ANALYSIS AND EVALUATION OF THE EFFECTIVENESS OF SAFETY SYSTEMS AT RAILROAD CROSSINGS IN POLAND

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Resume

The number of vehicles on the road is growing every year and each year too many people lose their lives and health on Polish roads. The number of accidents, including at level crossings, is very high. Despite the construction of new, safer roads, the number of collisions continues to grow and about three thousand accident participants die each year. The main causes of accidents are inadequate speed to the prevailing road conditions or regulations, driving under the influence of alcohol and random events. For this reason, the article analyzes the safety at railroad crossings in Poland. In the next stage, an exemplary system improving safety at railroad crossings is presented. The new solution was analysed using a survey. The research results presented may be applicable to other countries.

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1 Introduction

Railroad crossings are a very characteristic element of the railway infrastructure because two types of traffic flows (road and rail) intersect here. Due to the steady increase in traffic, the frequency of crossings is also increasing, which increases the likelihood of accidents at level crossings.

Safety is undoubtedly a very important element in the life of every human being. For years, it has been a specific object against which statistical research or various types of analyzes are conducted. Their aim is to increase the comfort in the sphere of safety of all the road users. The problem of accidents at level crossings is repeatedly mentioned on the radio and television. Social media also touches on this topic in order to reach the largest possible audience. This is to make people of all ages aware of the risk of carelessness and lack of concentration when approaching the railway crossings. However, it should be remembered that the safety itself at the railroad crossings depends mainly on behavior of the road users, as well as on the proper performance of tasks by rail and road infrastructure managers [1].

A sense of security is an integral part of the daily life of public transport users. There are many definitions of safety in the literature. One of them defines it as freedom from all the threats and such freedom of action in which we do not feel threatened [2]. There are many accidents at level crossings every year. The causes of accidents can be very different, they can be dependent on weather conditions or simply the carelessness of road users.

Safe road travel means following a number of established rules and regulations that should not be taken lightly [3]. The improvement of road safety is influenced by many elements related not only to the promotion of correct behavior among drivers [4-6], but to the proper organization of traffic, the appropriate technical condition of roads and vehicles, as well [7-11]. Training and examinations for future drivers are equally important. Road safety is a research field covering not only the above-mentioned aspects, as well as issues related to traffic supervision, emergency medical services and transport psychology [10]; road traffic safety in the analyzed city [12]; problems with the course of the procedure related to the proceeding of inflows in the first publication of [13-20].

Some publications focus on assessing the safety of level crossings in terms of detection and monitoring [21-22], others address safety using ultrasound and wireless

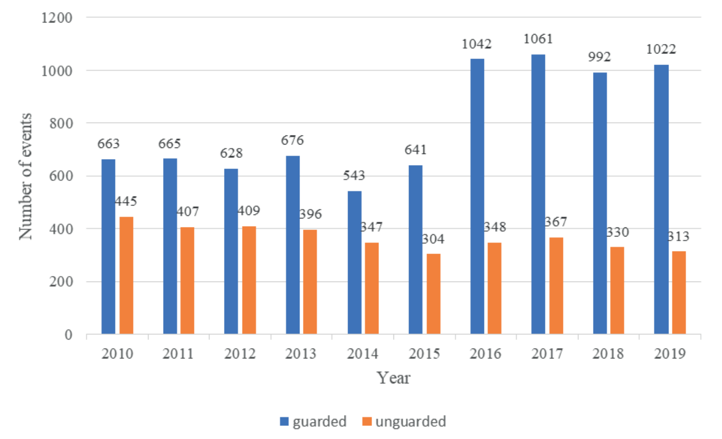

Figure 1 *Number of incidents at guarded and unguarded railroad crossings in Poland in 2010-2019 [35]*

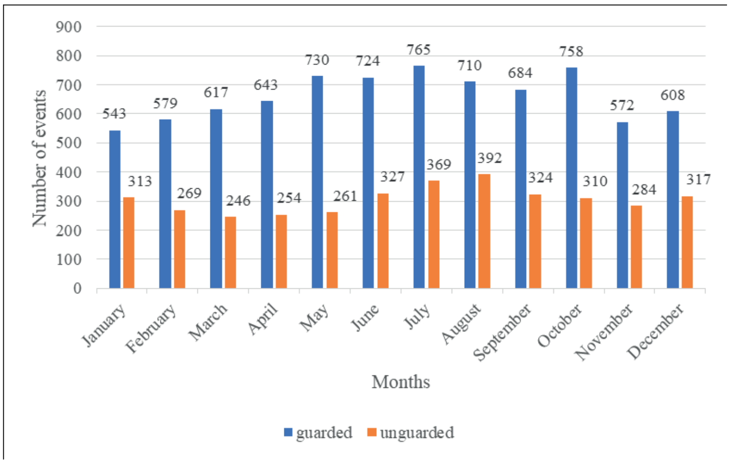

Figure 2 *The average number of incidents in individual months on guarded and unguarded level crossings in Poland in 2010-2019 [35]*

communication [23]. The possibility of increasing safety at road crossings is also discussed in Saunders et al. [24], which analyzes active elements at road and level crossings. In Widyastuti et al. [25], the authors address the safety of level crossings in Blitar on a model case. The probability of accidents at railway crossings also increases with the intensity of traffic, which is also pointed out by the publications Gasparik [26-27] and Mesko [28], which deal with capacity problems in railway transport. Addabbo et al. assess safety and safety analysis by targeted measurement. [29]. The authors of [30] investigated different situations and analyze them. Warnings for drivers before arriving at level crossings are addressed in Read et al. [31], where the authors focused on the warning alarm systems for drivers approaching the automatic level crossings. Zaman et al. dealt with map modelling of accidents at the railway crossings [32]. Another factor that affects safety at level crossings is the human factor. The reason may be carelessness, inexperience of drivers or violation of road traffic regulations. These factors are investigated by Akaateba et al. [33] and Salmon et al. [34]. The authors focused on the analysis of psychological factors that affect professional drivers and new drivers.

