**Journal of civil engineering and transport** **transEngin**

**2024**, Volume **6** Number **2** **ISSN 2658-1698, e-ISSN 2658-2120**

**DOI**: 10.24136/tren.2024.006

# SELECTED ROAD SAFETY ASPECTS IN SPECIAL VEHICLES

Przemysław **Simiński** [1,*], Robert **Leszczyński** [2]

[1] Siedlce University of Natural Sciences and Humanities, Department of Computer Science, Siedlce, Poland,
e-mail: przemyslaw.siminski@uph.edu.pl, https://orcid.org/0000-0002-2323-3152
[2] Special Forces Component Command, Krakow, Poland

* Corresponding author

**Reviewed positively**: 10.12.2023

**Information about quoting an article:**
Simiński P., Leszczyński R. (2024). Selected road safety aspects in special vehicles. Journal of civil engineering and transport. 6(2), 25-31, ISSN 2658-1698, e-ISSN 2658-2120, DOI: 10.24136/tren.2024.006

**Abstract** – The article presents analyses in the field of safety of utility and military vehicles, which are crucial for human life and health. It discusses the issues of active safety, aimed at accident prevention, and passive safety, minimizing the effects of incidents. It presents technical solutions used to ensure the safety of the crew and other road users, such as: driving stability control systems, blind spot monitoring systems, airbags, body reinforcement. It emphasizes the importance of continuous technology development to improve vehicle safety. It draws attention to the need to protect not only vehicle passengers, but also pedestrians. The article shows that despite advances in safety, there is still room for improvement and a need to implement new solutions.

**Key words** – special vehicles, vehicle safety, active safety, passive safety, technical solutions

**JEL Classification** – O14, O18

## INTRODUCTION

Vehicle safety is of paramount importance to people. Without safe vehicles, the risk of death or serious injury increases. For years, the development of vehicle design has been inseparable from the parallel development of safety aspects. Vehicle safety is divided into two categories. First, we try to avoid road accidents. This is prevented by active safety. When an accident occurs, we try to minimize its consequences. This is prevented by passive safety. This also applies to special vehicles: special, police, fire and rescue, and penitentiary.

For vehicles used in the prison service, which are used to transport detainees, solutions are needed to ensure the safety of the crew and detainees in these vehicles. This involves reinforcements to the structure, grilles on the windows, separating partitions, appropriate ergonomics. It should be emphasized that these vehicles must provide safety for transported persons as well as protect the surroundings from escape. It should be pointed out that there is a need for continuous improvement of technical solutions in this area.

The issue and concept of security is treated comprehensively, i.e. it covers the entire process of road transport, from developing a movement plan, through granting permission for the passage of convoys through Polish territory and carrying out the movement. It includes: settling formalities at the border, organizing the movement, marking convoys, escorting and securing the passage, and such detailed issues as: technical conditions that moving vehicles must meet, or the transport of hazardous materials.

Based on the analysis of selected literature, it can be seen that the safety of special vehicles is not, but should be, a key area of research. In recent years, significant progress has been made in the field of active and passive safety, which aims to prevent accidents and minimize their consequences. [3], [5], [10], [12] The research goal is to demonstrate the need for greater involvement of these achievements in special vehicles. Despite significant progress, road safety remains an urgent global problem, 1.19 million people die on roads every year [13].

With regard to technical solutions used in prison service vehicles to ensure passive safety, the following can be indicated:

1. Reinforced body structure - durable against mechanical damage, resistant to escape attempts.
2. Reinforced doors with locks - preventing opening by detainees.
3. Grilles on windows - limiting the possibility of getting out.
4. Partitions separating the driver's cab from the prisoner compartment - protecting the driver.
5. Special fixed seats for detainees - permanently attached to the floor, impossible to dismantle.
6. Seat belts and handcuffs for detainees - limiting freedom of movement during the ride.
7. CCTV monitoring system - controlling the behavior of transported persons.
8. Alarm system - enabling the driver to call for help if needed.
9. Resistance to arson or damage attempts - protections securing the interior of the vehicle.

