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AN EXAMPLE OF HOW TO IMPROVE SAFETY AT SELECTED PEDESTRIAN CROSSINGS

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Abstract

Road safety continues to be a critical issue, especially for vulnerable road users such as pedestrians walking across the road at a place designated for the purpose. The most effective method of safety improvement at pedestrian crossings is to install traffic lights to control traffic. Such a solution cannot be used anywhere, however, due to the risk of the lack of flow capacity, especially in the area of nearby junctions. Therefore, persons responsible for traffic safety look for alternatives to improve the situation at pedestrian crossings. To meet the expectations of those persons, this article proposes mechatronic systems which are worth installing at selected pedestrian crossings to improve safety and reduce the number of traffic incidents involving vulnerable people. Three pedestrian crossings, considered dangerous by the authors, and located in the town of Nowy Sącz, were taken for analysis. Among the safety features, the use of an active sign informing of a pedestrian crossing, reflective elements and LED lights embedded in asphalt, as well as active pedestrian crossing illumination, are suggested. The proposed solutions are distinguished by low operating costs, as energy needed to power those solutions is obtained from photovoltaic panels.

Keywords: pedestrian crossing; road safety; road incident; road transport

1. Introduction

The increase in the number of motor vehicles, as well as the growing population density of towns, affect the traffic volume in various road user groups and, consequently, the number of accidents [14, 17]. This is particularly evident in large metropolitan areas [10, 20]. Human inattention very often leads to fatal accidents [13, 18]. A large number of pedestrian accidents occur at pedestrian crossings [24]. Pedestrians are a group of road users most directly exposed to contact with vehicles. Half of all the pedestrian accidents are caused

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by the inappropriate behaviour of vehicle drivers, with nearly 70% of incidents occurring at pedestrian crossings, resulting in more than 200 deaths per year [1, 9]. A pedestrian is an important participant in road traffic, but, as statistics show, somewhat neglected by other road users [8].

Among road users, pedestrians belong to a particularly high-risk group as vulnerable road users [5, 22]. Particularly vulnerable are the elderly, those aged 75 years and over, and young people who use, for example, mobile phones when walking along the crossing [6]. Any actions to improve safety should therefore be aimed at ensuring adequate protection of the health and lives of road users, including pedestrians [3, 11, 23]. In Poland, delineating marked pedestrian crossings is still treated as the primary way to make it easier for the pedestrians to cross the road. Meanwhile, there is a misconception among the public that a pedestrian crossing is a place where it is safe to cross the roadway [19]. A pedestrian crossing leading through a roadway or tramway is an area where two road users, the vehicle and pedestrian, move at the same time. It is here where the hitherto safe pedestrian faces a fatal danger – entering the vehicle movement area [13]. Therefore, better pedestrian visibility at crossings has a significant impact on road safety improvement. Despite continuous efforts to improve the safety of pedestrians and other vulnerable road users, the number of accidents at pedestrian crossings is significant [25].

Figure 1 shows quantitative data pertaining to accidents at pedestrian crossings in 2018–2022. A downward trend in the number of accidents can be observed each year, which is a very positive phenomenon. A considerable decrease by 252 accidents in the first six months of 2020 and 536 accidents in the second half of that year can be noted compared to the previous year. One of the reasons for that phenomenon was the COVID-19 pandemic in Poland and the related quarantine and restrictions on moving around in public places.

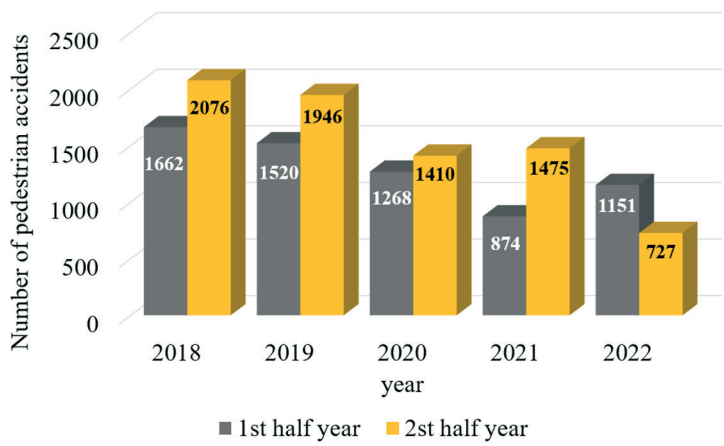

Fig. 1. The number of pedestrian accidents at pedestrian crossings in Poland

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However, a decrease in the number of road accidents at pedestrian crossings is still observed after 2020. Safety improvement can be attributed not only to higher driving culture, but also to changes in traffic regulations giving priority to pedestrians over vehicles, those changes becoming effective on 1 June 2021. Pursuant to the new regulation, a driver approaching a pedestrian crossing is obliged to exercise special caution and reduce speed so as not to endanger a pedestrian who is at the pedestrian crossing or entering onto it. At present, breaking that regulation is punishable by a heavy fine, which amounts to PLN 1,500, and by 15 penalty points. Recent years have seen the introduction of mechatronics at pedestrian crossings and their better illumination. This makes a pedestrian more visible, which also has a major impact on the reduction of the number of accidents at pedestrian crossings.