2 Safety at railroad crossings

Analyzing the data in Figure 1, one can see that more events take place at guarded crossings. These are crossings where the safety is ensured by people (railway crossing - category A). The increase in the number of accidents on guarded crossings as compared to unguarded ones, may result from the fact that in these places there is a man guard, who may faint at any moment, or simply forget to activate the barrier. In Poland, guarded crossings constitute 17.5 and unguarded crossings - 82.5 of all the crossings. The largest number of accidents on guarded level crossings (74 of events in a given year) took place in 2017, while the largest number of accidents on unguarded level crossings (40 of events in a given year) occurred in 2010. An incident at the unguarded level of crossings may also be caused by a careless driver who ignores the half-barriers at the level crossings. These are very dangerous situations and pose a threat to other road users, because the driver of the car does not comply with the road traffic regulations.

Most accidents at guarded level crossings in Poland (Figure 2) occurred in July (67% of events in a given month). In turn, the fewest events took place in

January (63% of events in a given month). At unguarded crossings, most accidents took place in August (36% of incidents in a given month), while the lowest number of accidents in March (29% of incidents in a given month). The reason for the increased number of accidents during the holiday months may be the fact that most people travel during this time, which is causing the increased traffic on the roads.

The largest number of persons who died on guarded crossings (Figure 3) was in 2010 (15 persons), seriously injured in 2017 (18 persons) and slightly injured in 2010 (18 persons). The smallest number of persons died in 2013 (4 persons), seriously injured in 2012 (4 persons), slightly injured in 2018 (3 persons).

Most persons died at unguarded railway crossings (Figure 4) in 2012 (33 persons), seriously injured in 2015 (24 persons) and slightly injured in 2011 (70 persons). The smallest number of persons died in 2010 and 2014 (18 persons), seriously injured in 2011 (16 persons), slightly injured in 2019 (17 persons).

The most common cause of accidents at guarded railway crossings in Poland was running into a railway barrier (72.83 %). The incident may have occurred because the drivers were rushing ahead of the oncoming train. Running an animal was the rarest cause of accidents (0.08 %). It can also be seen that the most common side collisions at rail and road crossings were sideways (45.46 %). The rarest animal was run over (0.20 %). The average number of incidents on guarded level crossings was 661 and at unguarded level crossings 326 [35].

The most common type of vehicles in incidents on guarded and unguarded railway crossings in Poland is a passenger car (50.56% - guarded crossings, 70.56% - unguarded crossings). The reason why a passenger car is most often involved in the incidents may be the fact that, according to GUS (Central Statistical Office) data, the number of registered vehicles increases every year [39]. The least frequent incidents involving a motorcycle with a capacity of up to 125 cm3 occur on guarded and unguarded crossings (0.05% - guarded crossings, 0.02% - unguarded crossings). The average number of vehicles on guarded crossings was 676 and on unguarded crossings - 342 [35].

As can already be seen from the above statistical data, the situation at the rail and road crossings in Poland is not ideal in terms of safety. To improve safety, a solution should be applied that will enthusiastically

Figure 3 *Number of persons who died, seriously injured and slightly injured on guarded railway crossings in Poland in 2010-2019 [35]*

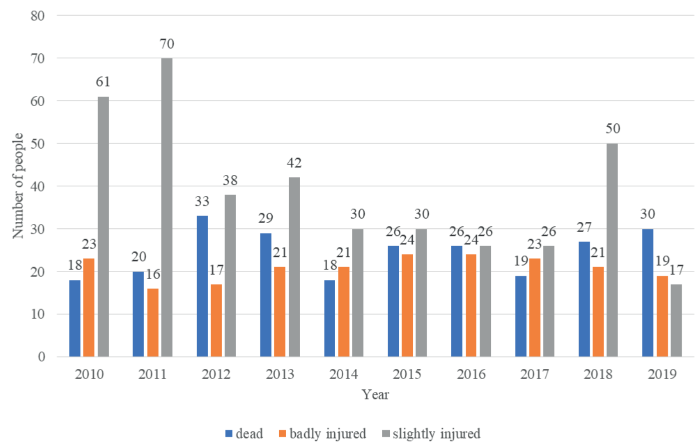

Figure 4 *The number of persons who died, seriously injured and slightly injured on unguarded railway crossings in Poland in 2010-2019 [35]*

