

Technical condition of railway vehicles as a safety factor in traffic

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Abstract. The railway vehicles in operation must have all subsystems functional and effective, especially brake, running gear, buffing and draw gear, suspension, etc. Any irregularities in the railway system (vehicles, tracks, signals, management, etc.) can affect transport safety. In this paper, only the influence of the vehicle's condition on railway transport safety was considered. Irregularities of railway vehicles can be observed at function failure, noticed in operation, or viewed in inspection performed by railway staff. In cases of accident or incident, the failure of the vehicle is stated in the investigation report. In operation or inspections, the failure of vehicles is stated by railway staff on labels and in workshops on measuring lists. Analysis of accidents and incidents caused by the technical condition of railway vehicles was done according to data from railway undertaker "Serbia Cargo". Analysis of irregularities was done according to data from inspections of freight railway vehicles. Analysis shows that irregularities in railway vehicles affect only some types of accidents and incidents.

Keywords: Railway vehicles, Traffic safety, Technical condition

1. INTRODUCTION

There are number of significant elements that influence safety of railway transport, so the indicators are defined that characterize traffic safety. One of these indicators are numbers of accidents and incidents. The number and type of accidents and incidents expressed by number or relatively to running kilometres and tonne of goods or number of passengers can be use as indicators of railway transport safety.

It is possible to determine traffic safety and the risk of accidents and incidents in railway traffic based on the safety indicators. By determining the main causes of train accidents and incidents, appropriate preventive measures can be proposed, and railway traffic safety can be increased. One of the causes of accidents and incidents in railway traffic is the technical condition of railway vehicles, and in this paper, only this influence on railway traffic safety was considered.

An accident is an unwanted or unplanned sudden event or a specific series of such events with harmful consequences, while an incident negatively affects traffic safety [1]. Incidents in railway traffic are avoided collisions of a train with rail vehicles or with obstacles within the clearance gauge, passing through the signals, broken rail, wheel or axle, track deformation, train brakes apart and others, and they must be investigated as well as accidents [1].

2. SAFETY INDICATORS IN RAILWAY TRAFFIC

Railway safety includes the conditions met by the railway system and railway workers, as well as other conditions relevant to the achievement of safe and undisturbed railway traffic [2]. The rulebook on common safety indicators in railway traffic [3] defines special indicators - Common Safety Indicators (CSI) for the assessment of safety levels in railway traffic. CSI relating to accidents are different types of accidents such as collisions of a train with rail vehicles or with obstacles within the clearance gauge, derailment of the train, level

crossing accidents, accidents to persons involving rolling stock in motion, fires in rolling stock and others [3]. CSI can also be presented as the number of persons seriously injured and killed by a type of accident.

Common Safety Indicators (CSI) are expressed in total or relative numbers [3], where the relative CSI is the total number per train-kilometres. To compare the safety of different railway undertakers, only a comparison of the same indicators by total or relative number can be made. To establish a framework for railway safety in European Union Directive 2004/49/EC on railway safety was first adopted. In addition to the harmonisation of the content of safety rules, the safety certification and the investigation of accidents the bodies and procedures that ensure safety in the member states are harmonized through the definition of responsibilities, the principle of certification of all elements of safety and the establishment of a national safety body, as well as the accident investigation body. Directive 2016/798 [4] developing common safety targets (CST) and common safety methods (CSM) to gradually remove the need for national rules. In the Republic of Serbia, the national body for railway traffic safety is the Directorate for Railways. The accident investigation authority is the Traffic Accident Investigation Center (CINS) established by the Law on accident investigations for aviation, railways, and waterborne transport [5].

Common Safety Indicators (CSI) for accidents are the total and relative number of significant accidents, as well as the total and relative number of seriously injured and fatally injured persons by type of accident [3]. The safety of railway traffic in the last 15 years is different due to changes in safety indicators, conditions in operation and regulations. With the restructuration of national railway undertaker "Serbian Railways" in 2015, three new companies were established:

- "Infrastructure of the Serbian Railways", the company for railway infrastructure management.
- "Serbia Cargo", the company for railway transport of goods and

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- "Serbia Train", the company for railway transport of passengers.

