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Diagnostics of Causes, Needs and Options of Improvement of Security in Railway Transport

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ABSTRACT: Ensuring safety of railway traffic is one of the most important goals of every state. All incidents connected with security that take place in the networks of railway lines result in taking actions aimed at elimination of similar situations in the future. The elements affecting security of the railway system include: technical condition of railway infrastructure and rolling stock, applicable law, people, that is, professional qualifications and proper performance of tasks by the workers.
The authors formulated the following research problem: what are the strengths of railway security, and what should be improved? The methodology of qualitative analysis was applied. The survey research on the level of security and diagnostics of causes, needs and options of improvement of security in rail transport were conducted. Broad analysis and inference were conducted. The directions of improvement of security in supervisory, technical, organizational and operational terms in railway transport were presented in this article.

1 INTRODUCTION

Transport is one of more important factors affecting economic development. Therefore, security should go hand in hand with developing infrastructure [1]. Railway transport, due to its features, plays significant role in transport of passengers and cargos [2-3]. Therefore, its systems affect the functioning, efficiency, quality of transport service and level of sense of security [4].

Security is a state giving a sense of certainty of existence and guarantees to maintain it. It is characterized by permissible level of the risk of loss of something very significant for an individual (health, life, tangible and intangible goods, work). The sense of security is a basic need of humans, social groups and states and international structures. Not being able to ensure security causes a sense of danger and anxiety. Human, social group, state, international systems are trying to affect their internal and external environment to avert or eliminate threats, eliminating fears, uncertainty and anxiety [11].

According to the authors of this publication, security can be defined as „processing ability, independence, identity, options of development, stability of existence" or as „state of freedom from threats, as freedom of action not associated with a sense of danger" [12]. Whereas, safety of railway traffic is „all technical and organizational actions allowing safe movement of railway vehicles and security of the workers and passengers" [26]. In accordance with definition from Ir-8 instruction manual on procedure in the event of accidents and incidents in railway transport: „Safety of railway traffic is the lack of unacceptable risk of damage in connection with execution of transport processes using railway infrastructure" [27].

The sense of security and self-confidence are the values that should be provided to the passengers at every stage of a transport process [8]. Above assumptions have significant impact on shaping safe transport systems and areas of influence (Fig. 1).

Moreover, tiredness and distraction of the engine drivers may cause the loss of concentration and slow reactions, causing dangerous behaviours while driving such as excessive speed. [23] The scientists combined subjective reports, physiological parameters and physical factors to develop the algorithms of detection of tiredness and distraction of the engine drivers [22], [24].

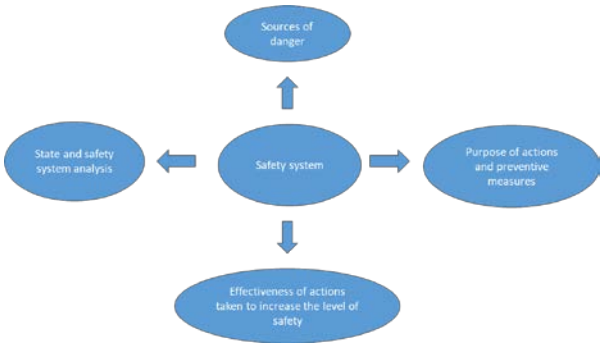

Figure 1. Security system in railway transport

Railway infrastructure is „railway lines and other structures, buildings and devices along with land occupied by them, situated in the railway area, for management, transport of people and goods, as well as maintenance of property of an administrator of infrastructure necessary for this purpose" [13].

Infrastructure of in railway transport is divided into nodal and linear [6]. Nodal infrastructure consists of operational points (operation points), expedition points, network of stations (passenger, freight, junction and intermediate). Nodal infrastructure also includes handling points and extended logistic centres along with rail-sea and rail-road terminals.

Linear infrastructure consists of the railroads, which can be divided in terms of permissible speed of trains and of intensity of transport into [14]:
- of local importance;
- primary;
- secondary;
- main.