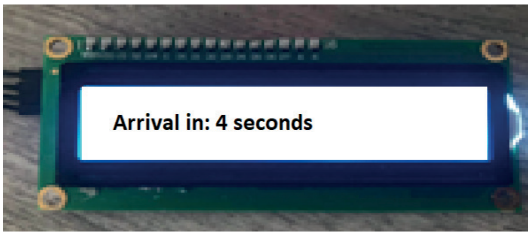

Figure 5 *Time display used in the demonstration model*

Figure 6 *Demonstration model with time display*

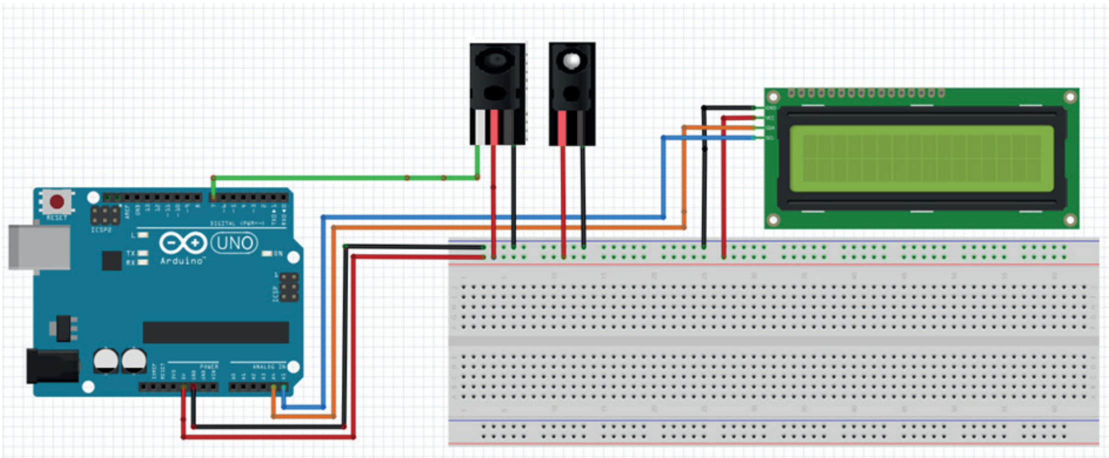

Figure 7 *Connection diagram*

encourage road users to improve conditions in such a dangerous place as the railroad crossing. For this reason, the authors propose to use the time display on the railroad crossings and it has not been tested or described anywhere. This is the basis for the implementation of the new solution as a test facility to improve safety at the railroad crossings.

A device that can improve safety at railroad crossings is a time display (Figure 5), which would count down the seconds until the front of the train appears at the railroad crossing. The solution would be placed at the single-track crossings. It can be a supplement to the already existing level crossing signals, e.g. at level crossings with traffic lights only. It could also be the main warning device at the D level crossings, because, according to PKP (Polish State Railways) data, these are the most numerous crossings in Poland [36]. Level crossings and level crossings are classified into the following categories [37]:

- category A - level crossings for public use with horned barriers,
- category B - level crossings of public use with automatic traffic lights and half barriers,
- category C - level crossings of public use with automatic traffic lights,
- category D - level crossings of public use without horns and half-gates and without automatic traffic lights
- category E - level crossings for public use,
- category F - crossings and level crossings of non-public use.

The inspiration for creating such a device was the already existing time display, which was used at road intersections. It tells drivers in how many seconds the light color will change. In European countries, exhibitions of this type are slightly less popular than in Asian countries, but there are, among others, in Greece, Belgium and Croatia [38]. There are two types of counters in Poland: for drivers and for pedestrians. The most frequently used counters in Poland are solutions attached to the siren. For the first time, the exhibition at intersections appeared in Opole in 2007. From that moment, more and more cities began to decide on this type of solution, including Torun, Poznan, Wroclaw, Zielona Gora and Szczecin [39].

3 Assumptions for the project

The time display counts down 6 seconds before the front end of the train reaches the level crossing. The train covers the entire length of the track in 9.8 seconds. The total length of the track is 280 cm. The train speed is 0.29 m/s. All the rail vehicles at the railroad crossing point move at the same speed. The sensors that the train must pass through for the display to start counting down are 174 cm from the railroad crossing. Figure 6 shows the demonstration model.

4 Connection diagram

The display and the infrared sensor (Figure 7) are connected via the contact plate to the 5 V (red) and GND (ground) (black) power supply. Signals that allow text to be displayed on the LCD (Liquid-crystal display) are connected to the SDA (data line) -> A1 and SCL (clock line) -> A0 connectors. The light barrier sends the obstacle signal with a green wire to connector 7 on the Arduino Uno. Arduino UNO is a board for learning electronics and programming.

5 The principle of operation of the device (on the mock-up)

The receiver and the transmitter of the infrared sensor are placed opposite to each other on both sides of the tracks (Figure 8). During the normal operation, both elements "see each other". When a train passes through them, the light barrier is broken and a signal is sent to the microcontroller during this time. Arduino uno, after receiving information about an obstacle, starts the time countdown algorithm. At the same time, the display shows information about the time remaining until the train arrives at the railroad crossing. After the train has passed through the crossing, the measuring device returns to the rest mode and waits for the next signal from the infrared sensor.

6 Assumptions for the actual use of the time display

The time display counts down 60 seconds before the front end of the train reaches the level crossing. The train speed is 70 km/h. All the rail vehicles at the railroad crossing point move at the same speed. The load cells through which the train must pass in order for the display to start counting down are 1166 meters from the railroad crossing and the inductive sensors are 1366 meters away.