The average number of accidents and incidents at national undertaker "Serbian Railways" from 2007 to 2011 [6] that includes cases for passenger and freight trains was 558.2 per year (Table 1), while the average number for freight railway transport of "Serbia Cargo" from 2018 to 2021 was almost half (248.8). The reasons for the difference in transport safety was that "Serbian Railways" performed both passenger and freight traffic and recorded all accidents and incidents on the Serbian public railway network. The total number of accidents and incidents on the entire public railway network of Serbia is higher than shown for "Serbia Cargo" because it includes other operators. In addition, the freight traffic of "Serbian Railways" from 2007 to 2011 was more than 30% higher than the traffic of "Serbia Cargo" in the last few years.

Table 1: Transport safety on the railway in Serbia

Year	Total number of accidents and incidents	Total number of accidents	Transport (million tonne-kilometre)	Relative number of accidents (per million tonne-kilometre)
"Serbian Railways"				
2007	653	158	8372	0.019
2008	541	105	8197	0.013
2009	528	112	5802	0.019
2010	574	161	6753	0.024
2011	495	130	6781	0.019
Average	558.2	133.2	7181	0.019
"Serbia Cargo"				
2016	213	119	4993	0.024
2017	392	170	5622	0.030
2018	285	161	5202	0.031
2019	244	149	4753	0.031
2020	177	109	4639	0.023
2021	182	119	4652	0.026
Average	248.8	137.8	4977	0.028

Today, more than 15 undertakers transport goods on Serbian railways. There was a decrease in the share of

transportation since 2018 of the railway undertaker in the state ownership "Serbia Cargo" in favour of private undertakers. Namely, the share of private undertakers on the market of total transported goods on Serbian railways increased from 5.9% in 2018 to 24.48% in 2021, compared in tonne-kilometre [7].

The total number of accidents however did not change in more than 15 years with an average of approximately 135 cases of accidents per year. Although the total (248.8) and relative number (0,053) of accidents and incidents at "Serbia Cargo" in the last few years were significantly lower (55% for the total and 32% for the relative number), the number of the accident has not decrease. The relative number of accidents increase from 0.019 to 0.028 (Fig. 1). In fact, the share of accidents in total number of accidents and incidents increased by 58%, since it was 24% until 2011 and in the last few years was an average 57%.

3. IMPACT OF TECHNICAL CONDITION ON ACCIDENTS AND INCIDENTS

The railway vehicles in operation must have all subsystems and systems effective, especially brakes. wheelset, running gear, etc, that can affect traffic safety. The vehicle's condition can be observed through regular inspections. The irregularity of vehicle subsystems was noted in regular inspections, at failures and in workshops by railway workers. Analysis of the technical condition of railway vehicles on railway transport safety was made based on the Statistical reports on accidents and incidents at "Serbia Cargo" for 2017 [8], 2018 [9], 2019 [10], 2020 [11], and 2021 [12]. Reports show that cases of technical condition of railway vehicles leading to accidents and incidents vary from 9 to 18 cases per year for locomotives, and 19 to 43 for wagons (Fig. 3). The technical condition of locomotives on average leads to 13.8 cases of accidents or incidents per year, while the technical condition of wagons leads to almost double number of accidents or incidents (28.2).