By analysing the data in the diagram, one can see that a higher number of accidents at pedestrian crossings occurs in the second half of the year. That situation takes place every year under analysis except 2022. The phenomenon can be explained by the increased traffic during the holiday season, when people mainly use road transport when going on holiday. In addition, in the second half of the year, in autumn and winter, road and environmental conditions are worse, fog and rain occur, dusk falls earlier and pedestrians often wear dark clothes. These factors reduce road visibility and contribute to a higher risk of a traffic incident at a pedestrian crossing.

Figure 2 presents the number of pedestrians injured in accidents at a pedestrian crossing, and Figure 3 summarises the number of pedestrians killed at the crossing. There is a downward trend in both the statistics pertaining to the number of pedestrians injured and those killed, which is directly related to fewer traffic incidents at pedestrian crossings. For comparison, 3609 persons were injured in 2018, an average of 300 per month, and only 1821 injured in 2022, an average of 151 per month. The situation is similar in terms of the fatalities. For comparison, 270 persons were killed in 2018, an average of 22 per month, and as few as 113 killed in 2022, an average of 9 per month.

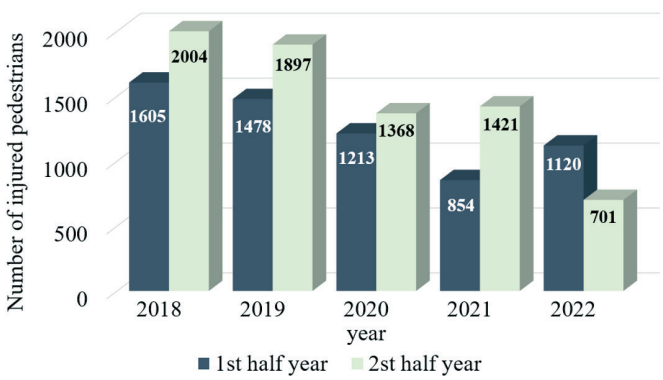

Fig. 2. The number of pedestrians injured in pedestrian crossing accidents in Poland

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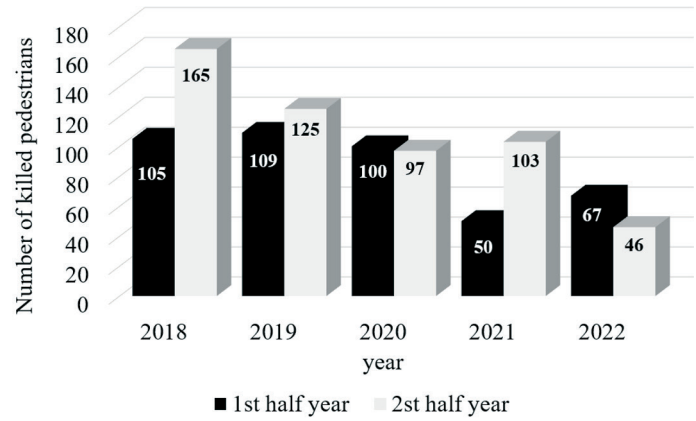

Fig. 3. The number of pedestrians killed in pedestrian crossing accidents in Poland

Pedestrian crossing accidents occur through the fault of both vehicle drivers and pedestrians. The most common cause of accidents through the driver's fault is his or her failure to give way to pedestrians due to inattention or excessive speed that prevents the vehicle from slowing down and stopping in time, and failure to stop at a red light. The causes of accidents through the pedestrian's fault include entering the pedestrian crossing directly in front of a moving vehicle, stepping onto the roadway from behind a vehicle or an obstacle, or walking through a red light.

Even though statistics show a smaller number of injuries and casualties at pedestrian crossings, dangerous traffic incidents still occur. They happen because there are places in Poland where pedestrian crossings are poorly marked or there are various obstacles close by, which reduce visibility to both pedestrians and drivers. In such a situation, it seems that intelligent pedestrian crossings are those elements of road infrastructure that improve pedestrian crossing visibility and directly influence safety [2, 7, 12]. Therefore, the aim of this article is to propose, at selected pedestrian crossings, the mechatronic systems that will improve safety and reduce the number of road incidents involving vulnerable people [20, 27]. Three pedestrian crossings, considered dangerous by the authors, and located in the town of Nowy Sącz, were taken for analysis. Similar crossings are, however, located in various places in Poland, and the proposed solutions may be implemented there, too. The article uses fragments of engineering work [26], the photographic documentation included in chapters 2–4 was used.