7 The principle of operation of the device at the selected intersection

On the Pila - Ulikowo railway line, on which there is a railroad crossing, the maximum axle loads for the wagon and locomotive are 221 kN (approx. 25 tons) [36]. In this case, for the display to work properly, one needs

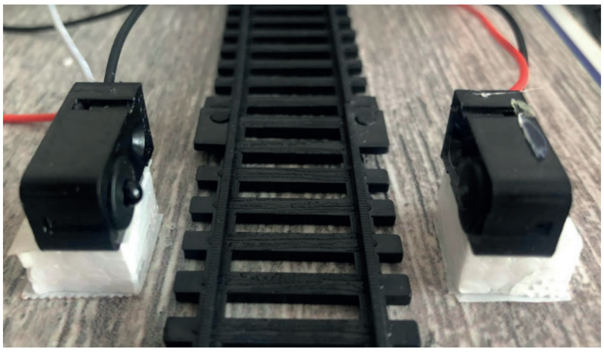

Figure 8 *Setting the sensors*

Figure 9 *Visualization of the device installation on the railroad crossing*

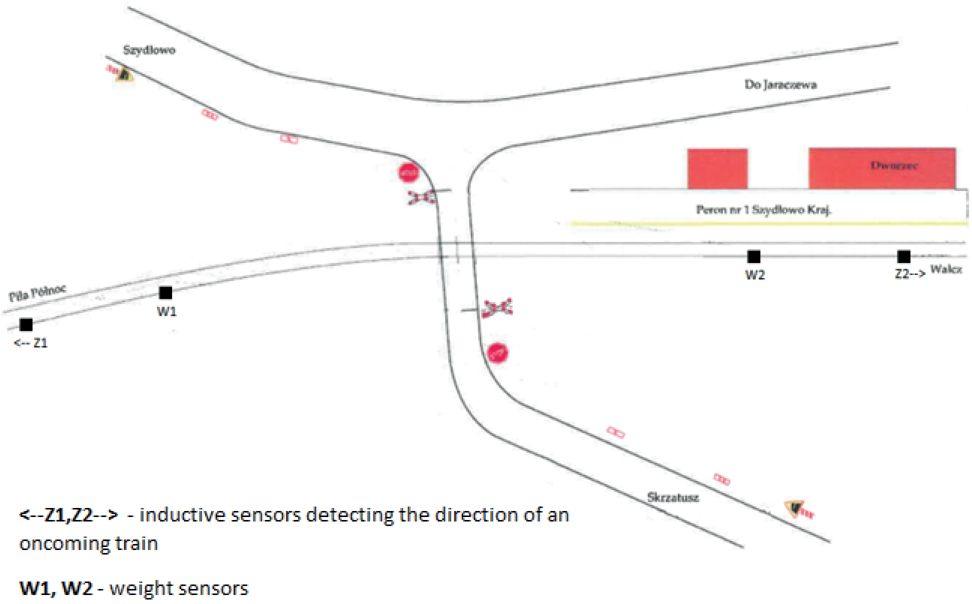

Figure 10 *Arrangement of sensors on the railroad crossing*

to use weight sensors. The infrared sensor could not be connected, as a passing animal or human may interrupt the light beam at any time, which would disturb the display. Another element that is actually used is an inductive (proximity) sensor that detects the direction of the train. This is necessary because the solution was applied at a single-track crossing where trains run in two directions. The inductive sensor sends a signal to the weighing sensor about the approaching train from the direction of the inductive sensor. Figure 10 shows the arrangement of strain gauges and inductive sensors. Arduino uno, after receiving information about exceeding the weight, starts the time countdown algorithm. At the same time, the display (Figure 9) shows information about the time remaining until the train's arrival at the railroad crossing. After passing the railway crossing, the measuring device returns to the ready state and waits for the next signal from the weighing cell.

8 Materials and methods

The survey technique was used to conduct this research. This was due to the prevailing COVID-19 pandemic from February to April 2021. The survey form is a deliberately created set of properly formulated questions that are then asked to the surveyed group of people. The survey was anonymous and consisted of 17 questions - including one on respondent's age. Before conducting the targeted research, a pilot one was carried out on a selected group of respondents. People were asked questions prepared for the target survey. Then, appropriate conclusions were developed, which showed that it is possible to conduct the study on a larger number of respondents. They could choose one of the answers provided or enter their own. The survey also included an open-ended question. The results obtained from the study are aimed at checking the level of knowledge in the field of behavior on the railroad crossings and checking whether drivers and pedestrians feel safe on the railroad crossings with the use of modern hazard warning systems, opinions on the proposed solution.

9 Object of research

The respondents constitute: 69.5% of women and 30.5% of men. The questionnaire was completed by 3.6% of women and 3.28% of men under the age of 18, 36.69% of women and 36.07% of men aged 18-25, 26.6 2% of women and 29.51% of men aged 18-25. 26-36 years of age, 18.71% of women and 11.48% of men aged 37-46, 14.39% of women and 19.67% of men over 47 years of age (Table 1). The greater number of answers given by women may result from the fact that, according to the latest data of the Central Statistical Office, the number of women in Poland is dominant (51.63%) [26].