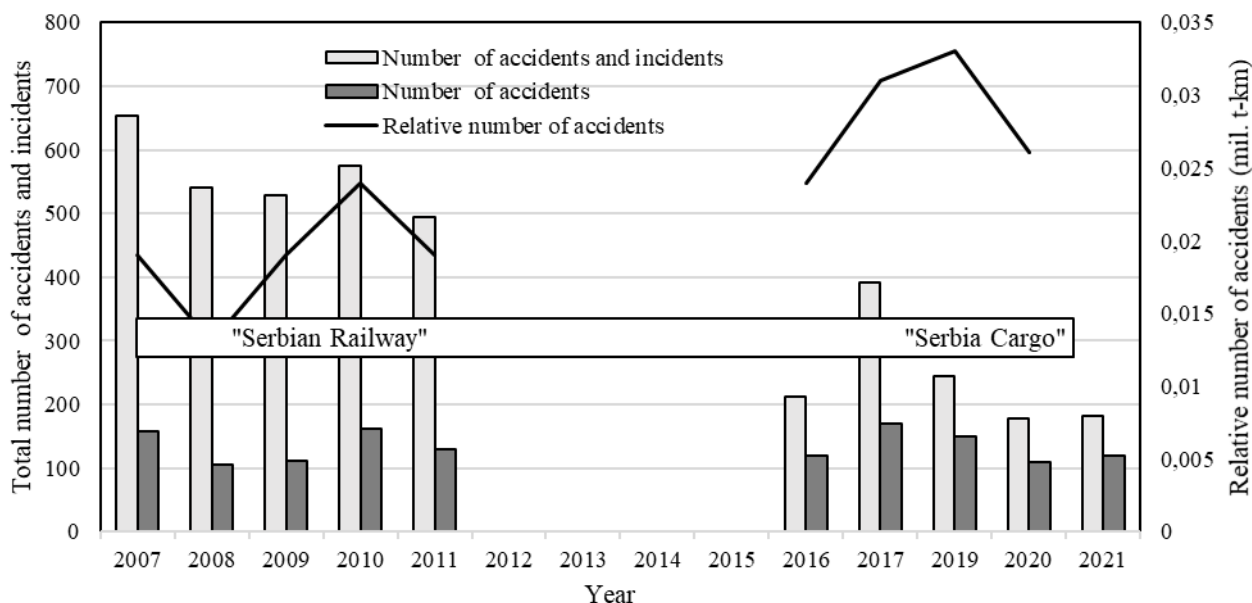


Figure 1: Total and relative railway transport safety

Besides technical conditions of railway vehicles, the origin of accidents or incidents can be technical conditions of tracks, telecommunication, control and signalling devices and power supply systems. Negligence of workers, passengers and other persons can also cause accidents or incidents, as well as unforeseeable circumstances, such as extreme weather, an earthquake etc. Origin of accidents and incidents at "Serbia Cargo" from 2017 to 2021 where irregularities of locomotives and wagons in 17% cases, irregularities of tracks, telecommunication, control and signalling devices and power supply systems in 24% cases (Fig. 4).

In 59% of cases, the origin was the negligence of workers, passengers and other persons and unforeseeable circumstances. Irregularities of locomotives and wagons at "Serbia Cargo" are the origin of accidents and incidents in 40.4% of all accidents and incidents caused by technical irregularities.

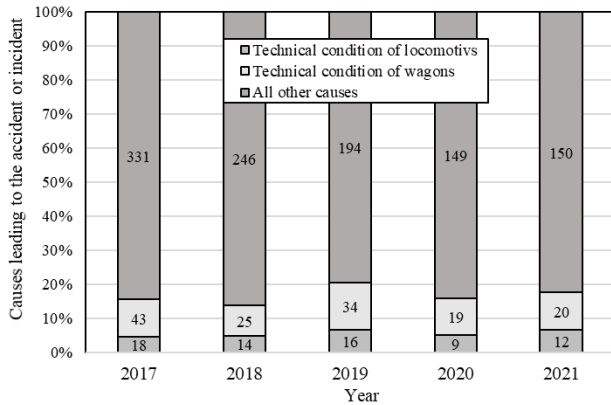


Figure 3: Technical condition of railway vehicles leading to the accident or incident

