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CONCEPT AND PROTOTYPE OF THE SAFETY SYSTEM FOR PEDESTRIANS AND CYCLISTS IN THE IMMEDIATE VICINITY OF LARGER VEHICLES

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Abstract – The article presents selected methods and technical solutions currently used to warn and inform road users about the possibility of a pedestrian-driver collision situation. The solutions available on the market do not provide solutions for the transmission of two-way information in the pedestrian-driver relationship for systems built on large-size vehicles. Possible detection devices are presented along with their evaluation, and additionally the research process confirming the validity of the adopted approach in relation to the created system is presented. A prototype of the System supporting the safety of vulnerable road users in the vicinity of large-size vehicles was also presented, meeting the assumptions regarding informing both drivers approaching large-size vehicles located in bus bays, sensitive places where pedestrians and cyclists are hit. The presented system stands out from among the generally available systems for increasing the safety of pedestrians and cyclists. The biggest innovation of the system is the introduction of the possibility of communication between users around large-size vehicles, the ability to transmit information to the outside to both drivers and pedestrians without having to engage the attention of the driver of the vehicle on which the system is built, which can significantly increase the chances that at the time of a potential dangerous situation, one of the parties will react correctly and thus no accident will occur. The article describes publicly available solutions as well as an innovative safety system for pedestrians and cyclists around large-size vehicles.

Key words – road safety, vulnerable road users, innovative safety systems

JEL Classification – C99

INTRODUCTION

Issues related to the safety of vulnerable road users in the vicinity of sensitive places such as bus bays or other such places are very topical. There are many solutions from manufacturers aimed at increasing the safety of vulnerable road users [4]. The biggest problem that arises is the problem of two-way pedestrian-driver communication, very often accidents involving vulnerable road users occur due to the lack of communication mentioned above, the inability to read mutual intentions [2]. There are also other solutions, such as the Mobileye C2-270 System, which is a solution that supports the driver by means of a camera located outside the vehicle, in addition to the possibility of warning of a potential collision, the system also warns of the appearance of pedestrians and cyclists [6]. Another example of an available solution is the use of the Wi-Fi Direct system, it is a solution from General Motors, the operation of the system consists in using the Wi-Fi network to locate devices that may belong to unprotected road users and providing information about the possibility of a collision situation in the next step [7]. A very advanced VOLVO solution is able to recognize a situation in which a pedestrian appears on the road, the appearance of vulnerable road users causes the vehicle to stop immediately in order to avoid a collision between the driver and the pedestrian. This solution can be used for speeds not exceeding 35 km/h [8].

Setra-Bus Assist is a safety assistance system that supports the driver in critical situations when cornering when visibility around a bulky vehicle may be limited. The purpose of the system is to determine whether there is an unprotected road user in the turning zone of the vehicle, those zones are shown in Figure 1. The way the system works and the warning concept are based on an analysis of accidents involving pedestrians and cyclists on curves. The system is based on a patented solution for analyzing images from cameras, which consists in transmitting information from the field of operation of the system to the driver of a large-size vehicle, thus prompting him to take appropriate actions to avoid a collision with an unprotected road user [22].

Karson Technology's system is another solution based on the analysis of images from video cameras, This technology is used for constant monitoring of the space in front of the vehicle and in blind spots on the sides of the vehicle which are shown in Figure 2. It identifies potentially dangerous situations with visual, audible and vibration warnings. It notifies the driver, allowing him to avoid an accident or significantly reduce its consequences. The system is based on a set of cameras with an advanced image processing processor with a built-in speaker, which is mounted on the windshield of a large-size vehicle, in addition, displays are installed to inform about the zone in which the vulnerable road user is currently located. The system is designed for drivers of large-size vehicles, informing them about the potential hazard [23].

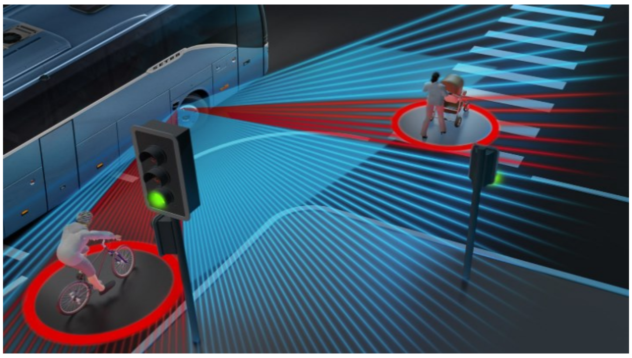

Fig. 1. How Setra-bus Assist works [22]