According to the data in Table 2, 82% of the respondents have a driving license and 18% do not. The majority of both men and women holding a driving license were aged 18-25 (women - 29.50%, men - 32.79

***Table 1** Gender and age structure*

	Woman	Man	Woman	Man
Under 18	5	2	3.60%	3.28%
18 - 25	51	22	36.69%	36.07%
26 - 36	37	18	26.62%	29.51%
37 - 46	26	7	18.71%	11.48%
Over 47 years old	20	12	14.39%	19.67%
Sum	139	61	100.00%	100.00%

***Table 2** Answers to the question: "Do you have a driving license?"*

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Yes	0.00	29.50	23.74	15.83	10.07
No	3.60	7.19	2.88	2.88	4.32
Sum	3.60	36.69	26.62	18.71	14.39
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Yes	0.00	32.79	27.87	9.84	18.03
No	3.28	3.28	1.64	1.64	1.64
Sum	3.28	36.07	29.51	11.48	19.67

Table 3 *Place of residence*

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Pila	0.72	10.07	12.95	9.35	6.47
5 - 12 km from the city center	1.44	3.60	2.88	2.16	2.16
13 - 25 km from the city center	0.72	6.47	5.04	2.16	1.44
More than 25 km from the city center	0.72	0.72	5.76	0.72	4.32
Sum	3.60	20.86	26.62	14.39	14.39
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
5 - 12 km from the city center	0.00	14.75	9.84	4.92	4.92
13 - 25 km from the city center	0.00	4.92	0.00	3.28	3.28
More than 25 km from the city center	1.64	6.56	4.92	0.00	6.56
Sum	1.64	1.64	14.75	1.64	4.92
5 - 12 km from the city center	3.28	27.87	29.51	9.84	19.67

Table 4 *Means of transport*

Woman, %					
Answer / Age	Under 18	18 – 25	26 - 36	37 - 46	Over 47 years old
Bike	1.44	2.16	1.44	0.72	0.72
Car	0.00	30.94	20.86	12.23	9.35
Train	0.72	1.44	0.72	1.44	0.72
Bus	1.44	2.16	3.60	4.32	2.88
Others - scooter	0.00	0.00	0.00	0.00	0.72
Sum	3.60	36.69	26.62	18.71	14.39
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Bike	3.28	1.64	0.00	0.00	0.00
Car	0.00	29.51	26.23	9.84	16.39
Train	0.00	0.00	1.64	0.00	0.00
Bus	0.00	4.92	1.64	1.64	1.64
Others - scooter	0.00	0.00	0.00	0.00	1.64
Sum	3.28	36.07	29.51	11.48	19.67

%). The overwhelming number of men may result from the fact that, according to the Central Register of Vehicles and Drivers, 17.6 million people have a category B driving license, of which 60% are men and 40% are women [35].

The data in Table 3 present the places of residence of the research group. According to the information, 38% of respondents live in Pila, 12% of persons are 5-12 km from the city center, 17% of persons live 13-25 km from the city center and 33% of respondents live more than 25 km from the city center. Most of the respondents living in Pila are women (12.95%) aged 26-36 and men (14.75%) aged 18-25. The highest number of answers was given by women from Pila (39.57 %), which may be because, according to the Central Statistical Office, 73,139 persons live in Pila, of which 52.2% are women [40].

10 Results

The first question asked to the respondents concerned the most frequently used means of transport (Table 4). According to the data, most of the respondents, both women (30.94%) and men (29.51%) aged 18-25, drive a car. The second place was taken by the group of persons aged 26-36 (women - 20.86%, men - 26.23 %). Most road users use a car (Figure 11) (76 %). The next most frequently used means of transport is the bus (13 %), 6% use the bicycle, 4% choose the train, 0.5% of the research group walk and 0.5% use the scooter.

The next question was whether the respondent witnessed an accident at the railroad crossing. Reading the data in Table 5, one can see that 12.50% of respondents participated in an accident at a railroad crossing, while the vast majority of respondents did not participate in such an event (87.50 %). The discrepancy may be because not all the railroad crossings with accidents are located in places with high traffic. Most women (4.32%) aged 18-25 participated in accidents.

Another question was about persons who were involved in an accident at a railroad crossing. According to the information contained in Table 6, it can be seen that a greater number of respondents did not answer this question (88.50 %), although 11% were observers of events at railroad crossings and 1 person was injured in an accident at the crossing. The group of observers was dominated by women (4.32%) aged 18-25.

Another question was posed to persons who witnessed an accident at the crossing and it was at which railroad crossing the accident took place. Most of the respondents (Table 7) witnessed an accident on a single-track crossing (54.17 %), while 45.83% saw an accident on a double-track crossing. The greatest number

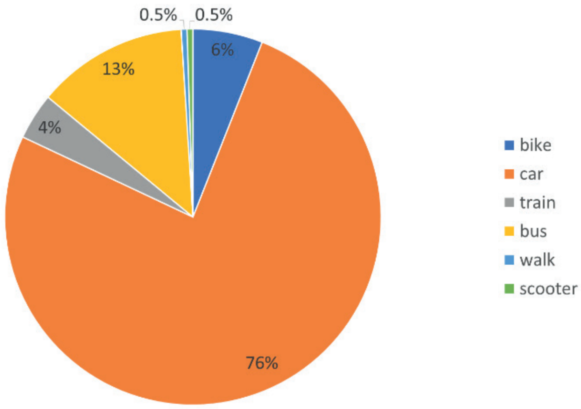

Figure 11 *Means of transport of the respondents*

Table 5 *Responses to the question: "Have you been / have you witnessed an accident at a railroad crossing?"*

		Woman, %			
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Yes	0.72	4.32	3.60	2.88	1.44
No	2.88	32.37	23.02	15.83	12.95
Sum	3.60	36.69	26.62	18.71	14.39
		Man, %			
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Yes	0.00	3.28	3.28	1.64	3.28
No	3.28	32.79	26.23	9.84	16.39
Sum	3.28	36.07	29.51	11.48	19.67