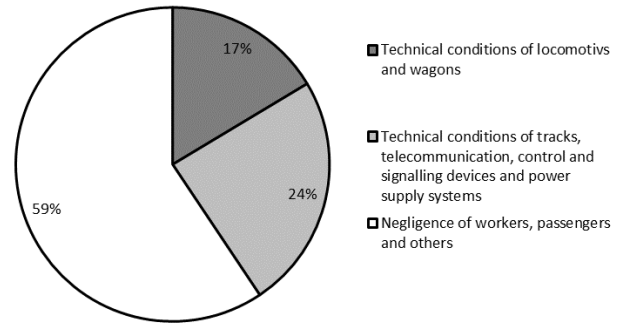
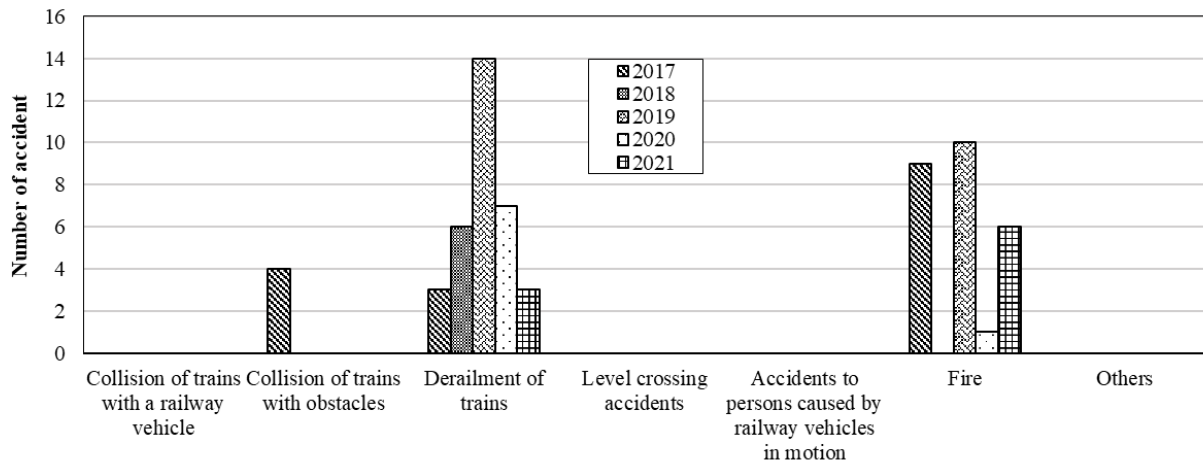
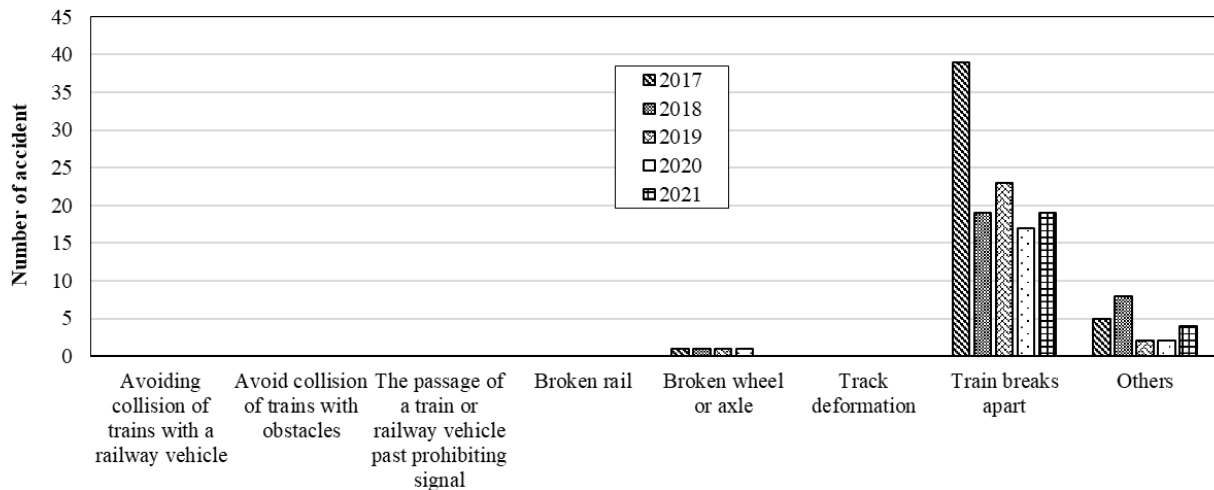


Figure 4: Average causes of accidents and incidents at "Serbia Cargo" from 2017 to 2021

The most frequent type of accident caused by the technical condition of railway vehicles at "Serbia Cargo" in the last few years were derailments of trains and fire, with an average of 15% of all accidents and incidents (Fig. 5, 6). The most frequent type of incident was train breaks apart, with an average of 56% of all accidents and incidents (Fig. 5, 6).



a) Type of accident



b) Type of incident

Figure 5: Accidents and incidents caused by the technical condition of the railway vehicles at "Serbia Cargo"

From 2017 to 2021 technical irregularities were the origin of accidents in 32% of cases and incidents in 68%. On average, in the analysed 5-year period, it has been 4 cases of collision of trains with obstacles, 33 cases of derailment, 31 cases of fire - a total of 68 cases of accidents caused by irregularity on railway vehicles. In the same period, incidents caused by irregularity on railway vehicles were 4 cases of broken wheels or axles, 117 cases of train breaks apart and 21 cases of other incidents - a total of 142 cases of incidents. The most frequent are train breaks apart with more than 23 breaks per year.