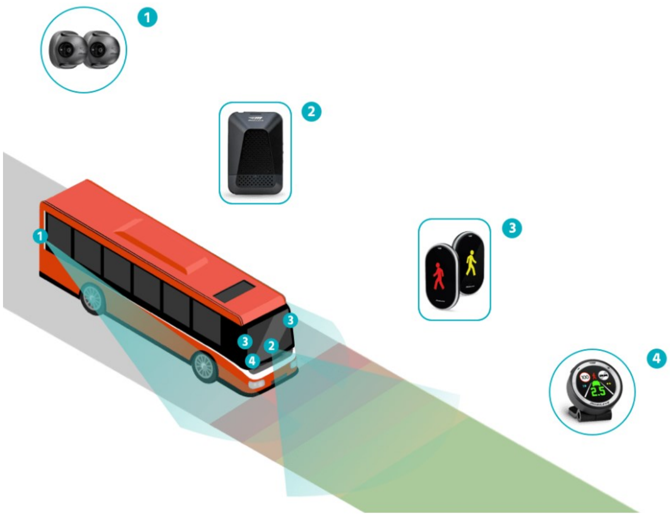

Fig. 2. Principle of operation of the system by Karson Technology [23]

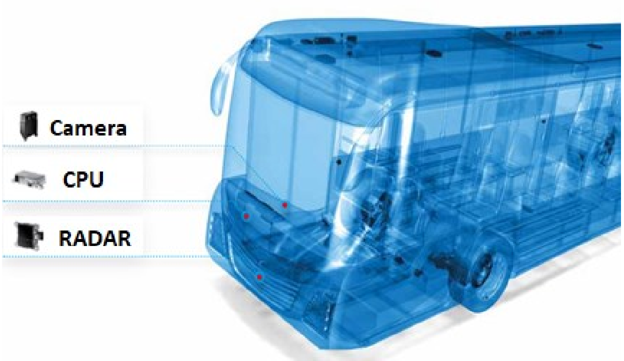

Fig. 3. Collision avoidance system for ZF buses, operating principle [24]

Fig. 4. An illustrative diagram of the situation in which drivers are obliged to stop the vehicle when passengers are entering and leaving a large-size vehicles [25]

The ZF City Bus Avoidance System is an innovative solution specifically designed for buses operating in highly urbanized environments to increase the safety of the public sector. The system actively detects vehicles, cyclists, pedestrians who are entering the path of a large vehicle. The system is distinguished by the use of CMS functionality in city buses, the solution is independent of OE manufacturers. ZF's solution is based on the use of a radar sensor, a camera and an image processing module shown in Figure 3 [24]. The use of both the radar sensor and image analysis methods is a very lucrative solution from the point of view of the effectiveness of the solution. It is widely used in systems related to the automotive industry [29].

A very popular solution to this issue are signage used especially in the United States. This solution assumes the use of illuminated or classic STOP signs activated when vehicles such as school buses are stationary, example is shown in Figure 4 which gives the possibility of safe exit of the vehicle by the people traveling in it [5]. Drivers are obliged to exercise extreme caution in this case, if the driver does not stop and will not give the opportunity to safely exit the school bus during the STOP signal or a manually set STOP sign appears, he is subject to a fine of $250, 5 penalty points and suspension of the driver's license for a period of 60 days, such regulations are in force in the State of Pennsylvania in the United States [25]. Behaviors related to stopping vehicles carrying children have been subjected to extensive research and analysis of the impact of the behavior process of drivers around the vehicle transporting pupils, including simulator tests [30].

All the solutions presented above are very positive solutions for increasing the overall safety of vulnerable road users, but each of the solutions does not work on the principle of two-way communication. Two-way pedestrian-driver communication was identified as the biggest road safety problem during the work on creating a solution to support the safety of vulnerable road users. The research work related to the creation of the System was aimed at the problem of two-way communication, and finally created a prototype of a solution providing clear information for both drivers and vulnerable road users. The aim of the research work was to develop the technology of a new solution, which is the "Safety System for Pedestrians and

Cyclists in the Immediate Vicinity of Larger Vehicles". Guaranteeing a significant increase in road and pedestrian safety. This solution is designed to be installed on public transport vehicles and all kinds of large-size vehicles. The assumption was to improve the safety conditions of vulnerable road users when crossing the road in places without marked road crossings, as well as in places with limited visibility. In addition, a significant improvement in the safety of drivers by reducing the possibility of a situation in which a vulnerable road user coming out from behind large-size vehicles onto the road would be hit.

The topic of safety of vulnerable road users is extremely important from the social point of view. Poland is still at the end of the list of European Union members in terms of road transport safety, and over the years these statistics have been slightly improving, but the problem is still very serious [2].

In 2022 alone, there were 759 road accidents involving vulnerable road users, the cause of these accidents was careless entry onto the road. Among these statistics, 614 accidents occurred when carelessly entering the roadway in front of a moving vehicle, and 145 accidents occurred due to an unprotected road user exiting from behind a vehicle/obstacle. There were as many as 121 fatalities in this type of accident in 2022. This system assumes a significant improvement in safety in the situation of the appearance of vulnerable road users from behind large-size vehicles, where visibility and the ability to assess the situation is close to zero [3]. It was assumed that the system must inform, among other things, about the direction from which the vehicle is approaching, the distance to the approaching vehicle, the speed at which the vehicle is approaching. Next, it is necessary that the information about the possibility of a collision between an oncoming vehicle and an unprotected road user who may be in the danger zone is transmitted in less than 1000 millisecond in a way that it is clear to the users of the system. The goal is for them to respond appropriately to a potential threat. It was also assumed that the system would have a detection efficiency of 95%.