Table 6 *Responses to the question: "During the incident, what were you?"*

		Woman, %			
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
An observer	0.72	4.32	3.60	2.16	1.44
The injured	0.00	0.00	0.00	0.00	0.00
Perpetrator	0.00	0.00	0.00	0.00	0.00
Not applicable	2.88	32.37	23.02	16.55	12.95
Sum	3.60	36.69	26.62	18.71	14.39
		Man, %			
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
An observer	0.00	1.64	3.28	0.00	3.28
The injured	0.00	0.00	0.00	1.64	0.00
Perpetrator	0.00	0.00	0.00	0.00	0.00
Not applicable	3.28	34.43	26.23	9.84	16.39
Sum	3.28	36.07	29.51	11.48	19.67

Table 7 Responses to the question about the crossing which the incident took place on

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Monorail	0.00	11.11	11.11	16.67	5.56
Two-track	5.56	22.22	16.67	5.56	5.56
Multi-track	0.00	0.00	0.00	0.00	0.00
Sum	5.56	33.33	27.78	22.22	11.11
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Monorail	0.00	16.67	16.67	16.67	33.33
Two-track	0.00	0.00	16.67	0.00	0.00
Multi-track	0.00	0.00	0.00	0.00	0.00
Sum	0.00	16.67	33.33	16.67	33.33

Table 8 Responses to the question: "What was the cause of your accident?"

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Driver error	0.00	29.41	23.53	5.88	11.76
Malfunctioning warning devices against railroad crossing	5.88	5.88	5.88	11.76	0.00
Other	0.00	0.00	0.00	0.00	0.00
Sum	5.88	35.29	29.41	17.65	11.76
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Driver error	0.00	0.00	0.00	0.00	33.33
Malfunctioning warning devices against railroad crossing	0.00	16.67	33.33	16.67	0.00
Other	0.00	0.00	0.00	0.00	0.00
Sum	0.00	16.67	33.33	16.67	33.33

of accidents was observed at single-track crossings, because according to statistical data on events at railway crossings, there are more single-track crossings [36]. Most of the surveyed women (16.67%) aged 37-46 and men (33.33%) over 47 saw the event while traveling. None of the respondents saw an accident on a multi-track crossing.

According to the respondents' answers in Table 8, 39.13% answered that the cause of the accident was a faulty warning device at railroad crossings, while 60.87% assessed the situation as a driver's error. The majority of women (29.41%) aged 18-25 and men (33.33%) aged over 47 stated that the cause of the accident was driver's error, while 11.76% of women aged over 47 and men (33.33%) aged 26-36 believed that the event occurred as a result of incorrect operation of warning devices at the railroad crossing.

In the next question, the respondents who witnessed the accident at the railroad crossing could present in writing what the accident looked like. Below are the most common descriptions provided by respondents:

- "The lights were off and a car was crossing the tracks. The train was approaching and began to warn with siren/honk. The passenger car sped up, but the train hit the rear of the car, pushing it to the side of the road. Nobody was hurt, but the entire rear of the car was crushed "
- "The driver did not stop in front of a stop sign and the train hit the back of the trailer"
- "We were driving with my brother-in-law and the traffic lights allowed us to cross the tracks. Suddenly, a train came around the bend. My brother-in-law sped up and drove into the ditch"- response of the injured person,
- "The driver did not adjust the speed and stopped at a stop sign and there was a collision"
- "There was a train and the gates did not close"
- "The barrier were almost deserted and the driver has pulled into the crossing. He survived, but it didn't look good. "
- "The barrier began to close and the traffic lights were on and the passenger car still wanted to pass before the gates were closed"
- "The machine reached the intersection, the warning lights were not flashing and the train was approaching"

Analyzing the answers of the respondents, one can see that incidents at the level crossings are caused both by drivers and by improperly operating warning systems of the oncoming trains. The participants in the accident also responded to an open question. The person should not place complete confidence in the safety system, i.e. not rely only on its proper functioning.

The next three questions concerned the behavior of drivers at the railroad crossings. According to the answers given by the respondents (Table 9), most of them always stick to the signs placed in front of the railroad crossing (88.5 %). 11% of respondents said that they "sometimes follow the signs". Out of the entire research group (0.5%) of persons replied that they never obey the signs placed there. Most women (33.81%) aged 18-25 and men (24.59%) aged 18-25, 26-36 replied that they always obey the signs at the railroad crossing. This may be because they are young drivers, which makes them more sensitive to dangerous situations and the things around them.

Another question was about the behavior at a railroad crossing equipped with barriers and traffic lights. Analyzing the answers of the respondents (Table 10), one can see that most road users know how to behave at an intersection equipped with barriers and traffic lights. As many as 84.5% of respondents replied: "I am waiting for the barrier to lift completely, the red light will stop flashing and only then I am crossing the railway crossing". It proves. that both pedestrians and drivers are particularly careful, which means that they obey traffic regulations [41] and that their own safety is important to them. Another answer was: "I check that nothing is coming and I cross the railroad". This answer was chosen by 15% of the respondents. Another answer

Table 9 *Responses to the question: "Do you follow the road signs placed there before entering / entering the railroad crossing?"*