## 1. ENSURING THE SAFETY OF TASKS CARRIED OUT BY A SPECIAL PURPOSE VEHICLE

The safety of a special purpose vehicle is greatly influenced by the relationship between people, the environment and technology. The modern world has achieved a high level of technical advancement. Therefore, the crew of a special purpose vehicle is required to have comprehensive knowledge and skills when carrying out transport tasks. Still, the human - the soldier, officer, as a crew member remains the most important link in the relationship with the machine. Their skills are sometimes the result of years of learning and training and cannot be immediately reproduced.

It should be mentioned that for humanistic reasons every designer's duty is to create the safest possible working and service conditions for the vehicle user.

Since the threats that must be dealt with periodically and permanently change, continuous modification of the vehicle's safety elements should be remembered. Improving and updating ergonomics and service conditions of vehicle components and devices with new possible threats is essential so that the relationship between people - environment - technology is in "safe correlation with each other". Above all, for crewed vehicles, the human should be the undisputed priority during the processes of designing, manufacturing, overseeing quality acceptance and operation [2].

Generally, the science of safety, being an interdisciplinary science, basically involves a systemic approach, through a holistic view of reality, according to the "think globally, act locally" theory. The concept of the safety of special purpose vehicles then includes: threat; threat to safety; catastrophic events; factor forcing a safety threat; system safety; safety reliability; safety indicator.

For special purpose vehicles, due to their specificity of operations and purpose, the safety structure requires a broader interpretation (compared to vehicles intended for the civilian market). This is related to the emergence in the safety structure of a special purpose vehicle of the so-called surplus, which generally increases the safety of the vehicle through applied systems. The above concerns the surplus of: elements; strength; parameters; rarely, but also functionality; structural; informational.

The long period between the design and operation of a special purpose vehicle and the short time needed to introduce design changes related to the specific needs of users are important in this process. When introducing successive risk mitigation systems, an important threat (regarding loss of safety in other aspects and reducing the required parameters of individual vehicle systems) may be omitted. Therefore, risk management should be implemented and shaped at each stage and in all "life" phases of the vehicle [2].

When analyzing and assessing vehicle safety, it is necessary to:

- identify threats to the vehicle and those created by the vehicle;
- estimate the level of risk associated with the selected, analyzed threat;
- assess the uncertainties of the estimated risk;
- if necessary (when the risk exceeds or significantly or too dynamically approaches an acceptable level),
- absolutely discontinue operation or supervise it in a special way;
- continuously analyze the risk and draw conclusions.

In general, the sources of threats to special purpose vehicles are related to:

- the condition of the crew (especially psycho-physical condition, effects of devices, level of training, operator errors);
- the impact of the enemy (aimed at reducing crew efficiency or damaging the vehicle);
- the technical condition of the vehicle (method of operation, reliability of diagnostic and service systems);
- logistics support (proper operation, i.e. repairs, overhauls and maintenance, proper provision of technical supplies, proper exchange of information);
- vehicle design (erroneous assumptions or design changes introduced during operation that may reduce important parameters).

It should also be remembered that all factors generating threats also mutually influence each other.

The safety of the crew of a special purpose vehicle, i.e. the protection of the crew, is achieved by counteracting the threats mentioned above. The goal is to achieve a state in which the vehicle can optimally ensure the safe performance of tasks by the crew.

As mentioned earlier, the consequence of optimal crew protection is a high level of the vehicle's set of features, among which are:

- firepower (effective impact on the enemy with own fire means);
- ballistic and anti-mine resistance (related to vehicle armor);
- mobility (vehicle traction properties such as driving dynamics, overcoming terrain obstacles, maneuverability, mobility), safety of vehicle movement.

To achieve the expected safety level, the above features must be comprehensively developed and, above all, a compromise must be reached between them. Excessive development of one of them may negatively affect the others and vice versa. The above determinants defining the safety of a special purpose vehicle, according to the "chain principle must be links of the same strength".

In summary, the safety of special purpose vehicles depends in particular on active protection, passive protection, mobility and traffic safety [2].

In the case of passive protection, we are dealing with a set of properties of a special purpose vehicle that reduce the effects of a threat that has already occurred. They concern, among others: hull design, level of ballistic protection, interior organization and seats, e.g. blast resistant, seatbelts, etc.

Active protection includes a set of properties of a special purpose vehicle that allow avoiding the threat of the enemy. These include, among others: active protection systems, masking systems, requiring electronic systems (against WMDs, etc.).