Analyzing the solutions available in Poland, Europe and the world, one does not find solutions identical to the technology used by DR-TECH Company, the solutions available mainly focus on drivers of large-size vehicles, refer to systems related to the blind spot of large-size vehicles, warning of emerging vulnerable road users in front and behind the vehicle [1]. The only system that bears some resemblance to the described system is a solution that has been in place in the United States many years ago. It is described in more detail above. This solution assumes that in a situation where there is a situation of passengers leaving the vehicle in a bus bay, a manual stop sign is installed or an automated version is used, this sign informs drivers that there is a possibility of pedestrians appearance, they in turn are legally obliged to stop under penalty of a fine and even loss of driving license. In Poland and Europe this is not standardized in any way, so this solution perfectly fits the needs of safety of vulnerable traffic participants. In addition, it protects passengers and those behind and in front of the bulky vehicle from the possibility of a collision not only in the bus bay. The system is not designed strictly for the driver of the large-size vehicle, but for the vulnerable traffic participants and vehicles moving in the vicinity, so that external traffic participants get a chance to receive early information about the possibility of danger and then react correctly. Hence, the described solution is significantly different from those available on the market [33].

1. Devices tested during the development of the system

1.1. Vision technology

The use of vision technology in the application to the identification of moving objects in the indicated zone has been very widely promoted due to its applications in the field of automotive and video surveillance of public utility facilities and for private purposes, this type of analysis is also used in the analysis of human behavior, navigation of industrial robots or traffic analysis, the presented examples are just some of the few wide range of applications technology [25]. The cameras have the ability to distinguish objects in terms of their colors and the ability to classify objects, which is very important in many projects. [27].

There are also solutions that combine several solutions in one system, such as the fusion of radar and camera solutions combined with the machine learning method shown in Figure 5. For detecting objects such as pedestrians or vehicles [26].

The biggest problem for vision technology is the problems of dynamically changing traffic scene, lighting, appearance of shadows [15]. Broad vision technology is used very often in the context of recording traffic incidents or observing blind spots and other areas where a large-size vehicle is moving, but existing applications for systems for detecting traffic and then transmitting information outward to road users such as drivers or vulnerable road users have not been recorded [12]. Very extensive tests related to the use of such solutions for system assumptions have been carried out, but it turns out that despite the many advantages that vision systems have for the system in question, they proved to be insufficient [11]. For the solution in question, classic and thermal digital cameras were taken into account. The tests carried out confirmed the validity of the use of vision technology for this type of application. Detection of objects using cameras in laboratory conditions was characterized by very high efficiency. Tests conducted in real conditions revealed the weaknesses of this solution. The main disadvantage of vision technology are the problems associated with the dirtiness of the camera lenses, which has a huge impact on the functioning of the system and correct detection [9]. Of course, it is possible after installing the system to set a schedule for cleaning camera lenses, but in "everyday" conditions this can prove very problematic. In the autumn-winter period, even a short drive can cause dirt on the lenses, which will prevent detection of objects at a satisfactory level, while cleaning of objects can take place, for example, at the end stops or in the depot (in the case of installation of the system on a public transport vehicle). In addition, the installation of such a solution necessitates the installation of a control unit (PC, video recorder) inside the vehicle, which complicates the system installation process [14]. It is worth mentioning that the mentioned solution is characterized by a relatively high demand for electricity, which in the long term may cause problems with the vehicle's electrical installation. Despite promising test results under laboratory conditions, the solution had to be rejected due to problematic operation during the autumn-winter period and reduced detection efficiency, well below 90%. The biggest problem for vision technology is the problems of dynamically changing traffic scene, lighting, appearance of shadows. Broad vision technology is used very often in the context of recording traffic incidents or observing blind spots and other areas where a large-size vehicle is moving, but existing applications for systems for detecting traffic and then transmitting information outward to road users such as drivers or vulnerable road users have not been recorded [31].

1.2. Object detection using microphones

The ability to detect objects with the use of microphones will be presented on the basis of the tested Smartek Acoustic Sensor SAS-1 shown in Figure 6. This sensor was mounted on a downward mast, in the direction of movement as in Figure 7. The SAS-1 uses spatial signal processing to provide high-resolution audio to image vehicles passing by the sensor. This type of microphone can collect information from 1 to 5 lanes of traffic. Acoustic signals generated by the vehicle (engine noise, aerodynamic noise, tire noise) are picked up by the SAS-1. Each acoustic signal reaches the SAS-1 with a different signal level and at a different waveform angle. This microphone uses 91 acoustic sensors, analog signal conditioning from each, an analog-to-digital converter, a DSP, a memory circuit, and communications. The software provided by the manufacturer allows you to detect vehicles, their direction of movement, speed and count them.