In the European countries, geographic density of railway network amounts to about 6,2 km per 100 km2. Quick and free movement of people and cargos in the domestic logistic system depends on the condition and availability of technological infrastructure of various branches of transport [5], [7].

2 AN ANALYSIS OF PASSENGER AND FREIGHT TRANSPORT IN POLAND

Due to geographical situation, railway network in Poland plays fundamental role in international transport of goods and passengers in Europe. Poland is also a place of junction of European broad gauge network 1520 mm with standard gauge network 1435 mm (Fig. 2).

Polish transport system is a part of the European network. One of the key elements of the European network is Transeuropean Transport Network (TEN-T). TEN-T has been designed to increase efficiency of functioning of common market and to provide internal economic coherence of the European Union [25]

Figure 2. Maximum timetable speeds on the railway lines in Poland [16]

In Poland, transport activity in passenger railway transport in 2020 was lower than in 2019 - 12 654 bn passenger kilometres (Fig. 3). In comparison with previous years, the share of major long-distance carrier, that is, PKP Intercity, has clearly decreased. It was caused by the pandemic that considerably limited long-distance transport of the passengers using railway branch of transport.

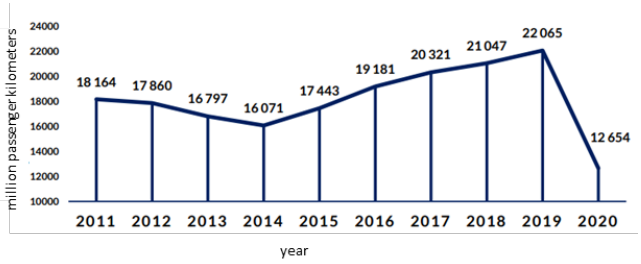

Figure 3. Transport activity in passenger railway transport in the years 2011–2020 [18]

During pandemic of coronavirus in 2020, the number of started trains has become a very important determinant, which gave the share of passenger carriers according to transport activity (Fig. 4).

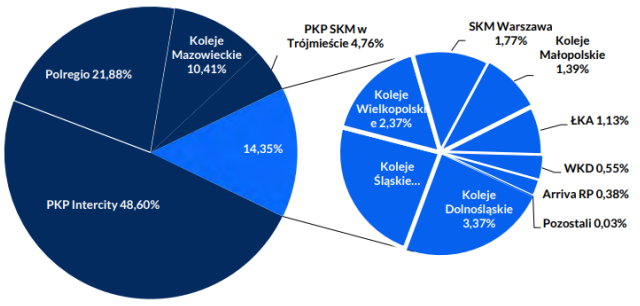

Figure 4. The share of passenger carriers according to transport activity in 2020 [18]

The impact of coronavirus epidemic on transport of goods was less perceptible in comparison with passenger transport. The results for 2020, although they were worse than in 2019, show that transport of goods by train in Poland has large potential. (Fig. 5.)

Figure 5. Mass of cargos in railway freight transport in the years 2010–2020 [18]

The last year brought major changes in market share of some carriers. The role of the enterprises functioning on the market of railway transport has increased in recent years. It is connected with such phenomena as: better access to the railway carriages and locomotives due to larger number of entities lending the rolling stock, aspirations to shorten supply chain (especially in the event of the operators of intermodal terminals), emergence of the entities providing services only in a specific geographical range – carriers working on the border areas, or creation of the railway enterprises for the purposes of execution of activity auxiliary to the main activity of the enterprises like, for example, in the sector of the producers of aggregates, or making infrastructural investments. The highest share in terms of mass and transport activity still had PKP Cargo (Fig. 6.)