This article is an introduction to the development of specific standard solutions, which will be discussed in detail in subsequent publications.

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2. Research methodology

The article proposes mechatronic solutions that improve safety at selected pedestrian crossings. In order to identify the most dangerous, according to the author, pedestrian crossings, a site visit was carried out.

After selecting selected pedestrian crossings, a survey was conducted in their area to learn the opinions of people using these crossings regarding safety.

The survey was conducted among drivers and pedestrians using selected pedestrian crossings. A total of 520 persons of different ages and genders took part in the survey, and selected responses are presented in Chapter 4.

Based on the survey results and the author's own observations, appropriate mechatronic systems were proposed that could improve the safety of pedestrians and drivers at pedestrian crossings.

Next, road traffic safety experts were asked to comment on the application of the proposed remedial measures to improve road traffic safety at the indicated pedestrian crossings.

The study was conducted using the Delphi method. The Delphi method is a type of expert research in which experts' opinions, often intuitive, are treated as a significant contribution to establishing a vision of the future of the research subject [4].

The research methodology consisted of the following stages [4]:
- formulation of the Delphic theses,
- development of the Delphi survey questionnaire,
- selection of experts,
- development of results
- formulating conclusions and recommendations.

In the first stage of the research procedure, four Delphi theses were formulated regarding ways to improve safety at previously selected pedestrian crossings. They read as follows:

Thesis 1: The safety of road users within selected pedestrian crossings will be improved by the use of high-speed signaling.

Thesis 2: The safety of road users within selected pedestrian crossings will be improved by the use of a speed bump.

Thesis 3: The safety of road users within selected pedestrian crossings will be improved by the use of a mechatronic system, which includes: active reflective elements, active D-6 road sign, active crossing lighting.

Thesis 4: The safety of road users within selected pedestrian crossings will be improved by the use of new, more efficient pedestrian crossing lighting.

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In the second stage, a Delphi survey questionnaire was developed. A set of the same questions was formulated for each of the theses.

In the third stage of the research procedure, experts were selected. Eight road safety specialists were invited to participate in the study.

In the fourth stage, research was carried out. The experts were provided with a Delphi survey questionnaire and asked to respond. Each of them defined their position on the theses presented.

The fifth stage of the presented methodology consisted in developing the results of the Delphi study.

3. The choice of pedestrian crossings with reasons

The first of the places under analysis is the pedestrian crossing located at Lwowska Street. This is a crossing near the junction with Heleny Modrzejewskiej Street. That street is one of the busiest roads in the town because of the direct connection with national roads DK–28 and DK–75 and because of a large shopping mall located in the area. There is a high risk of pedestrian incidents at that location due to limited visibility to both pedestrians and drivers. A sample photograph of that location with poor visibility to a pedestrian wishing to cross is shown in Figure 4. Visibility is often reduced by cars parked nearby, which limit the driver's field of vision. When cars are parked as shown in the figure, a driver travelling along Lwowska Street from the junction with national road No. 75 often notices the pedestrian at the very last moment and is forced to brake sharply. After dark or in unfavourable weather conditions, the visibility of a pedestrian entering that crossing decreases dramatically. In the picture, the pedestrian is marked with a red arrow.

Fig. 4. A pedestrian crossing the road at the crossing located at Lwowska Street – the view from the driver's perspective

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In order to be noticed at that crossing, the pedestrian has to step out from behind the motionless car, which creates a dangerous situation on the road. Cars parked on the right also reduce the visibility of pedestrians who want to cross the road at that location. They cannot see whether a car is approaching from the right and often step out onto the roadway as shown in Figure 5 when assessing the situation on the road. Thus, the pedestrian is already on the crossing, so pursuant to the new regulations, the driver is obliged to give way to the pedestrian. In many cases, sudden braking takes place, which creates the risk of further cars crashing into each other.

Fig. 5. A pedestrian crossing the roadway at Lwowska Street

As mentioned previously, that street is one of the busiest in the town and a large number of pedestrians cross the roadway there. The authors' observations show that every tenth car stopping in front of the crossing has to brake sharply because the driver notices a pedestrian crossing the road at the very last moment. From the pedestrian's perspective, visibility is reduced, too, and the pedestrian cannot see vehicles coming from the right.