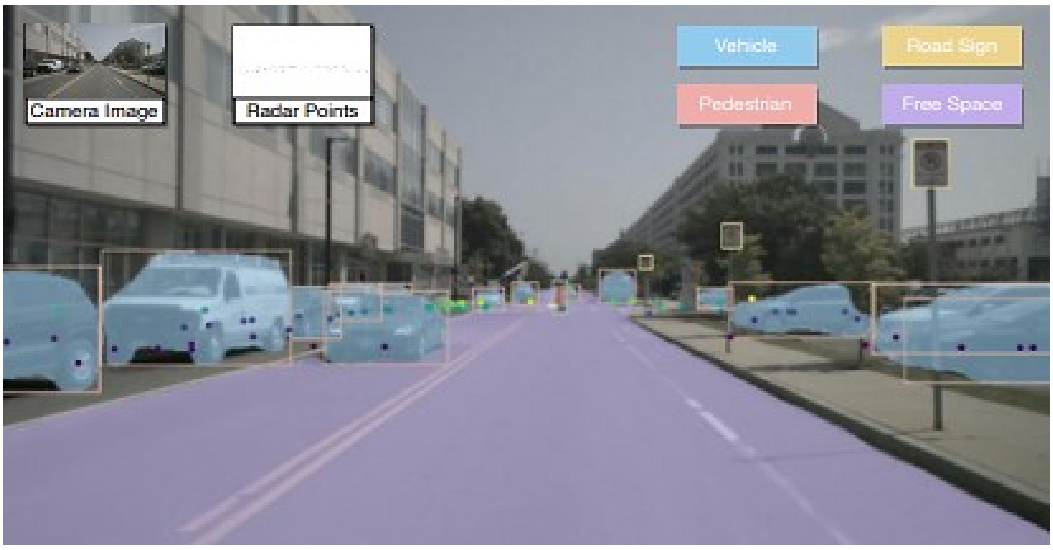

Fig. 5. Common scenario of object detection and sematic segmentation [27]

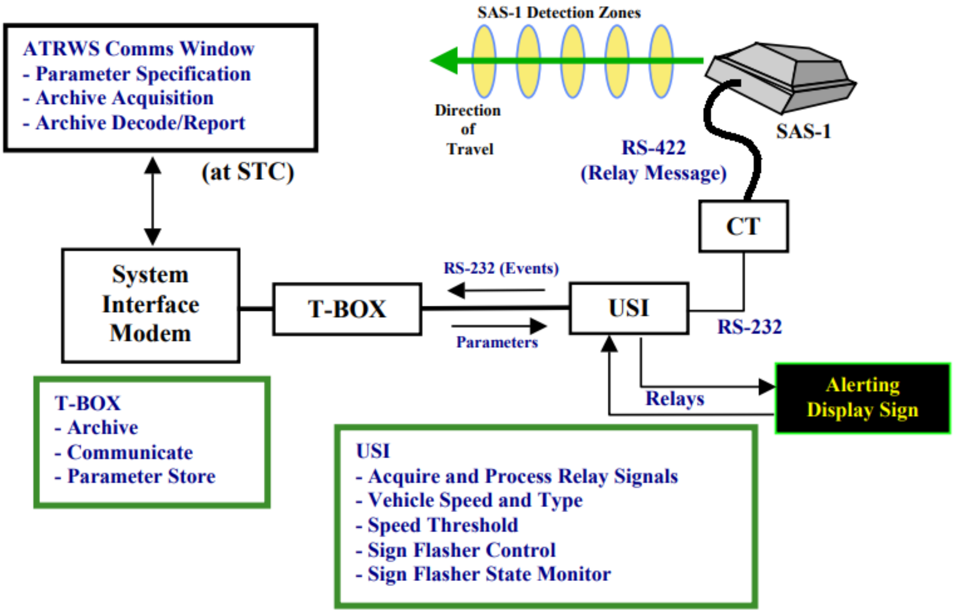

Fig. 6. SAS-1 dependences [13]

Fig. 7. Diagram of the SAS-1 device concept [13]

Table 1. Technical specifications (own design)

RS-422 (standard)	Hard wired home run (up to 2000 feet)
RS-232 (optional)	Hard wired home run (up to 100 feet)
Wireless (optional)	Wireless Link (2.4 GHz spread spectrum)
Supply Voltage at the sensor	8 to 24 VDC
Required power	Less than 2 Watts
Dimensions	12x8x3.5 centimeters
Weight	Less than 7 lb.
Material/Finish	Aluminium/Enamel.Stainless, Steel Fasteners
Mounting Bracket	2 inch Diameter Aluminum Tube/Stainless Steel Bands
Humidity	5% to 100%
Shock	NEMA TS2-2.1.10
Vibration	NEMA TS2-2.1.9

The solution presented above has been tested in terms of its applicability in the system under development. Laboratory tests have shown that the system correctly detects approaching cars, but the level of detection of pedestrians approaching a larger vehicle was not at a satisfactory level. The use of this type of detection would necessitate the need to integrate it with another method that precisely detects pedestrians in the vicinity of a large vehicle. An additional problem related to the use of quality solutions based on this technology and the entire system is the need for the system to operate in very diverse, often extreme weather conditions. It is necessary to be resistant to increased levels of moisture and rain, as well as to temperature variations in positive and negative directions. The possibility of using this technology is associated with the use of a number of electret microphones, equipped with appropriate safety devices. However, this solution is very expensive. One of the assumptions of the system is its availability also in the economic context, too high price of the system automatically causes limitations related to the wide use of the system. Device parameters are shown in Table 1.