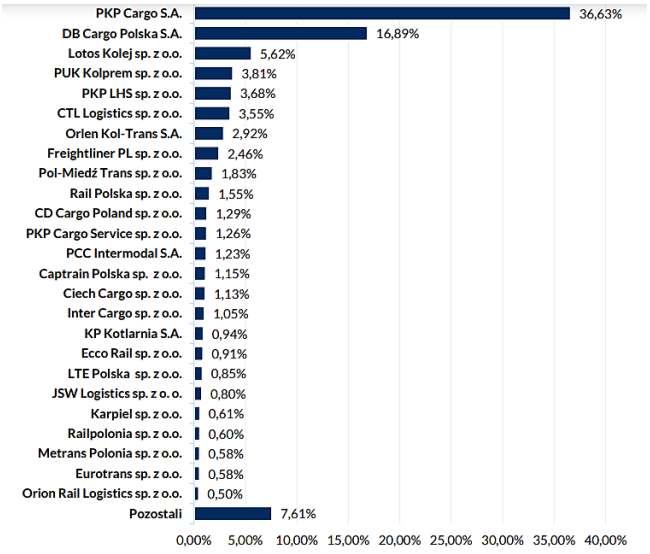

Figure 6. The share of the carriers of goods in the market in terms of mass in 2020 more than 0,5% [18]

3 THE FACTORS SHAPING SECURITY OF DRIVING IN THE LIGHT OF CONDUCTED RESEARCH

Safety of railway traffic depends on working conditions of an engine driver [10]. Therefore, in order to improve security, comprehensive actions supporting the work of this group are required [19], [21]. It must be emphasized that new rules of examinations shall apply in Poland since 2023. The changes shall be applicable only to the engine drivers. On the one hand, appropriate training is necessary since the beginning of professional career, on the other hand, work should be supported by modern technology compatible with global solutions [20].

The goal of conducted research was to present strengths of railway security and what should be improved [17]. 50 engine drivers driving rail vehicles of a railway company with a registered office in the Mazovia province took part in the survey research. The respondents were men and women. They filled in the questionnaire on their own. The respondents answered for 22 closed-end questions. Information obtained as a result of conducting the survey research include:

1. Age, sex and education.
2. The degree of perception of railway transport as a safe means of transport.
3. Determination of the number of railway accidents (collisions, derailments, incidents on the crossings, incidents involving people caused by moving railway vehicle and fires of a railway vehicle).
4. Determination of the number of incidents (incidents different than accident or serious accident affecting security).
5. The frequency of accidents involving unauthorized people while crossing the railroads.
6. The frequency of accidents involving people committing suicide and suicide attempts.
7. Determination of frequency of accidents involving people on the rail-road crossings.
8. The degree of thefts and destructions of railway infrastructure.
9. Determination of the number of train robberies and thefts of the parcels.
10. The frequency of incidents connected with throwing objects at trains.
11. The obstacles on the tracks.
12. The assessment of technical condition of the rolling stock.
13. Determination of frequency of failure of the rolling stock.
14. Non-observance of the principle of 11-hour uninterrupted rest of the workers.
15. Non-observance, at least once every four weeks, of the principle of one free Sunday.
16. Working at night-time longer than for two subsequent nights.
17. Being forced to work during sick leave.
18. Working for more than 12 hours during one shift.
19. The frequency of compliance with substitute signals or written orders.

In accordance with the assumptions, men and women at the age between 19 and 60 took part in the survey research. Table 1 presents the sample group in terms of sex.

Table 1. Description of the sample group of the respondents in terms of sex

Gender of the respondents	Number of respondents	%
Women	4	8
Men	46	92
Together	50	100

In the sample group, there are only four women working as an engine driver (Table 1). This profession is relatively not popular among women due to the character of work and source of impact of electromagnetic field [9].

The second question in the survey questionnaire distinguished the respondents in terms of their age. In the sample group, age range is uneven. The largest group of the respondents were young people at the age between 19 and 25 and between 26 and 40. The respondents at the age between 19 and 25 were 28% of all respondents, and the largest group of the respondents were at the age between 26 and 40 (52%), half of the respondents. Another group consists of people at the age between 41 and 50 - 12%. The smallest group of the respondents taking part in the survey were people at the age between 51 and above 60. (Fig. 7.)

