sources of the Railway Infrastructure Administration, which includes approximately 1 000 occurrences annually per last ten years (2009 – 2018). The database includes detailed information about registered occurrences. The output of the partial part of the research is the identification of the relation between specific occurrence and its cause and the level of the security in the place of the origin of the occurrence. The results of the research will be consequently used for the evaluation of benefits connected with the increasing of the safety and the reliability of the railway.

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Keywords: Projects on Railways; Occurrences; Safety and Reliability; Evaluation of Benefits; Economic Analysis

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1. Introduction

The paper deals with partial results in the field of railway control and signaling equipment and is based on the research project „Evaluation of increased safety and reliability of railway infrastructure after its modernization or reconstruction" (acronym EVARAIL), which is focused on the evaluation of benefits associated with increasing the safety and reliability of the railway infrastructure as a result of the implementation of new construction projects or renovations involving also investments in control and signaling equipment.

From the methodological point of view the paper is based on detailed analysis of the database of occurrences, which is for statistical purposes administrated by Czech Railway Infrastructure Administration (SŽDC). These occurrences are in the database classified into groups and sub-groups according to the character of their generation. The results of the research presented within the paper will be in next steps used for the purposes of the evaluation of the socio-economic impacts of occurrences on the society, which will be consequently included into the economic evaluation of the projects of the railway infrastructure of Czech Republic.

2. Present state references

The research presented in the paper is quite unique and is focused on the reaching of objectives defined within the research projects mentioned above, however in the past there were carried out research activities in related areas. The research described by Johnsen and Veen (2013) is oriented on the risk assessment and resilience of critical communication infrastructure in railways, especially discusses "the significant findings of an extended risk assessment of the key communication infrastructure used in emergency communication in railways in Norway". Resilience was explored as a strategy in the risk assessment to improve safety, security, and quality of service. The proactive approach to train control is the subject of the research of Thurston and coll. (2012), consequently the resource allocation decisions to reduce the risk on railway is solved by King (2016).

3. Overview of partial types of railway control and signaling equipment in Czech Republic

The railway control and signaling equipment can be defined as follows. „Railway control and signaling equipment is a set of technical devices and interfaces between them that contribute to the safety of railway operation. In particular, by controlling or replacing the activities of the railway staff in the management of rail transport and the operation of railway vehicles"

There are different types of railway control and signaling equipment, depending on location and situation:

- Station-mounted control and signaling equipment,
- Track-mounted control and signaling equipment,
- Vehicle-mounted control and signaling equipment.

3.1. Station-mounted control and signaling equipment

Equipment for creating and ensuring conditions for safe train movement along a selected path in a station. There are 3 categories:

1. Category – the simplest and least secure system:

- The signals are not dependent on the position of the switches to be passed by the train.
- The devices do not allow the exclusion of all concurrently prohibited train journeys.
- Only the staff (e.g. dispatcher) is responsible for creating the train path and for the correct charging of switches.

2. Category – (electro-) mechanical or electro-dynamic security system:

- The signals are dependent on the position of the switches to be passed by the train (does not apply to shunting).

- The devices do allow the exclusion of all concurrently prohibited train journeys (does not apply to shunting).
- No control of clearance of the train path.

3. Category – relay or electronic security system:

- The signals are dependent on the position of the switches to be passed by the train (also for shunting).
- The devices do allow the exclusion of all concurrently prohibited train journeys (also for shunting).
- Control of clearance of the train path.

3.2. Track-mounted control and signaling equipment

Equipment to ensure the secure movement of trains on the wide track between track sections or stations. It observes the running of following trains and eliminates the opposite running of trains (on single-track routes). There are also 3 categories:

1. Category – the simplest and least secure system (e.g. telephone communication):

- No control of clearance of the track section for following trains.
- No control of opposite running of trains (on single-track routes).

2. Category – (relay) semi-automatic block:

- Partially control of clearance of the track section for following trains.
- Control of opposite running of trains (on single-track routes).

3. Category – bi-directional three-sign automatic block and automatic line block:

- Control of clearance of the track section for following trains.
- Control of opposite running of trains (on single-track routes).

3.3. Vehicle-mounted control and signaling equipment

Equipment to ensure the secure ride of the vehicle by checking the train driver of compliance with the limit parameters of train running. This is achieved by the so-called system LS (“Liniový Systém”, in English “Continuous System”). It is a cab signaling and train protection system, which continuously transmits and shows a signal aspect of the next main signal in driver's cabin. It also checks the driver's activity (e.g. reduction of train's speed) and his vigilance (by periodically pressing the “vigilance button“– else the emergency brake is applied). The trackside part of the LS-system is based on coded track circuits using carrier frequency 75 Hz combined with amplitude modulation (“on-off-keying”). There are used four modulation frequencies:

- 0.9 Hz – Red aspect: Demand to stop at the next signal;
- 1.8 Hz – Yellow annulus aspect: From the main signal and in the circumference of the switches adjacent to the signal, the train shall run at a reduced speed specified by a two-light signal including light bars and digits;
- 3.6 Hz – Yellow aspect: The nearest main signal shows WARNING or EXPECT SPEED with 100, 80, 60 or 40 km/h;
- 5.4 Hz – Green aspect: No speed restrictions at the next signal.

4. Methodology: Evaluation of the database

The database, used as input for analysis, includes all occurrences recorded on the state railway infrastructure in the Czech Republic for the years 2009 to 2018. The database has a very complicated structure and includes a large amount of information on each occurrence. For easier orientation in the database of occurrences, the classification of occurrences has been adopted for the purpose of its analysis, which divides the occurrences into the following three groups:

A – Serious accidents (A1 – A4),
B – Accidents (B1 – B10),
C – Incidents (C1 – C21).