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Always	3.60	33.81	23.74	16.55	14.39
Sometimes	0.00	2.88	2.16	2.16	0.00
Never	0.00	0.00	0.72	0.00	0.00
Sum	3.60	36.69	2.88	2.16	14.39
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Always	3.28	24.59	24.59	9.84	18.03
Sometimes	0.00	11.48	4.92	1.64	1.64
Never	0.00	0.00	0.00	0.00	0.00
Sum	3.28	36.07	29.51	11.48	19.67

Table 10 *Responses to the question: How do you behave at the railroad crossing equipped with barriers and traffic lights?*

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
I wait for the turnstiles to go up completely. the red light to stop blinking and I pass	3.60	33.81	23.74	14.39	11.51
I check that nothing is coming and I am crossing the railroad crossing	0.00	2.88	2.88	4.32	2.88
Otherwise (the respondent could enter his/her answer here)	0.00	0.00	0.00	0.00	0.00
Sum	3.60	36.69	26.62	18.71	14.39
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
I wait for the turnstiles to go up completely. the red light to stop blinking and I pass	1.64	22.95	22.95	11.48	19.67
I check that nothing is coming and I am crossing the railroad crossing	1.64	13.11	4.92	0.00	0.00
Otherwise (the respondent could enter his/her answer here)	0.00	0.00	1.64	0.00	0.00
Sum	3.28	36.07	29.51	11.48	19.67

Table 11 *Responses to the question: How do you behave at the railroad crossing equipped with traffic lights?*

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
I check if the train is coming. If not - I pass	1.44	9.35	5.04	6.47	0.72
I stop and I wait for the blinking lights to go out	2.16	27.34	21.58	12.23	13.67
Otherwise (the respondent were able to enter their answer here)	0.00	0.00	0.00	0.00	0.00
Sum	3.60	36.69	26.62	18.71	14.39
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
I check if the train is coming. If not - I pas	3.28	14.75	8.20	1.64	1.64
I stop and I wait for the blinking lights to go out	0.00	21.31	21.31	9.84	18.03
Otherwise (the respondent were able to enter their answer here)	0.00	0.00	0.00	0.00	0.00
Sum	3.28	36.07	29.51	11.48	19.67

Table 12 *Response to the question: "Do you ever enter the railroad crossing without being particularly careful?"*

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Always	0.00	1.44	0.72	1.44	1.44
Sometimes	0.00	9.35	5.76	2.16	0.72
Never	3.60	25.90	20.14	15.11	12.23
Sum	3.60	36.69	26.62	18.71	14.39
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Always	0.00	1.64	1.64	0.00	0.00
Sometimes	0.00	19.67	14.75	1.64	2.88
Never	3.28	14.75	13.11	9.84	5.76
Sum	3.28	36.07	29.51	11.48	8.63

was chosen by a man aged 26-36 and it was: "I am waiting for the gate to rise high enough for my car to fit and I am going through." It can be concluded that the person who marked this answer does not pay attention to the safety systems used at the level crossings. It is therefore necessary to continuously educate road users to minimise the risks at the level crossings.

The next question was concerned with behavior of the road users on crossings equipped with traffic lights. The information provided by the respondents, given in Table 11, shows that as many as 75% of the respondents replied, "I stop and wait until the flashing lights go out". Such an answer was given by the greatest number of women (27.34%) aged 18-25 and men (21.31%) aged 18-25 and 26-36. This proves that both pedestrians and drivers care about their own safety and pay attention to the safety systems used. On the other hand, 25% of respondents only check that the train is not coming and if it does not they pass.

The next question was, "Do you ever enter a railroad crossing without being careful?" Analyzing the responses (Table 12), one can see that the majority of respondents (70%) are particularly cautious at the railroad crossings. As many as 25.5% of the research group persons sometimes forget the said rule, which is the cause of undesirable events at the railway crossings. The questionnaire was also completed by persons who are not particularly careful (4.5%) and thus pose a threat to themselves and other road users. Persons with the answer "always" are mostly women. The greatest number of "never" answers was given by women (25.9%) and men (14.75%) aged 18-25. This is evidenced by the fact that the majority of students in this age group obtain their knowledge on the road safety at school.

Another question, related to the sense of security, was: "Do you think that the current safety devices at the railroad crossings (traffic lights, gates, sound devices) provide sufficient safety?" According to the answers given by the respondents (Table 13), most of them do not feel completely safe using the current security

Table 13 *Responses to the question: "In your opinion, do you think the currently used safety devices at the railroad crossings (traffic lights, barriers, sound devices) ensure sufficient safety?"*

	Woman, %				
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Yes - I feel safe	2.16	15.83	9.35	7.19	3.60
I do not know - despite the devices used. I still do not feel safe entering the railroad crossing	0.00	17.27	13.67	8.63	7.19
No	1.44	3.60	3.60	2.88	3.60
Sum	3.60	36.69	26.62	18.71	14.39
	Man, %				
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Yes - I feel safe	3.28	11.48	4.92	1.64	4.92
I do not know - despite the devices used. I still do not feel safe entering the railroad crossing	0.00	18.03	18.03	9.84	6.56
No	0.00	6.56	6.56	0.00	8.20
Sum	3.28	36.07	29.51	11.48	19.67

Table 14 *Responses to the question: "What do you think about the use of an additional device before the railroad crossing, which is a time display, which would count down seconds (e.g. 20 seconds) until the train enters the railroad crossing?"*