The second location analysed in this article is the pedestrian crossing located at Aleje Piłsudskiego (Figure 6). This is a dual carriageway with national road DK–75 running along. At the avenue, car, bicycle and pedestrian traffic is heavy. The road is a section of the route to Krynica–Zdrój and Slovakia. There are also shops and a housing estate in the area. The speed limit at the road section under analysis is 60 km/h. The pedestrian crossing under analysis is well signposted. Pedestrian crossing and speed limit signs are placed on reflective boards. Pedestrian safety at that location may, however, be at a greater hazard than at other crossings due to the factors mentioned previously, so completing the crossing with mechatronic systems would be a good solution.

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Fig. 6. A pedestrian crossing at Aleje Piłsudskiego as seen from the driver's perspective

The third pedestrian crossing discussed in this article is the crossing located at Zygmuntowska Street. That street runs within the DK-87 national road leading to, including other places, Piwniczna-Zdrój and Slovakia; therefore vehicle traffic at that place is busy, particularly during rush hours. It is also noticeable that of children using the nearby primary school. Thick traffic is also generated on Sundays. As a church attended by worshippers from all over the town and surrounding areas is also located at that street. That crossing appears to be unsafe due to certain infrastructure elements that may impede visibility to both drivers and pedestrians. Figure 7 shows the pedestrian crossing from the driver's perspective, with a pedestrian waiting to cross (red arrow). Figure 8, on the other hand, shows the same crossing, but from the perspective of a pedestrian assessing the situation on the road on his or her left side. The pedestrian standing on the other side of the street is also poorly visible, especially during the rush hour, as they are obscured by a line of cars waiting to drive onto the nearby junction. The pedestrian there has limited visibility and only assesses the situation at the other lane once he or she has entered the centre of the roadway.

Fig. 7. The pedestrian crossing at Zygmuntowska street as seen from the driver's perspective

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Fig. 8. A pedestrian crossing at Zygmuntowska street as seen from the pedestrian's perspective

4. Analysis of the survey results

The question regarding the feeling of safety at the pedestrian crossing was answered as presented in Figure 9.

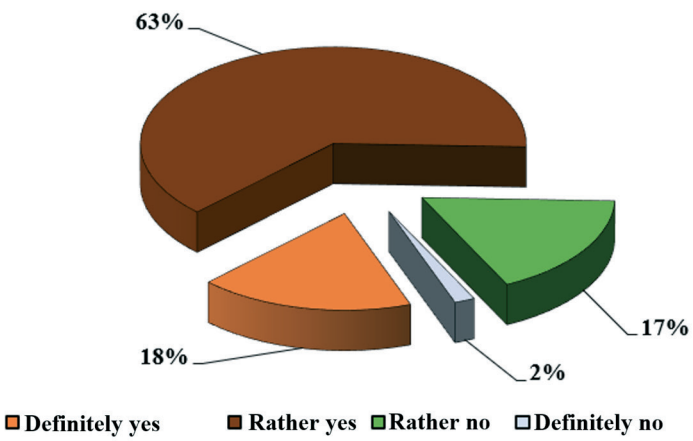

Fig. 9. The response to the question: "Do you feel safe at this pedestrian crossing?"

The most common response to the question was "Rather yes". This response was given by as many as 63% of the respondents, which may indicate a lack of confidence about safety at all the three pedestrian crossings. The respondents feel that the crossings are marked clearly enough to cross the street at ease, but would see a need to highlight the crossings in these locations more distinctly. The "Rather yes" responses were mainly given by pedestrians.

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Local drivers know that special caution should be exercised by them when they approach these pedestrian crossings. 17% of respondents believe that those crossings are among the dangerous ones, and 2% of respondents are afraid to use them due to poor visibility from the perspective of any road user. The answers given to this question suggest that safety improvement elements should be implemented at those pedestrian crossings. Dynamic mechatronic systems would be the best solution.

The second question was about the factors which, according to the respondents, influence the lack of the feeling of safety at pedestrian crossings. The results of the survey are presented in Figure 10.

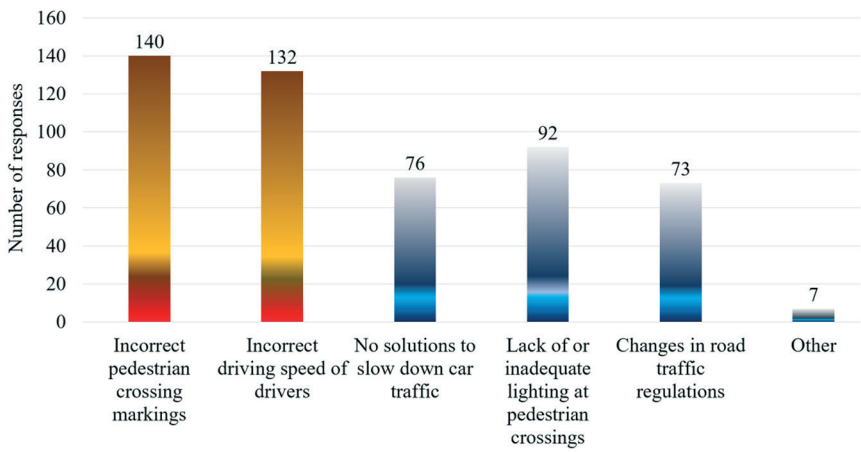

Fig. 10. The answer to the question "In your opinion, which factor contributes most to the lack of the feeling of safety at a pedestrian crossing?"