As can be seen from the above structure, each of the groups is further subdivided into sub-groups according to the specific nature of the occurrence.

From the database, all the occurrences related to the railway control and signaling equipment were first filtered out, distinguished between infrastructure-mounted (caused by train dispatcher or signaler) and vehicle-mounted (caused by train driver) occurrences. It was only considered the human factor that means, no occurrences caused by technical defects or failures (e.g. power blackouts, failures of technical components), the analysis affect only occurrences related to stations when entering and leaving trains and line sections but no industrial tracks. Furthermore, no account was taken to occurrences involving railway crossings, as these are not part of the EVARAIL project. The occurrences in terms of infrastructure then were subdivided into the safety levels 1, 2 and 3. Since level 3 already allows the greatest possible safety, only the occurrences of level 1 and 2 were analyzed in detail, as here – at least in theory – the upgrading to a higher safety category (usually level 3, in rare cases level 2) would have been a possible prevention of specific type of occurrence.

To make it clearer, some of the most common occurrences concerning human factor in this context are occurrences regarding the infrastructure signaling system and occurrences regarding the vehicle (basically caused by train driver).

Occurrences regarding the infrastructure signaling system (basically caused by train dispatcher or signaler):

- Unauthorized train departure,
- Sending a train to a wrong (already occupied) track,
- Wrongly charged switch,
- Switch charging under the vehicle.

Occurrences regarding the vehicle (basically caused by train driver):

- Departure without an order to leave,
- Disobeying a signal (e.g. specified maximum speed),
- Passing the signal "Stop" ("red light").

5. Results

The most important results related to the railway control and signaling equipment are summarized in the table 1.

Table 1 Analysis of occurrences related to the railway control and signaling equipment of categories 1 and 2

Year	Group of occurrence	Number of occurrences	Material damage (CZK)	Expenses (CZK)	Number of occurrences, infra-structure-mounted	Number of occurrences, vehicle-mounted	Material damage + expenses (CZK), infra-structure-mounted	Material damage + expenses (CZK), vehicle-mounted
2009	B	2	2,543,937	0	2	0	2,543,937	0
	C	16	34,427	0	8	8	34,427	0
	Total	18	2,578,364	0	10	8	2,578,364	0
2010	C	20	68,916	16,208	13	7	44,470	40,654
	Total	20	68,916	16,208	13	7	44,470	40.654
2011	A	1	6,820,615	62,300	1	0	6,882,915	0
	C	24	2,489	249,046	11	13	188,950	62,585
	Total	25	6,823,104	311,346	12	13	7,071,865	62,585
2012	C	25	36,772	60,439	13	12	56,941	40,270
	Total	25	36,772	60,439	13	12	56,941	40,270
2013	B	1	730,958	3,605	1	0	734,563	0
	C	21	881,805	142,144	9	12	289,429	703,067
	Total	22	1,612,763	145,749	10	12	1,023,992	734,520
2014	C	21	172,874	210,005	12	9	332,934	49,945
	Total	21	172,874	210,005	12	9	332.934	49.945
2015	A	2	29,405,676	177,270	1	1	6,944	29,576,002
	C	19	345,115	239,016	11	8	231,078	353,053
	Total	21	29,750,791	416,286	12	9	238,022	29,929,055
2016	B	1	1,244,611	0	1	0	1,244,611	0
	C	18	50,281	102,734	5	13	57,797	95,218
	Total	19	1,294,892	102,734	6	13	1,302,408	95,218
2017	B	1	1,140,191	84,520	1	0	0	1,224,711
	C	13	483,320	336,491	6	7	293,432	526,379
	Total	14	1,623,511	421,011	7	7	293,432	1,751,090
2018	A	1	6,325,581	0	1	0	6,325,581	0
	B	2	2,584,660	84,794	1	1	1,619,163	1,050,291
	C	31	57,752	121,908	11	20	87,614	92,046
	Total	34	8,967,993	206,702	13	21	8,032,358	1,142,337
Total (2009-2018)		219	52,929,980	1,890,480	108	111	20,974,786	33,845,674

Source: Author's own work according to SŽDC (2009 – 2019)

In the years 2009 – 2018 there happened in total 219 occurrences caused by human factor on railway lines equipped with control and signaling equipment of safety levels 1 and 2. 108 of them were caused due to wrong operation of the infrastructure signaling system basically by train dispatcher or signaler and 111 due to bad vigilance of the train driver of the vehicle. With regard to the three groups of severity, the following statements can be made:

- Category A – serious accidents: 4 occurrences (3 infrastructure-mounted, 1 vehicle-mounted),
- Category B – accidents: 7 occurrences (6 infrastructure-mounted, 1 vehicle-mounted),
- Category C – incidents: 208 occurrences (99 infrastructure-mounted, 109 vehicle-mounted).

The monetary overall damage (excluding socio-economic impacts) amounts to 54.820.460 CZK (of which 20.974.786 CZK caused due to wrong operation of the infrastructure signaling system and 33.845.674 CZK due to bad vigilance of the train driver of the vehicle).

6. Conclusions

The subject of the paper was to present partial results of the research project "EVARAIL" focused on the evaluation of benefits associated with the (theoretical) improvement of railway control and signaling equipment of categories 1 and 2 of the state railway infrastructure in the Czech Republic. Specifically, the paper focuses on the analysis of the database of occurrences, which includes detailed characteristics of occurrences on the state railway infrastructure of the Czech Republic for the period 2009 – 2018. The aim of the analysis was to verify the applicability of data for further research activities.

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