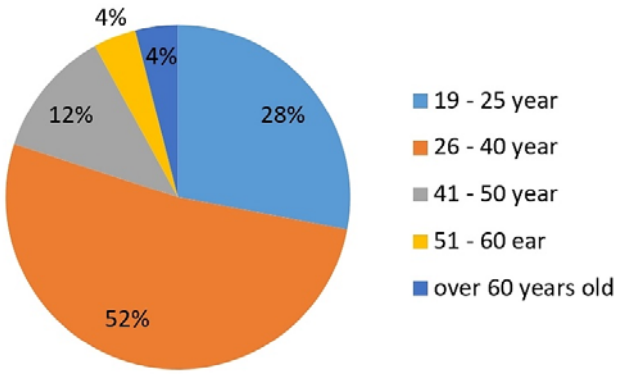

Figure 7. Description of the sample group of the respondents – age range

Question 1 referred to education of the engine drivers. Data show that among respondents, the largest group consists of people having secondary education (64%). Large percentage of the respondents have had higher education (22%). In the sample group, there are no people who have had elementary education (Table 2)

Table 2. Description of the sample group of the respondents in terms of education

Education	Number of respondents	%
Basic	0	0
Vocational	7	14
Medium	32	64
Higher	11	22

Question no. 2 referred to security of means of transport. 58% of the respondents answered that railway transport is a safe means of transport. Whereas, 36% of them that it is rather a safe means of transport, and only 6% had no opinion on this subject. In the sample group, there are no people who think that railway transport is not a safe means of transport. The opinions about security of railway transport were presented in Table 3.

Table 3. Safety of the means of railway transport

Safety of the means of railway transport	Number of respondents	%
Yes	29	58
Probably yes	18	36
I do not know	3	6

Question 3 referred to the number of railway accidents (collisions, derailments, incidents on the crossings, incidents involving people caused by a moving railway vehicle and fires of a railway vehicle) during professional career of the respondents. Figure 8 shows that during their professional career, 60% of the respondents had no railway accident. 22% of the respondents had between 1 and 5 railway accidents. Only small number of the respondents answered that the number of accidents was larger than 11. This fact shows that railway transport is safe.

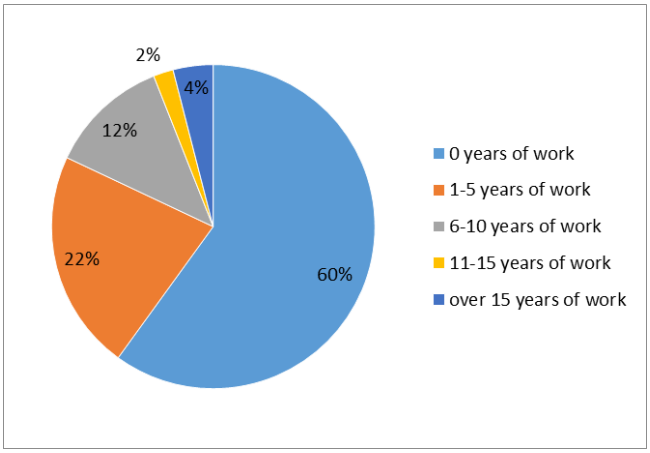

Figure 8. Railway accidents, incidents, collisions, derailments

Question 3 referred to serious railway incidents (incidents with at least one fatality, at least five heavily injured people, causing considerable damage to the railway vehicles, infrastructure). Conducted research showed that during their professional career, 65% of the respondents had no serious railway accident. 22% of the respondents had between 1 and 5 serious railway accidents. 3% of the respondents answered that the number of accidents was larger than 11. (Fig. 9.)