1.3. Radar object detection

The microwave motion detector uses the Doppler effect to detect the movement of objects, shown in Figure 8. The Doppler effect is an apparent change in the frequency of a wave reflected from a moving object. The microwave transmitter sends the signal, the receiver receives its reflected echo, and the detector circuits process the received signal so that after processing information about the speed and direction of movement, as well as the amount of the object's displacement. Radars of this type have a very wide range of applications, among others, for detecting vehicle traffic in order to extend the green light in a given direction of traffic, active marking of dangerous places in limited visibility, detection of speeding, traffic jams or control of variable message signs. The use of radar technology turned out to be an accurate assumption due to a number of advantages of microwave radars. Also in this case, several types of microwave radars were tested, and below is the solution finally used in the prototype of the system [20].

The microwave motion detector uses the Doppler effect to detect the movement of objects. The Doppler effect is an apparent change in the frequency of a wave reflected from a moving object [19]. The microwave transmitter sends the signal, the receiver receives its reflected echo, and the detector circuits process the received signal so that after processing information about the speed and direction of movement, as well as the amount of the object's displacement [32].

Radar is the best solution for detecting objects at a considerable distance its parameters are shown in Table 2. They have the ability to work regardless of changing weather conditions [12]. There are also some disadvantages associated with the use of radar technology, namely the problem with distinguishing colors, but if this parameter is irrelevant for the project, it can be ruled out in further analysis [28]. The use of microwave radar in the system in question ensured resistance to changing weather conditions. Enclosing the radar in an appropriate housing makes it resistant not only to weather conditions, but also to vandals. The microwave radar can be connected to a control unit equipped with a gyroscope that informs whether the vehicle is in motion. If the vehicle is moving, the radars are switched off. The assumption was that the system would be activated only when the vehicle is stationary, when there is the highest probability of a dangerous situation occurring. The biggest advantage of this solution is that the radars are insensitive to all kinds of dirt, which have a huge impact on the functioning of other solutions that have been considered as potential for use in the system [21].

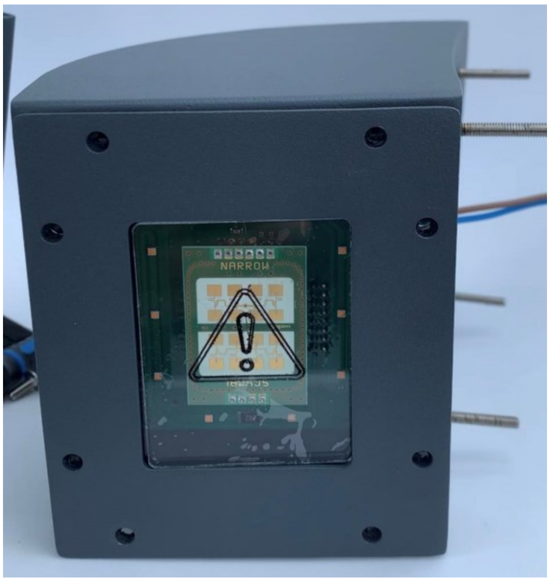

Fig. 8. MFDR microwave radar (own design)

Table 2. Technical specifications (own design)

Detection range	1-350 m
Case material	Polycarbonate
Operational Frequency	77 GHz
Microwave transmitter power	100 mW (20 dBm)
Radiation angle of the horizontal component	12°
Radiation angle of the vertical component	25°
Bandwidth	10 kHz
Weight	1 kg
Detection speed range	1-200 km/h
Measurement accuracy	(+- 5 km/h)
Dimensions	170 mm x 140 mm x 55 mm
Operating temperature range	(-25°C - 60°C)