The most frequent two answers mentioned inadequate signage of the pedestrian crossing and the drivers' excessive speed. The respondents justified their answers by stating that the zebra was not always repainted and, due to that, it nearly completely disappeared. On the other hand, drivers noted that some pedestrians are distracted and enter the crossing without first making sure that no vehicles are approaching. The second most frequent answer was substantiated by the respondents by stating that some drivers exceed the allowable speed and fail to slow down before the pedestrian crossing. There are also drivers who overtake a vehicle that stops in front of the pedestrian crossing. That situation was observed on the dual carriageway at Aleje Piłsudskiego.

In the next question, the respondents were requested to indicate, in their opinion, the most effective safety improvement solutions at pedestrian crossings. The responses to this question are shown in Figure 11.

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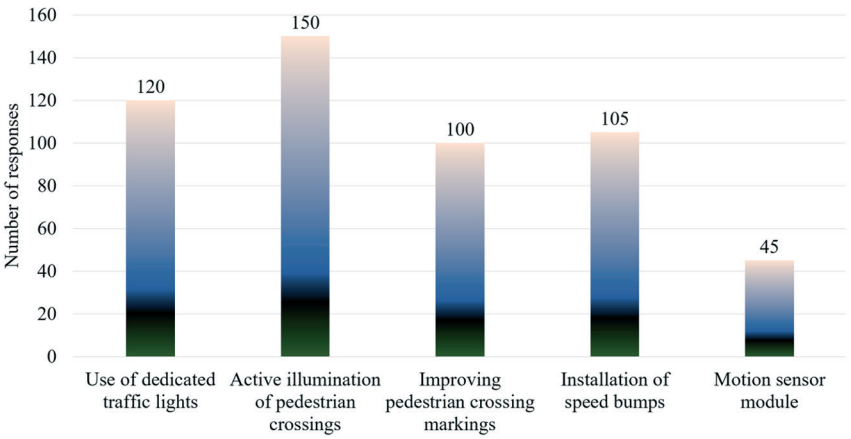

Fig. 11. The answer to the question: "Please indicate, in your opinion, the most effective safety improvement solutions at a pedestrian crossing?"

The most common answer was the use of active illumination for pedestrian crossings. This type of lighting works particularly well after dark or in difficult road conditions, such as during fog or on cloudy days. As part of active illumination, the respondents indicated not only lamps that provide extra light at the pedestrian crossing, but also systems embedded in asphalt or the foot pavement that are activated when a pedestrian appears. The use of active lighting will enable the driver to spot the pedestrian in sufficient time and avoid the risk of an accident.

In the survey, drivers were also asked about the risks created by pedestrians. The responses to this question are presented in Figure 12.

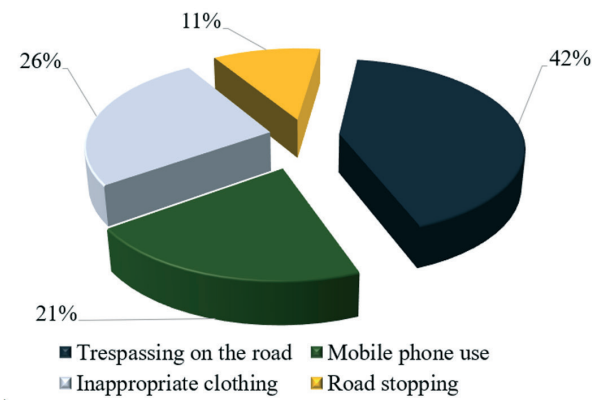

Fig. 12. The answer to the question "Please indicate situations hazardous to safety at a pedestrian crossing due to the pedestrian's fault?"

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The survey results demonstrated that, according to drivers, the most common factor directly jeopardizing safety at a pedestrian crossing is a pedestrian stepping onto the roadway without first ensuring that there is no oncoming vehicle. This may be due to the pedestrian being lost in thought or a conversation with a companion. It is common for a pedestrian to rush into the roadway from behind an obstacle or a parked vehicle. The second major cause of dangerous situations at pedestrian crossings, according to drivers, is the inappropriate clothing of the pedestrian. Pedestrians often wear dark or black clothes, which makes it difficult to see them from a distance after dark. The situation becomes worse when, after dark, it is wet and raining.