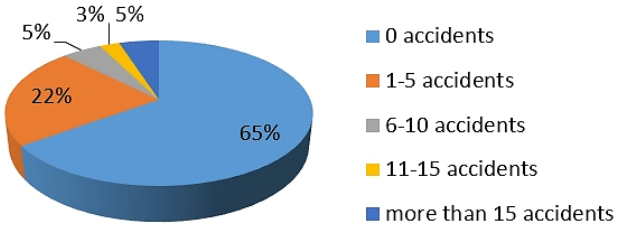

Figure 9. The accidents during professional career of the engine drivers

Question 4 referred to the number of incidents (incidents different than accident or serious accident, connected with railway traffic and affecting its security) during professional career. Conducted research showed that during their professional career, 68% of the respondents had no incident. 14% of the respondents had between 1 and 5 incidents. None of the respondents had between 11 and 15 incidents. 10% of the respondents answered that the number of accidents was larger than 15 (Table 4).

Table 4. The number of incidents during professional career

Answers given	Number of respondents	%
0	34	68
1-5	7	14
6-10	4	8
11-15	5	10
Above 15	5	10

Question 5 referred to the accidents involving people crossing the railroads. 88% of the respondents had no accidents involving unauthorized people crossing the railroads. Only one person said that above incidents are frequent phenomenon. It means that railroads are not crossed by unauthorized people who are not railway workers. Perhaps, it results from the fact that people know how dangerous is unauthorized staying on the tracks (Table 5).

Table 5. The accidents of unauthorized people while crossing the railroads

Answers given	Number of respondents	%
Not	44	88
Probably not	3	6
Probably yes	2	4
Yes	1	2

Question 6 referred to the frequency of accidents involving suicides and suicide attempts of the outsiders. 76% of the respondents said that accidents involving people committing suicides and suicide attempts are not frequent phenomenon. Only one person said that such accidents are frequent (Fig. 10).

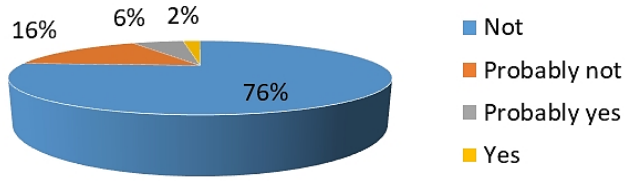

Figure 10. The frequency of suicides and suicide attempts of the outsiders

The respondents (question 7) were also asked how frequently they have accidents involving people on the rail-road crossings. 82% of the respondents answered that accidents involving people on the railway crossings never take place. Only one person said that above incidents are frequent phenomenon. Data probably show awareness and responsibility of people staying on the railway crossings and risks and threats (Fig. 11).

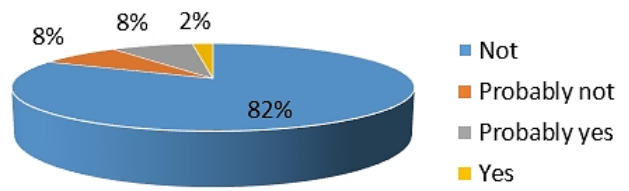

Figure 11. The accidents involving people on the rail-road crossings

Question 8 referred to theft and destruction of railway infrastructure. Thefts and destructions of railway infrastructure are not frequent phenomenon. Such answer was given by 28%. Only 6% said that thefts and destructions of railway infrastructure are frequent phenomenon (Table 6).

Table 6. Thefts and destructions of railway infrastructure

Thefts and devastation of the railway infrastructure	Number of respondents	%
Not	28	56
Probably not	9	18
I do not know	3	6
Probably yes	4	8
Yes	6	12

Question 9 referred to the frequency of train robberies and thefts of the parcels. 80% of the respondents said train robberies and thefts of the parcels never happen. Only 2 respondents answered that such phenomena rather occur (Table 7).

Table 7. The frequency of train robberies and thefts of the parcels

Frequency of train robberies and thefts of parcels	Number of respondents	%
Not	40	80
Probably not	6	12
Probably yes	2	4
Yes	2	4

Question 10 referred to the frequency of incidents connected with throwing objects at trains.