1.4. Object detection with a Lidar laser

The use of Lidar technology provides a wide range of possibilities related to the detection of objects and extensive knowledge of their size, shape and spatial location, tested example is shown in Figure 9. The solution is immune to a factor that has proven to be very negative and even eliminating for use in the system, namely the lack of sensitivity to the possibility of glare. Recently, deep neural network has been developed to learn powerful object features from sensor data. However, the sparsity of LiDAR point cloud data poses challenges to the network processing [10]. Plenty of emerged efforts have been made to address this difficulty, but a comprehensive review literature is still lacking [30]. The use of Lidar technology has proven to be an unfavorable solution when it comes to use as detection devices installed on large-size vehicles. The device tested was an optical occupancy detector ODZ-2. During the tests carried out, attention was drawn to the problems associated with the use of the solution during very adverse weather conditions, which is associated with the lack of resistance to contamination associated with normal use in an operational environment. Attention was also drawn to the poor thermal stability and the occurrence in large numbers of false alarms indicating potential object detection, which is unacceptable in the proposed solution. Po .The tested device was equipped with relay outputs with the possibility of supplying DC voltage from 18-24V, with a simple ergonomic design, shown in Table 3. The tested solution under laboratory conditions showed very high measurement accuracy of up to +/- 5 centimeters with the possibility of both stationary and moving objects. The biggest problem in the application of the Optical Occupancy Detector was the range of measurement, as it was only 15 meters, this solution could be applied during the detection of unprotected traffic participants, however, when using this solution during vehicle detection, it would not be possible to obtain satisfactory results. Therefore, since the system should, by design, be unified, it was decided to use one type of equipment for the entire system, not as it is in many cases of competitive solutions, where, for example, both cameras and radars are used. This approach greatly simplifies the operation of the system and reduces the number of devices that can be damaged. After testing of the optical detector was completed, it was decided to reject it as a potential detection solution for the proposed solution. The use of Lidar technology provides a wide range of possibilities related to the detection of objects and extensive knowledge of their size, shape and spatial location. The solution is immune to a factor that has proven to be very negative and even eliminating for use in the system, namely the lack of sensitivity to the possibility of glare [33].

Fig. 9. Optical occupancy detector ODZ-2 (own design)

Table 3. Technical specifications (own design)

Detection range	15m
Case material	Polycarbonate
Technology	LiDAR
Light wavelength	850 nm
measurement accuracy	>2%
Dimensions	115 mm x 55 mm x90 mm
Case color	Grey
Weight	1 kg
Distribution angle	3°
Supply voltage	18-24V

Table 4. Summary of tested detection devices (own design)

TECHNOLOGY	ULTRASOUNDS	INFRARED	LASER	CAMERA	RADAR
RANGE	bad	medium	good	good	good
TARGET RECOGNITION	bad	bad	medium	good	good
NIGHT WORK	good	good	good	bad	good
WEATHER CONDITIONS	bad	bad	bad	bad	good
PRICE	good	good	medium	bad	good
FALSE ALARMS	bad	bad	medium	medium	good
THERMAL STABILITY	bad	medium	good	good	good
DIRT RESISTANCE	medium	bad	bad	bad	good

bad | medium | good

1.5. Summary of the possibilities of using the tested devices in the System

After an extensive analysis related to the possibility of using various solutions that would eventually be used as detection devices for vehicles and vulnerable road users, a decision was made to use microwave radars with the best parameters in operational conditions. Below is a comparison table of all tested solutions.

An extensive analysis of the tested in-situ devices are shown in Table 4, which were crucial for the design assumptions to ensure that the emerging system met all the challenges posed to it, radar devices were selected for use in the system prototype in question, as mentioned above. They have a number of advantages that were unattainable for other tested devices. We are talking about a very long range of object detection, the possibility of distinguishing the target, it was not important whether the tested devices work during the day or night, and the weather conditions were also irrelevant. Microwave radars performed their tasks regardless of external conditions. The criterion related to the number of potential false alarms and the price was also met, which was extremely important from the point of view of the future of the offered system. Thermal stability and resistance to contamination significantly outperform competitors when conducting tests under operational conditions.

Regarding the application of the various technological solutions shown in the table above, the following facts can be stated. Solutions based on ultrasound, such as the tested microphones perform better in the detection of vehicles in particular on expressways, where it is possible to adapt the microphones to the operating conditions on site, adjusting the individual devices to operate for several lanes, unfortunately, it was difficult to adapt this solution to the detection of people. Solutions using both infrared and classic digital cameras do a great job with algorithms that detect details in the image, they are able to distinguish many movement situations, faces, people, crossing of given zones, colors and others, they have a very wide range of applications and are used in automotive, however, since the tests of the system also took place in places such as quarries, There, unfortunately, there was a very high disturbance of the camera lenses, through dust. They also wanted to test such operating conditions, so that the system could work in the harshest environmental conditions. This turned out to be a very big problem for the video equipment despite its very many advantages. The available ODZ LIDAR detector also showed a number of advantages, but the best application of this solution was, for example, in assessing the distance from the mounted device to the object in question. They did a great job, for example, in assessing the distance between the roof of the vehicle and the distance from the bridge and whether in this situation the vehicle would be able to safely pass under the overpass. However, under operational conditions when testing devices of this type for use in the project, there were many inconveniences associated with erroneous indications of the device, the main problem being that the device was dirty. The device that showed the most positive side during the tests was the microwave radar tested, it met all the assumed parameters for detection devices to be used as detection devices on large-size vehicles for detecting objects from far and near distances.