5. Results of an expert study conducted using the Delphi method

Experts answered questions regarding the four Delphic theses. They determined their level of knowledge about issues related to improving safety at selected pedestrian crossings. They also determined the time period within which the thesis could be implemented in order to improve traffic safety. Then they determined the importance of the thesis for improving road safety. A summary of the experts' knowledge level is presented in Figure 13.

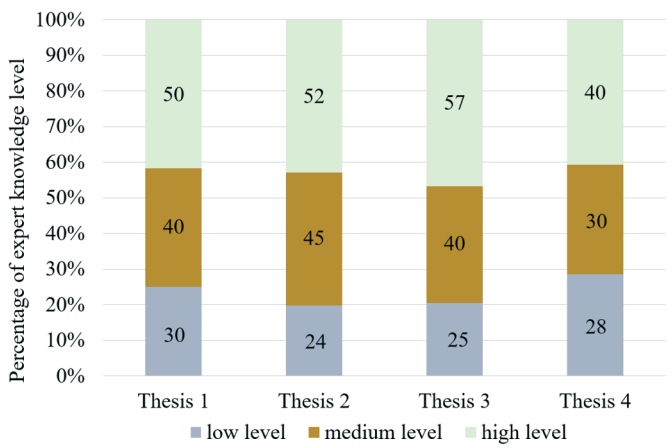

Fig. 13. A summary of the level of expert knowledge

Experts participating in the Delphi study declared a comparable level of knowledge on the topics discussed in all theses. However, they declared the highest level in the case of thesis 3, i.e. The safety of road users within selected pedestrian crossings will be improved by the use of a mechatronic system, which includes: active reflective elements, active D-6 road sign, active crossing lighting.

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In order to determine the significance of individual theses for the development of logistics, significance indicators were determined according to formula (1) [4]:

$$W_I = \frac{n_{BI} \cdot 100 + n_I \cdot 75 + n_{RI} \cdot 50 + n_{MI} \cdot 25 + n_{NI} \cdot 0}{n} \quad (1)$$

where:
n_{BI} – number of "very important" responses,
n_I – number of "significant" responses,
n_{RI} – number of "rather important" responses,
n_{MI} – number of "not very important" responses,
n_{NI} – number of "irrelevant" responses,
n – number of all answers.

This indicator ranges from 0 to 100 [4]. The closer the indicator is to 100, the more important the thesis is for improving the safety of road users at designated pedestrian crossings. Figure 14 shows the distribution of indicators for individual theses.

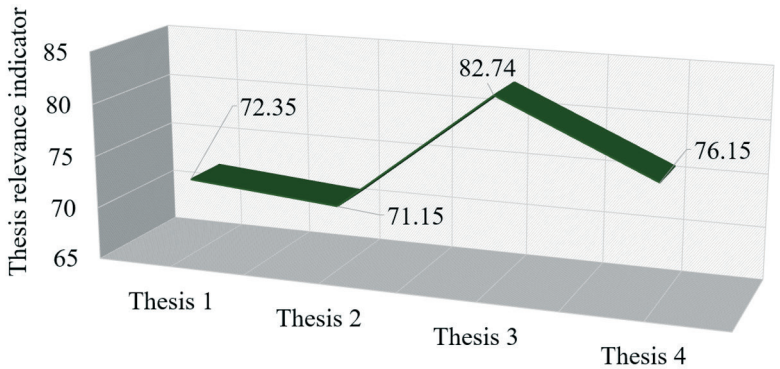

Fig. 14. Significance indicators for improving safety at selected pedestrian crossings

Analyzing the obtained results, it should be noted that the most important thesis for improving safety at the analyzed pedestrian crossings is thesis 3. The significance index for this thesis reached the value of 82.74. According to experts, the least important thesis is improving safety at pedestrian crossings by using a speed bump. The indicator for this thesis received a score of 71.15.

A summary of experts' opinions on the most probable implementation time for individual theses is presented in the Figure 15.