66% of the respondents have never faced such phenomenon. Whereas, 26% them answered that no one threw objects at their railway vehicles. 4% of the respondents said that such phenomenon occurs frequently (Table 8).

Table 8. Throwing objects at railway carriages

Railway carriages forging events	Number of respondents	%
Not	33	66
Probably not	13	26
I do not know	0	0
Probably yes	2	4
Yes	2	4

Then, question 11 was connected with the frequency of the obstacles on the tracks. The obstacles on the tracks are rather not left behind (54%). As many as 30% of the respondents said that this phenomenon is not frequent. Only 4% of the respondents said that obstacles often appear on the tracks (Table 9).

Table 9. The obstacles on the tracks

The answers given	Number of respondents	%
Not	15	30
Probably not	27	54
I do not know	1	2
Probably yes	5	10
Yes	2	4

Question 12 referred to the assessment of technical condition of the rolling stock. 46% of the respondents answered that technical condition of the rolling stock was good, 40% answered that it was sufficient, and 6% of the respondents that its condition was very good. Whereas, only 4% of the respondents said that condition of the rolling stock was bad. It shows that

general technical condition of the rolling stock was sufficiently good (Fig. 12).

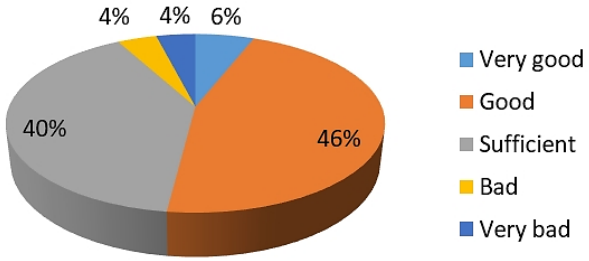

Figure 12. The assessment of technical condition of the rolling stock

Question 13 referred to the frequency of incidents connected with failure of the rolling stock. The failures of a train rather never happened to 56% of the respondents, and 30% said that such phenomenon is not frequent. This fact is very satisfactory because rolling stock used for movement of people and goods is, according to the respondents, practically failure-free (Table 10).

Table 10. The failures of the rolling stock

Rolling stock failures	Number of respondents	%
Not	36	72
Probably not	3	6
I do not know	3	6
Probably yes	5	10
Yes	3	6

Question 14 referred to the frequency of incidents of non-observance by the workers of the principle of 11-hour uninterrupted rest. Non-observance of the principle of 11-hour uninterrupted rest never happened to 76% of the respondents. Only 6% of the engine drivers faced mentioned phenomenon. Conducted research showed that in most cases, employer tries to observe the regulations on rest of the workers (Table 11).

Table 11. Non-observance of the principle of 11-hour uninterrupted rest

Failure to keep 11 hours of uninterrupted rest	Number of respondents	%
Not	36	72
Probably not	3	6
I do not know	3	6
Probably yes	5	10
Yes	3	6

Sunday Non-observance of the principle of one free Sunday at least once every four weeks never happened to 56% of the respondents. 22% of the respondents faced mentioned phenomenon (Table 12).

Table 12. Non-observance of the principle of one free Sunday

The answers given	Number of respondents	%
Not	28	56
Probably not	6	12
I do not know	0	0
Probably yes	5	10
Yes	11	22

The respondents (question 16) were asked about working at night-time longer than for two subsequent nights. The majority of the workers did not work at night-time longer than for two subsequent nights (40%). 28% of the respondents said that it rather never happened, whereas, mentioned phenomenon happened to the 24% of the respondents (Table 13). In the above case, employer also tries to observe the regulations on working at night-time. It is alarming that in the event of large number of the workers, employer does not observe above regulation.