2. SYSTEM PROTOTYPE

Based on laboratory and real - environment tests we decided to reject detection methods using vision technology and microphones. Both of these methods have undoubtedly pros, but in such unique installing place as buses these are not reliable and maintenance-easy enough. In addition installing these devices on vehicle would be much more expensive and harder to complete in order to meet the water and dust resistant standards. Vision system was not be a good fit for prototype system because of problems with dirty lenses and dazzling. These problems caused the concept not possible to install on real vehicle because of the necessity of frequent cleaning, especially in autumn and winter when weather is not favorable. Acoustic system would be easier to maintain but the certainty of pedestrians detection was not satisfying. In addition high purchase cost and problems with water and dust resistance in difficult weather conditions made this solution not worth installing on real vehicle. Application of LIDAR sensor would not meet the required high level of detection and versatility of installation. Surroundings around the places where bus stops vary and calibration of LIDAR sensor would not be possible. Solution consisted of microwave radar prove resistance to water, dust and dirt. In addition the quality of vehicles and pedestrians detection was on high level. That's why this concept was chosen to apply in final prototype.

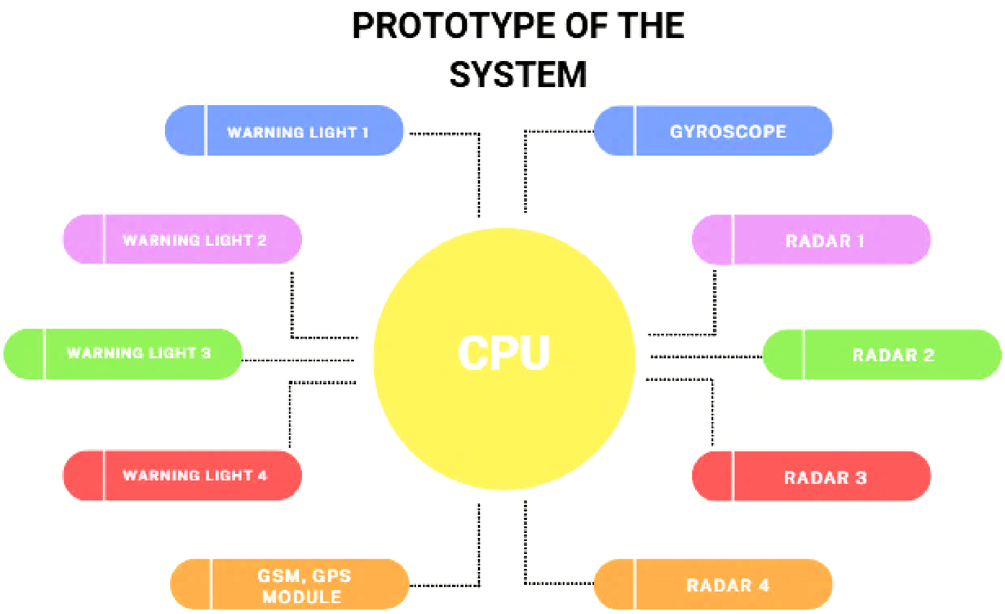

Fig. 10. Target concept of the system (own design)

The system of DR-TECH Ltd. aimed at improving the safety of vulnerable traffic participants in the vicinity of large-size vehicles consists of a set of four MFDR microwave radars, these radars are designed to detect objects appearing in the detection zone, motor vehicle drivers as well as pedestrians or cyclists shown in Figure 10 [18]. After detecting objects in the two zones, the information is transmitted further to the control unit, importantly, information warning of a possible collision between a vulnerable traffic participant and a motor vehicle is transmitted at the time of detection in the two fields. The transmission of information through the use of conjunction is intended to increase the attentiveness of pedestrians in particular to avoid a possible accident situation, where this very group is most vulnerable to injury [16]. In addition, the system assumed as much as possible to eliminate the situation of system users becoming accustomed to emerging signals, which could turn out to be erroneous. The control unit equipped with the appropriate management software, after receiving information from radars, and earlier also from the gyroscope informing the system about the state in which the vehicle on which the system is mounted, processes the information in order to launch warning light signs designed to warn both vulnerable traffic participants and motor vehicle drivers of the possibility of a collision situation, the innovation is also to inform two parties of the potential danger for this type of system solution. In addition, the system assumes remote diagnostic access via a GSM and GPS module, which provides additional opportunities to supervise the proper operation of individual systems mounted on different vehicles in variable locations. The final version of the prototype differed significantly compared to the earlier versions, the differences result from the approach to the change concerning informing vulnerable road users, but also drivers, about the possible risk of a collision in normal road traffic. The target version is a functionally advanced solution equipped with a control unit and a gyroscope that transmits information to the control unit about the state of the vehicle. The system initiates its operation only when the vehicle is stationary. The system is also equipped with a GSM module ensuring constant control over the correct operation of the system, providing remote observation of individual installed systems. Progress has also been made in adapting the system to a wide implementation on public transport vehicles, the following is the adaptation of the system to a public transport vehicle such as the Mercedes Citaro, the functionality of the system allows for a very wide implementation and adaptation of the solution to be installed on virtually any large-size vehicle [17].