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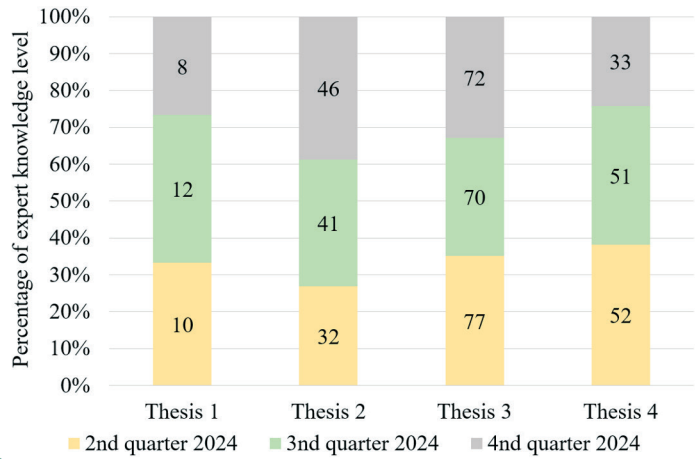

Fig. 15. Experts' opinion on the most likely time for implementation of individual theses

In the opinion of experts, the theses that should be implemented in the shortest time are thesis 3 and 4. Experts believe that the use of mechatronic systems and better lighting of the pedestrian crossing will definitely affect safety in this place and these theses should be implemented as soon as possible. According to experts' opinions, thesis 1 should be implemented at the latest. They believe that the introduction of traffic lights at selected pedestrian crossings will only cause difficulties in road traffic.

6. Solutions improving safety at selected pedestrian crossings

Based on the survey results and the authors' own observations, several solutions can be proposed to improve safety at the pedestrian crossings under analysis.

One option is to install traffic lights that activate a green light for pedestrians when a pedestrian clicks a button in advance. However, that solution is not very practical due to the location of the crossings at a small distance from a junction with traffic lights. Traffic signals are provided at pedestrian crossings if the conflicting vehicular traffic is heavy and time-separation is needed for safe crossing [15]. Such a solution would quite certainly improve safety on the one hand, but due to the heavy traffic, that solution would cause traffic disruption and the lack of flow capacity at nearby junctions on the other.

The most sensible solution, however, seems to be the use of adaptive D-6 (pedestrian crossing) road signs with an LED light module, which would be activated when a pedestrian approaches the crossing.

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These road signs could be completed with reflective elements or LED lights, the so-called cat's eyes, embedded in asphalt along the zebra. After dark, these elements will highlight the pedestrian crossing line by shining white or yellow. The LED lights, however, will blink when a pedestrian appears by the crossing. The visualisation of the pedestrian crossing at Lwowska Street with the use of mechatronic systems is shown in Figure 16. It is also possible to install those.

Fig. 16. The visualisation of the pedestrian crossing at Lwowska Street with the use of mechatronic systems

The selected pedestrian crossing has lamps which illuminate the crossing. However, if a smart crossing module is used, the replacement of the existing lamps with motion detectors providing extra light at the crossing would be a good solution. Active crossing illumination is one of the most important elements increasing safety at the crossing. The system becomes

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active after dark. Detectors are activated as soon as a pedestrian approaches the crossing. Owing to the installed motion detectors, the detectors shine at 100 per cent of their capacity. An important feature of the crossing light module is that it adjusts the lights in such a way that they do not dazzle the driver, but only improve visibility to the driver after dark. The use of that type of solution at the Lwowska Street crossing will significantly improve the safety of pedestrians who wish to cross the road at that place.

The proposed solution for improving the visibility of the pedestrian crossing as well as of the pedestrian himself or herself can be completed with a sound system informing the pedestrian about the crossing which a pedestrian approaches. Owing to sound modules which trigger messages of any content, these modules will definitely influence the pedestrian's attention. The system will be particularly useful for pedestrians who stare at their mobile phone screens, but also for the visually impaired. The audible message will certainly take the pedestrian's eyes off his or her phone and draw their attention to what is happening around him or her.

Similar solutions may be adopted at the pedestrian crossing located at Aleje Piłsudskiego. The crossing located there is particularly dangerous due to its location on a dual carriageway with a higher speed limit of 60 km/h, which is why extra elements were used in addition to the system described in the previous case. Figure 17 shows the visualisation of the pedestrian crossing at Aleje Piłsudskiego with the use of mechatronic systems.

Fig. 17. The visualisation of the pedestrian crossing at Aleje Piłsudskiego with the use of mechatronic systems

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The mechatronic system highlighting the pedestrian crossing at that location consists of four elements. The first one is spot active LED reflective elements powered by photovoltaic panels. Those elements delineate the pedestrian crossing line, so drivers will have time to slow down or stop. The elements will activate when a pedestrian approaches the crossing. That solution is particularly important for drivers in the inner lane, whose view to the right side of the crossing is obstructed by cars moving by. The second element of the mechatronic system is an active pedestrian crossing information sign (D–6). A walking man on the sign will change his position in parallel to the pulsating LED lights embedded in asphalt. The third element built into that pedestrian crossing are the pulsators placed above the D–6 sign. The pulsators are intended to warn drivers approaching the pedestrian crossing and make them exercise greater caution. The pulsators are activated when the microwave sensor detects an approaching pedestrian. The fourth component of the system are the S–Line active strips installed at the threshold of the pedestrian crossing. The strips can change the colour depending on the presence of a vehicle near the crossing. The strip will shine yellow if there is no car nearby and red if a vehicle is approaching the crossing. Loudspeakers may also be installed to inform the pedestrian of the situation on the roadway.