Table 13. Working at night-time longer than for two subsequent nights

The answers given	Number of respondents	%
Not	20	40
Probably not	14	28
I do not know	3	6
Probably yes	1	2
Yes	12	24

The goal of the next question no. 17 was to analyse whether the respondents have ever worked during sick leave. Conducted research showed that this phenomenon never happened to the engine drivers (Table 14).

Table 14. Working during sick leave

The answers given	Number of respondents	%
Not	50	100

Question 18 referred to working for more than 12 hours during one shift. Conducted research showed that 54% of the respondents said that they worked longer than their applicable working time provides for. It is alarming because regulations clearly prohibit working for more than 12 hours during one shift. It may result in making more mistakes by the engine drivers because tired worker is not efficient. Only 30% of the respondents said that they did not work for more than 12 hours during one shift (Fig. 13).

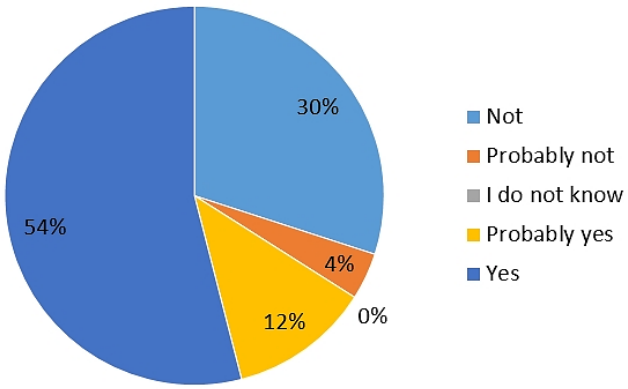

Figure 13. Non-observance of the principle of 11-hour uninterrupted rest

Finally, the respondents (question 19) were asked how often they had to comply with substitute signals or written orders while driving the train. This phenomenon occurs frequently (40%) and rather frequently (36%) (Fig. 14). It shows that there are many faults of railway traffic control devices, which during failure force the workers dealing with railway traffic control to frequently give written orders or using substitute signals, which may in consequence may pose a threat to security of the railway transport. Driving on incorrectly surfaced route and incorrectly

transmitted information are the most frequent causes of accidents.

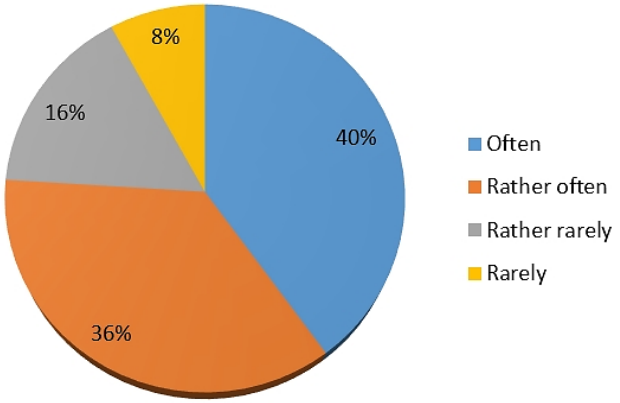

Figure 14. Compliance with substitute signals or written orders

4 RESULTS AND DISCUSSION

Conducting survey research in a group of the respondents working as an engine driver within the scope of safety of railway traffic allowed to draw significant conclusions. The majority of the respondents were men, working as an engine driver at the age between 19 and 60.

During their professional career, 60% of the respondents had no railway accident. The survey showed that 68% of the engine drivers never had an incident that would affect security. Whereas, 88% of the respondents had no accident involving outsiders in the railway area. Next part of the questions referred to the frequency of accidents involving suicide attempts. More than 75% of the respondents said that such phenomena are not frequent. The results of the research are very satisfactory because they show high degree of security in the railway transport.

Technical condition of the rolling stock is very important. 46% of the engine drivers think that condition of the rolling stock is good and 40% that it is sufficient. More than half of the respondents said that trains are failure-free.