	Woman, %				
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Absolutely - I am open to new technological solutions that will improve safety at railroad crossings	3.60	32.37	23.74	16.55	11.51
I do not know	0.00	0.72	1.44	2.16	1.44
No - I don‘t see the need for such a device	0.00	3.60	1.44	0.00	0.72
Other (here the respondent was able to enter his/her answer)	0.00	0.00	0.00	0.00	0.72
Sum	3.60	36.69	26.62	18.71	14.39
	Man, %				
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Absolutely - I am open to new technological solutions that will improve safety at railroad crossings	1.64	32.79	24.59	11.48	14.75
I do not know	1.64	0.00	3.28	0.00	1.64
No - I don‘t see the need for such a device	0.00	3.28	1.64	0.00	3.28
Other (here the respondent was able to enter his/her) answer	0.00	0.00	0.00	0.00	0.00
Sum	3.28	36.07	29.51	11.48	19.67

systems (48.5 %). The answer "No" was given by 17% of the respondents, while 34.5% of the research group answered "Yes". The majority of both women (17.27%) aged 18-25 and men (18.03%) aged 18-25 and 26-36 do not feel safe using the current security systems. This proves that road users are waiting for new safety systems' improvements that will increase their safety comfort when approaching a railway crossing.

Another question posed to the respondents was: "What do you think about the use of an additional device before the railroad crossing, which is the time display proposed by the authors, which would count down seconds (e.g. 20 seconds) until the train enters the railroad crossing?" According to the answers of the respondents (Table 14), one can see that most of them (87%) are interested in a new technological solution, which is a time display. The answer "I do not know" in the survey was given by 6% of the respondents and 6.5% saw no need to use such a device. 0.72% of women over 47 believed that the application of the above solution would pose a threat as it would provoke careless drivers to pass in front of the train. To dispel any doubts, the new solution could be implemented on a single level crossing in conjunction with a camera to observe the behavior of drivers and then consider whether the device is completely safe.

Table 15 *Responses to the question: "If an additional device was used that could improve safety at railroad crossings, would you pay attention to it?"*

Woman, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Yes	2.16	32.37	24.46	17.99	12.95
Maybe	1.44	4.32	2.16	0.72	1.44
No	0.00	0.00	0.00	0.00	0.00
sum	3.60	36.69	26.62	18.71	14.39
Man, %					
Answer / Age	Under 18	18 - 25	26 - 36	37 - 46	Over 47 years old
Yes	1.64	31.15	29.51	11.48	19.67
Maybe	1.64	4.92	0.00	0.00	0.00
No	0.00	0.00	0.00	0.00	0.00
sum	3.28	36.07	29.51	11.48	19.67

The last question asked by respondents was: "If an additional device was used that could improve safety at railroad crossings, would you pay attention to this?" Analyzing the responses (Table 15) of the respondents, the majority, as many as 91% of respondents, declared that they would pay attention to a new, additional device and 9% of the respondents answered "Perhaps". Neither person gave a negative answer. The majority of both women (32.37%) and men (31.15%) aged 18-25 answered "yes", while 4.32% of women and 4.92% of men aged 18-25 answered "maybe".

11 Discussion

When assessing a new safety system, first of all, attention should be paid to the annual number of accidents. Among other things, it was this factor that prompted authors to propose the time display as a security solution. One should constantly strive to reduce the accident statistics from year to year. The answers of the respondents play a key role in this case, because, as one can see in the question about what traffic users think about the new, additional device, as many as 87% of respondents said that they are most open to new technological solutions that would improve safety at the level crossings - road traffic. If the road users accept the new solution, the time display could also be used on crossings of other categories, not only D. However, the priority is given to crossings of this category, as they are dominant by the number of unfortunate events.

Another way to reduce the number of accidents is to focus on reducing the number of the level crossings, which can be achieved through cooperation between the state, regions and municipalities. The modernization of the level crossings must be in line with national and international standards and norms, as declared by the research of Luptak et al. [42]. Another solution is to take technical measures aimed at clarifying and simplifying the traffic situation at the level crossings, as proposed and recommended in several studies [43-45]. For this reason, it makes sense to introduce this solution at one of the level crossings and to observe the behaviour of drivers crossing the crossing. Will they respect the timer or will they enter the crossing despite the countdown to the train's arrival?

12 Conclusion

The main goal of improving the safety at the railroad crossings is to significantly reduce the risk for life and health in rail and road traffic. In most cases, haste and lack of care for security systems lead to material losses at best.

The poor technical condition of the pavement at the intersection of public roads and railroads should be repaired as soon as possible from the moment the pavement damage is reported. However, in majority of cases, the retrofitting occurs at the time of an accident.

According to statistical data, most accidents occur at level D level crossings. These crossings are only equipped with a "Stop" warning sign. Equipping D category crossings with the new technological solutions, such as a time display, can significantly improve safety in such difficult places. The new system can also complement the existing systems (e.g. at level C level crossings). Modernization or additional auxiliary systems may lead to a gradual lowering of the accident curve at the railroad crossings.

Another important aspect is educating the public and future road users about the dangers and rules of behaviour at the railway crossings. An example of such activities are special actions conducted by PKP. Increasing the awareness of young drivers that stopping a vehicle before each railroad crossing is an obligation to save lives. Eliminating behaviours leading to accidents will definitely improve the level of safety at the railroad crossings.

The research results presented may be applicable to other countries. Authors of the article propose an improvement in safety at a single-track crossing where the train moves at a set speed. In the next stage, the authors plan to extend the research to double-track crossings where the trains would move at different speeds.

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