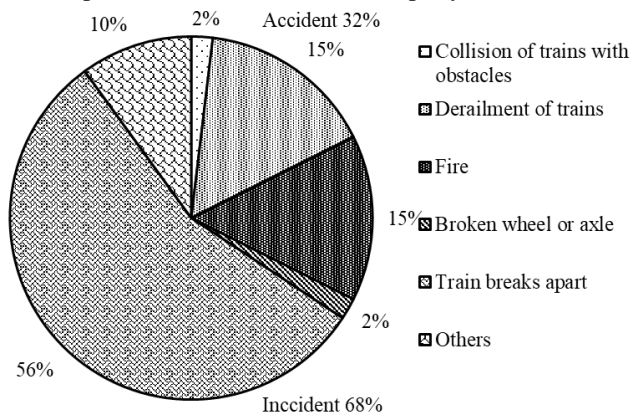


Figure 6: Accidents and incidents caused by the technical condition of the railway vehicles at "Serbia Cargo" from 2017 to 2021

In the reports on accidents and incidents at "Serbia Cargo", in the case of a derailment of railway vehicles technical irregularities of vehicles were stated as an origin, but it was usually the poor condition of the public railway network. The technical condition of the railway vehicles has not once caused accidents such as a collision of a train with a railway vehicle or level crossing accidents or accidents to persons caused by rolling stock in motion (Fig. 5a). In addition, the technical condition of the

railway vehicles has not caused accidents such as an avoided collision of trains with a railway vehicle or with obstacles, the passage of a train or railway vehicle past a signal prohibiting further driving (Fig. 5b).

The frequency of accidents and incidents caused by the technical condition of the railway vehicles has stochastic distribution from 2017 to 2021, due to changes in operational conditions (Fig. 5). Although certain types of accidents and incidents may vary through the years, there is no continuous increase that indicates serious problems.

The percentage of accidents and incidents caused by the technical condition (malfunctions) of railway vehicles is only 17%. This shows that the influence of the technical condition of railway vehicles on the occurrence of accidents and incidents is small and that other conditions leading to a large number of accidents and incidents in railway transport are crucial.

4. TECHNICAL CONDITION OF RAILWAY VEHICLES

Irregularities of freight wagons are classified by functional subsystems (Fig. 7) according to their construction and function:

- Running gear (wheelset and axle box),
 - Suspension,
 - Brake (including hand brake),
 - Bogie frame (without running gear, suspension and brake),
 - Car body and underframe,
 - Buffers and draw gear (including screw coupling).
- Irregularities concerning loads and intermodal loading units are not discussed in this analysis.

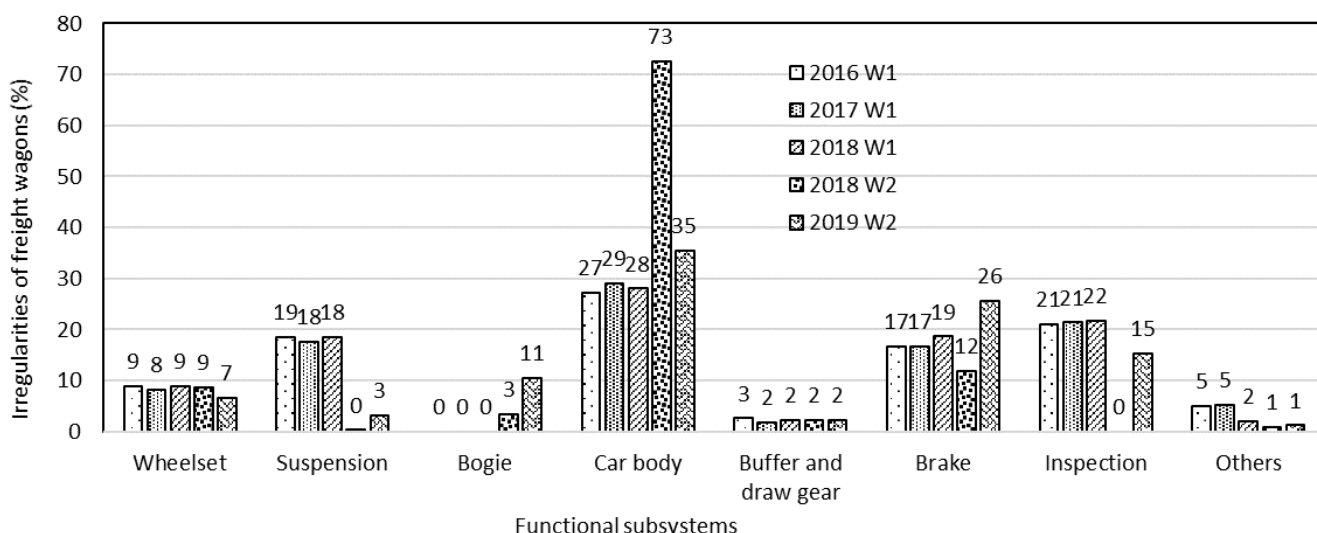


Figure 7: The frequency of irregularities in freight wagons from 2016 to 2019

Data on irregularities of freight wagons at the workshop in Niš show that 2261 wagons were taken out of operation due to malfunctions, defects and failure from 2016 to 2018. Wagons were sent for maintenance at the workshop in Niš for large-scale emergency maintenance, while 306 wagons had minor repairs (without excluding