Mobility, on the other hand, is related to: traction properties, acceleration intensity, maneuverability, ability to traverse terrain, range and adaptation for long-distance transport. The impact on vehicle mobility of parameters such as power, engine unit power and suspension quality should be considered here [3]. It should be remembered here that terrain trafficability includes the ability of a vehicle to overcome natural and artificial obstacles, various types of surfaces, as well as water obstacles. To improve the throughput parameter, a number of design parameters must be improved. A high level of mobility parameters (through high mobility) has a positive effect on crew protection against enemy threats.

Any problem related to vehicle design generates a new threat that can adversely affect traffic safety, which is directly related to crew safety. Therefore, changes in vehicle design parameters also strongly affect traffic safety [4].

An important element is the so-called stability of the vehicle while it is moving, i.e. the ability to maintain the vehicle's path of motion according to the driver's will [5]. Of course, it is directly related to the safety of vehicle traffic and thus the safety of the crew. We can deal with longitudinal stability (during rectilinear motion) and lateral stability - more dangerous for the vehicle crew and vehicle (during curvilinear motion). In the latter case, the vehicle may fishtail. The danger of losing stability increases when the surface has a high coefficient of friction and the vehicle has a high center of gravity. In extreme cases, the vehicle may roll over or roll over several times at higher speed.

Another problem related to vehicle traffic safety is its behavior during curvilinear motion on a rigid surface [6]. The above factors also mutually influence each other.

In summary, military vehicles containing technical solutions completely different from commercial vehicles are specially prepared for the needs of the army. From the analysis of their specifications and technical characteristics, their intended use can be inferred, e.g. wheeled vehicles, where we can find: from heavy tractors, technical evacuation vehicles, combat vehicle transporters, through combat vehicles, armored personnel carriers, mine resistant vehicles to light armored vehicles. These vehicles are characterized by high mass, dimensions and moments of inertia, often due to various special superstructures, a high center of gravity, off-road tires, lack of active and passive safety systems, additional equipment mounted outside the body shell. The design of these vehicles is primarily related to the diversity and limitations associated with the working conditions of drivers and crews. These include, among others: limited visibility, e.g. due to applied armor and anti-mine protection systems; special seats; special seat belts.

The above is related to ensuring the safety of special purpose vehicles. In fact, the main goal is to ensure crew safety. Proper security for the crew depends on the efficient and proper performance of the tasks entrusted to it and, after restoring its capabilities, the performance of further tasks. The vehicle should protect the crew to the maximum extent from loss of health and sometimes life.

The active (relates to a set of vehicle features enabling the driver to reduce or avoid the risk, e.g. the probability of a traffic collision) and passive safety (possible counteracting injuries during such a collision) of the vehicle mentioned earlier, as well as the compromise between firepower (the ability to previously and effectively hit with own fire means), ballistic and anti-mine resistance (i.e. resistance to enemy influence) and high mobility (driving dynamics, maneuverability, ability to cope with terrain obstacles) [6] determines its quality, which overall affects the safety of the vehicle and its crew. These "communicating vessels" should achieve a certain "state of equilibrium", which will allow achieving an optimal solution. Unfortunately, it must be accepted that there will always be some areas for improvement and the ideal state on the subject may be unrealistic to achieve.

## 2. Design solutions

Vehicles are divided into passenger cars and commercial vehicles (trucks, tractors and buses) and can form vehicle combinations e.g. a tractor with a trailer. Designers are constantly developing and improving newer and newer systems that greatly affect both the active and passive safety of passengers and pedestrians. Every year, several or even several dozen new systems intended for the automotive industry appear on the market.

In the case of the aforementioned active safety, which aims to prevent accidents, we primarily influence the dynamic properties, such as:

- the ability to limit skidding and fishtailing;
- reducing wheel lift-off from the road surface during braking;
- high acceleration capability on a slippery surface [7].