At the third pedestrian crossing under consideration, the previously used mechatronic system could also be applied using the infrastructure already present at that location. As there is a primary school nearby, additional interactive signs may be used to inform drivers about the school, as well as sound amplification systems may be used for pedestrians, especially children, to inform them about approaching vehicles. Figure 18 shows the visualisation of the pedestrian crossing at Zygmuntowska Street with the use of mechatronic systems.

Fig. 18. The visualisation of the pedestrian crossing at Zygmuntowska Street with the use of mechatronic systems

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As mentioned in the initial part of the article, the pedestrian crossing under analysis is one of the difficult ones because the pedestrian cannot be seen from a greater distance. Heavy traffic during peak hours and on Sundays, as well as certain elements of the road infrastructure, contribute to this condition. Therefore, the use of the systems shown in the figure above will ensure full safety at that location. School children and the elderly and visually impaired will also be able to feel safe due to the option to use systems informing about the current situation on the road.

It is possible to install a dedicated mechatronic system on the elements of current infrastructure, which will reduce installation costs. Spot reflective elements fitted in the roadway are provided with photovoltaic panels and a 1200 mAh battery, which enables 72-hour operation and does not require an additional power source. Such a solution is not only environmentally friendly (because PV panels do not produce harmful CO_2), but also cost-effective, and increases pedestrian crossing safety, too. When seeing flashing lights, a driver will slow down to make sure no pedestrian is approaching the crossing. Interactive D-6 road signs, one on either side of the road, can also be installed. That system can also be powered by 20 W photovoltaic panels, which it is possible to install above the sign. That sign effectively draws the driver's attention with flashing LED lights. Owing to that, the driver will notice a pedestrian who wants to cross the road at the selected place. The aforementioned elements of the system can be completed with pedestrian crossing lamps with LED bulbs, which produce stronger light than traditional lamps and are cheaper to operate.

Another solution to improve safety in this place may be to raise the pedestrian crossing above the road level. This is one of the simplest solutions, but it forces drivers to reduce speed and pay attention to the situation at the crossing. The proposed solution may be an alternative to the solution described in the previous paragraph if the use of mechatronic systems is not technically and economically possible.

7. Conclusions

The aim of this article was to propose, at selected pedestrian crossings, the mechatronic systems that will improve safety and reduce the number of road incidents involving vulnerable people. Proposals for mechatronic systems are discussed using selected pedestrian crossings in the town of Nowy Sącz as an example. However, similar problematic pedestrian crossings can be found all over Poland.

The survey conducted among road users confirmed the suspicions that the pedestrian crossings selected for analysis are not safe and there is a need to use solutions to improve safety. 63% of respondents believe that they feel rather safe at these pedestrian crossings. However, 17% of respondents indicated that they rather did not feel safe in these places.

Therefore, the question arises whether traffic safety at the indicated pedestrian crossings should be improved before a disaster occurs.

Smart pedestrian crossings ensuring better safety are an alternative to old and unsafe ones that have existed for years. Active illumination, reflective elements, movement sensor modules etc. significantly increase pedestrian visibility at the crossing. As a result, drivers are able to spot a pedestrian who wants to cross the road. Those solutions are mainly based on LED technology, which directly reduces electricity costs and generates significant savings.

Mechatronic systems such as active pedestrian crossing illumination, an active pedestrian crossing information sign or LED lights embedded in asphalt significantly heighten the pedestrians' feeling of safety at the crossing. Those modules also improve visibility and draw the attention of traffic participants, which influences drivers' and pedestrians' mindfulness. Communes should therefore invest in such solutions, thus reducing the infamous statistics on the number of people injured or killed at pedestrian crossings.

The need to use intelligent mechatronic systems at the pedestrian crossings in question was confirmed by the opinion of experts during the Delphi study. The indicator of the significance of the use of mechatronic systems determined on the basis of a survey conducted among randomly selected experts in the field of road traffic safety was as high as 82.74. According to experts, the use of speed bumps will have the least impact on improving safety. The significance index in this case was 71.15. Experts believe that mechatronic systems improving safety at pedestrian crossings should be implemented as soon as possible. An expert study showed that the best date would be the second quarter of 2024. This answer was chosen by 77% of experts. The least proposed solution, according to experts, is the use of traffic lights.

8. References

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