Fig. 11. Target version of the prototype (own design)

Fig. 12. Target version of the prototype (own design)

The prototype of the system has been built on a bulky vehicle shown in Figure 11 and Figure 12, along with the prior adjustment of the enclosures to the vehicle components, the application of the solution is very wide and there is the possibility of applying this solution to any type of bulky vehicle, not only for passenger transport. It can just as well be built on a garbage truck or a trailer. According to the presented comparison table of possible technological solutions, it was decided to use microwave radars that meet all the assumptions set for the prototype system supporting the safety of vulnerable traffic participants. Thanks to the use of elements of the vehicle, which in this case is a Mercedes Citaro, we were also able to visually appropriate the solution to warn by means of pictograms located in specialized enclosures all traffic participants located around the large-size vehicle. When a vehicle and a pedestrian approach a collision zone, a situation in which a pedestrian could appear from behind a vehicle on the roadway, the consequence of which could be an accident and serious injury, these objects are detected, and in the next step visual warning signals are transmitted to the displays to increase vigilance and the appropriate response especially of drivers in the above-mentioned collision situation.

CONCLUSIONS

The developed system is distinguished by its versatility with regard to the possibility of implementing the solution on virtually any large-size vehicle, thanks to this versatility, it becomes a solution extremely beneficial for increasing the safety of vulnerable traffic participants, the conducted research and tests have shown high effectiveness and increased attention of research participants. Extensive surveys indicate that it is important to develop solutions in the field of safety of vulnerable traffic participants due to the still very difficult situation in this issue in Poland. The ongoing activities aimed at making citizens aware of the dangers of moving in and out of urban areas are bringing tangible benefits, but still statistics show that these activities are insufficient, hence the proposal to implement an innovative solution that will indirectly inform vulnerable traffic participants of an approaching vehicle. A major advantage is also the ease of implementation on the vehicle, the installation time does not require many hours of service work, because the adaptation can already be carried out during the production work of the systems on the original components of the vehicle, which significantly reduces the installation time. Initiation of the system while the vehicle is stationary ensures that the system will be able to effectively detect a situation in which another motor vehicle, or a cyclist, is approaching towards the vehicle in the bay. When there is a likelihood of an unprotected traffic participant appearing from behind the vehicle, the system will transmit a warning message via light panels with an appropriate pictogram. The transmission of this information to both parties will significantly improve traffic safety. The system has been tested for a year on a Mercedes Citaro bus in Bielsko Biała, during the tests in real conditions, discussions were held with drivers working with the system as well as people using public transportation were asked about their understanding of the light messages displayed by the system. All of the interviewees spoke very positively about the system. They noted a great need for solutions to support the safety of a particularly endangered group such as pedestrians. It is planned to conduct extensive observational studies as well as surveys directly related to the system to increase safety, as well as to conduct eyetracking studies that will indicate how individual traffic participants perceive the system.

KONCEPCJA I PROTOTYP SYSTEMU BEZPIECZEŃSTWA DLA PIESZYCH I ROWERZYSTÓW W BEZPOŚREDNIM OTOCZENIU POJAZDÓW O WIĘKSZYCH GABARYTACH

W artykule przedstawiono wybrane metody i rozwiązania techniczne obecnie stosowane w celu ostrzegania, informowania użytkowników dróg o możliwości wystąpienia sytuacji kolizyjnej pieszy-kierowca. Rozwiązania dostępne na rynku nie przewidują rozwiązań przekazywania informacji dwukierunkowej w relacji pieszy-kierowca dla systemów zabudowanych na pojazdach wielkogabarytowych. Przedstawiono możliwe do wykorzystania urządzenia detekcyjne wraz z ich oceną, dodatkowo przedstawiono proces badawczy potwierdzający zasadność przyjętego podejścia w stosunku do tworzonego systemu. Przedstawiono również prototyp systemu wspierającego bezpieczeństwo niechronionych uczestników ruchu znajdujących się w okolicy pojazdów wielkogabarytowych, spełniających założenia dotyczące informowania zarówno kierowców zbliżających się do pojazdów wielkogabarytowych znajdujących się w zatokach autobusowych, czyli miejscach newralgicznych, gdzie dochodzi do potrąceń pieszych i rowerzystów, jak również niechronionych uczestników ruchu drogowego, takich jak piesi. Prezentowany system odróżnia się na tle dostępnych systemów zwiększających bezpieczeństwo pieszych i rowerzystów. Największa innowacja systemu to wprowadzenie możliwości komunikacji pomiędzy użytkownikami znajdującymi się wokół pojazdów wielkogabarytowych, możliwość przekazania informacji na zewnątrz zarówno do kierowców jak i pieszych bez konieczności angażowania uwagi kierowcy pojazdu, na którym system jest zabudowany. Może to znacząco zwiększyć szanse, że w momencie wystąpienia potencjalnej sytuacji niebezpiecznej, któraś ze stron zareaguje w sposób prawidłowy i tym samym nie dojdzie do wypadku. Artykuł opisuje rozwiązania ogólnodostępne jak również innowacyjny system bezpieczeństwa dla pieszych i rowerzystów w otoczeniu pojazdów wielkogabarytowych.

Słowa kluczowe: bezpieczeństwo w ruchu drogowym, niechronieni uczestnicy ruchu, innowacyjne systemy bezpieczeństwa.

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