Another important factor affecting security on the railway lines is comfort of work of an engine driver, rest and performance of obligations in accordance with applicable working time, along with rest breaks. More than 70% of the respondents never worked for 11 hours without rest break. Unfortunately, more than 50% of the respondents performed their obligations for more than 12 hours during one shift.

Properly surfaced and secured route plays a significant role in terms of accidents, incidents and events. The faults in devices and permanent modernization of railway lines forces the workers to comply with substitute signals and written orders. Conducted research showed that it is a frequent phenomenon (40%). Every mistake, violated regulation and erroneous transmission of information may turn out to be a direct threat to security.

5 THE DIRECTIONS OF IMPROVEMENT OF SECURITY IN RAILWAY TRANSPORT

The directions of improvement of security of railway transport in Poland refer, above all, to the following issues [15]:

- conditions of security of railway system;
- task force for monitoring of the level of security of railway sector;
- supervision of the entities of railway market;
- an analysis of railway incidents;
- an analysis of the accidents, serious accidents and railway incidents; incidents involving unauthorized people staying in the railway area;
- incidents involving people beyond the crossings in the stations and trails;
- suicides and suicide attempts;
- security on the rail-road crossings;
- accidents on the crossings;
- improvement of security on the rail-road crossings; acts of hooliganism on the railway network;
- thefts and destructions of railway infrastructure;
- train robberies and thefts of the parcels;
- throwing objects at trains; obstacles on the tracks;
- the assessment of technical condition of railway infrastructure;
- the assessment of technical condition of the railway vehicles;
- technical condition of the rolling stock; failure rate of the rolling stock;
- supervision of the entities of railway sector;
- supervisory actions taken by the chairman of the Railway Transport Office;
- supervision of security management systems in railway transport;
- supervision over qualifications of the railway staff;
- supervision of working time of the engine drivers employed in a few entities;
- supervisory actions taken on the railway crossings;
- the controls of the causes of application of substitute signals.

To sum up, it can be said that the issue of security of railway transport will always be topical and should be practically constantly monitored, analysed and updated.

6 CONCLUSIONS

The railway carriers and administrators of railway infrastructure, all subcontractors, operators of the traction vehicles are responsible for safety of railway traffic, as well as entities responsible for their maintenance.

In order to improve security of traffic on the railway lines and improve Security Management System (SMS), supervisory, technical and organizational and operational actions are taken, that is:

- organization of the contest „security is the most important”;
- trainings of the workers using simulators of railway traffic control and communication devices;
- sobriety checks of the workers connected with security of traffic control;
- supervision of operation points;

- listening to the conversations between engine drivers and train dispatchers;
- psychophysical trainings;
- application of protective systems, which would be installed both in the vehicles and railway infrastructure;
- running campaigns making people aware of the scale of the problem of people crossing the railroad tracks in forbidden places, leaving behind the obstacles on the tracks;
- equipping railway crossings with additional warning and security devices;
- preventive actions of the police and international initiatives for elimination of threats connected with destruction of property and theft;
- modernization and other actions connected with improvement of condition of railway infrastructure: extensive replacement of railway permanent way, modernization of railway crossings, replacement of railway traffic control devices and heavy current engineering;
- the use of DSAT devices in order to detect malfunctions of the rolling stock threatening safety of railway traffic: hot axle boxes, brakes, deformations of the wheels, exceeding dynamic loading on the track;
- implementation of the register of engine drivers in order to control working time of the engine drivers employed in a few entities;
- supervisory and administrative actions of the chairman of the Railway Transport Office towards the administrators of infrastructure
- within the scope of the causes of application of substitute signals.

Regardless of the quality of training of the engine drivers, human will always be exposed to the risk of error. Therefore, it is also important to invest in technical devices and systems supporting the work of the engine drivers. Security in railway transport should be constantly improved along with technological progress within this scope. It must be emphasized that the main goal of development of strategy of transport is to increase transport availability, improving also security of traffic participants and efficiency of transport sector, through creation of coherent, balanced and user-friendly transport system in national, European and global dimension.

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