from train). The distribution of malfunctions by functional subsystems of freight wagons is presented in Fig. 7 and 8. Data from two workshops for railway vehicles were processed [13]: one in Niš from 2016 to 2018 (mark W1 on Fig. 7) and another in Belgrade from 2018 to 2019 (mark W2).

From 2016 to 2019, it was no significant deviations in number of wagon irregularities, except for the car body in 2018 in workshop 2, when malfunctions doubled. This can be a consequence of major accidents or incidents, or other repairs carried out on wagons.

Regardless of the relatively small impact of technical irregularity of railway vehicles on transport safety, it is necessary to:

- Monitor and inspect railway vehicles for indicators of failure,
- Carry out detailed analyses of the reasons for the irregularity of railway vehicles and propose measures for their reduction,
- Implement procedures and measures for reduction.

Serious accidents are the result of the superposition of several unfavourable factors or failures. For example, if trains brake apart, automatic braking is applied. If there are vehicles with malfunctioning or disconnected brakes, the parts of the uncoupled train may come to a slower stop and pass through a closed signal or road crossing. This can result in human casualties or greater expenses. Therefore, the relatively low severity of accidents and incident consequences in everyday practice should not be a reason not to take all measures to improve the technical condition of railway vehicles.

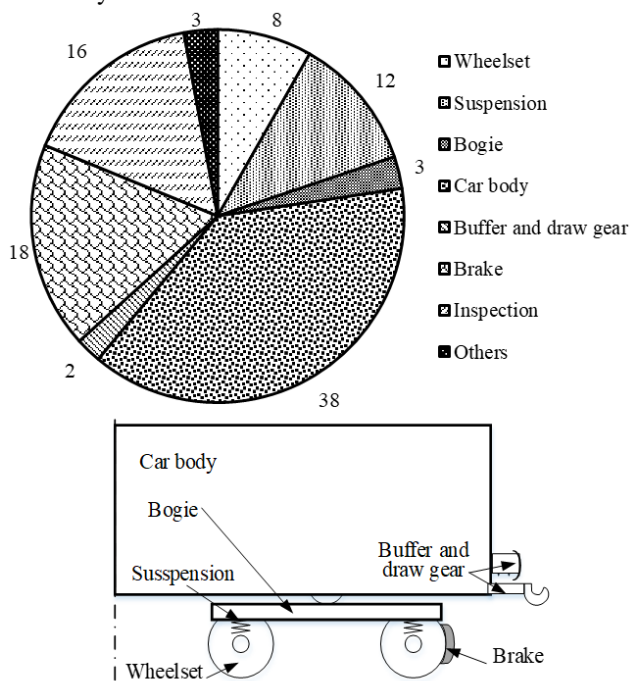


Figure 8: Average irregularities on freight wagons from 2016 to 2019

5. CONCLUSIONS

The total number of accidents on the public railway network in 2021 is approx. 15% higher than in the previous calendar year. Causes that have a great influence on this situation were unforeseeable circumstances as well as the poor condition of the public railway network, which is a consequence of long-term insufficient and inadequate investment maintenance resources and carelessness or negligence of drivers of road vehicles. Increased influence of the vehicle's condition on railway transport safety were only frequent fires in railway vehicles due to the age of the

rolling stock, wear and tear of certain components, material fatigue and inadequate maintenance [14].

Regarding the precursors of accidents, in 2021 it increased by more than 300% compared to the previous calendar year, especially the number of passing trains past a signal prohibiting further driving and crossing junctions. Personal failures of railway drivers and executive staff were determined as the main reasons, which raises issues of adequacy knowledge of regulations and concentration during work. It is also noted an increase in cases of rail fracture or track deformation, which is a consequence of the general condition and deterioration of the network of public railways, as well as inadequate maintenance [14].

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