One of the most important systems used in motor vehicles is ESP (Electronic Stability Program, loosely translated as electronic driving stability control system, driving stability control system). This is the most advanced safety system that works in conjunction with other systems, such as: ABS (anti-lock braking system), ASR (traction control system), EDS (electronic differential lock), EBD (electronic brake force distribution). As of November 1, 2014, the obligation to use the ESP system in all newly registered passenger cars and lighter commercial vehicles with a total mass of up to 3.5 tons came into force. The remaining motor vehicles have been covered by this obligation since 2015. Expanded with appropriate functions, it is also used in tractor-trailer combinations. The ESP system is an active safety system that reduces the risk of skidding when cornering or making sudden maneuvers, as well as when overtaking by reducing engine power and controlling the braking force on each wheel. The system also counters the "jacking" of vehicle combinations (e.g. tractor with trailer) by controlling the braking force in the trailer, even if it is equipped with a conventional, pneumatic braking system. This system detects an increased risk of trailer rollover at an early stage. If the driver does not realize that the trailer is in danger of overturning, for example on long bends, on highway exits or when quickly changing lanes, the system reduces the speed of the entire combination until stability is restored [8]. The above system operation significantly reduces the risk of trailer rollover, of course within physical possibilities.

Another system is the so-called Night Driving Assistant, which is based on night vision technology and assists the driver in driving the vehicle after nightfall. This system consists of a thermal imaging camera and an infrared sensor, which record objects on the road based on the heat they emit. Thanks to this, the system is able to accurately identify a person walking along the shoulder of the road or a running animal.

In addition, it is able to detect objects at a distance of 300 meters, which the human eye cannot see after dark and at such a distance. Thanks to this, the driver gets the time needed to properly react. Additionally, the objects detected by this system are properly illuminated so that they are noticed by the driver without blinding them at the same time [9].

The driver can observe the recorded image on a special display mounted on the dashboard. In addition, if the threat is high, the system sends an audible and visual alarm signal about possible danger.

Another system is the so-called Emergency Braking Assistant, which initiates braking when there is a high risk of collision with a slower vehicle ahead. Using radar, the system detects obstacles moving in front of the vehicle in the same lane, at a distance of several to over a hundred meters, calculating the speed difference between the two vehicles. When a situation occurs in which a collision is unavoidable, the system notifies the driver with an audible and visual signal. If the risk of collision increases, it automatically initiates partial braking (30% of maximum pressure in the braking system). If the driver still does not react, the system initiates full emergency braking, but does not take full control of the vehicle from the driver [8]. Sometimes this system does not always prevent an accident, however the use of full braking force significantly helps reduce the speed at which a collision can occur, and thus above all allows to reduce its possible effects.

Designers of driver assistance systems have also devoted much attention to the typical maneuver of changing lanes, which is a frequent cause of collisions and accidents, caused by not noticing a vehicle in the so-called blind spot of the side mirror. Thanks to this, a system has been created which, using radar or a small camera, observes the area behind and around the vehicle. Using a warning light placed in the housings of both mirrors (both left and right), it signals a possible risk of collision. If a vehicle approaches from the left or right, and the driver does not turn on the turn signal indicating the desire to change lanes, the warning light turns on. However, if there is a vehicle on the right whose relative speed is low and the driver turns on the turn signal, the light will flash to indicate a threat [9].

The lane keeping assist system prevents unintended lane departure by gently correcting the steering. If the driver does not hold the steering wheel for a specified time, an audible signal sounds and a message prompting to take control of the vehicle is displayed. This system is particularly important when the driver's concentration decreases [11].

However, these systems may become redundant over time as research is underway on vehicles that monitor the driver's condition. Companies are working to introduce systems that will:

- control whether the driver gets behind the wheel after drinking alcohol;
- detect whether the driver is falling asleep while driving;
- check if the driver is sufficiently focused.

If the system detects any of the above situations, it will react and inform about e.g. delayed body reactions. Currently, wristbands that monitor the driver's fatigue level perform this function. In addition, car manufacturers also offer factory-prepared alcohol interlocks, which allow measuring the alcohol content in exhaled air. The alcohol interlock requires the driver to blow into the mouthpiece when starting the engine. If alcohol is detected in the exhaled air, the starter is blocked.

Currently, systems are also used that prepare the vehicle for a possible collision by:

- tightening seat belts better (more firmly);
- closing open windows;
- improving the position of power seats.

In addition, if the collision is avoided, the system restores the previous settings by itself.

In addition, so-called multi-collision brakes are installed in vehicles, which are activated automatically when the vehicle is involved in an accident. Their task is to stop it and minimize the risk of further collisions.

It should be noted that active safety systems primarily prevent a collision from occurring, however once it does occur, passive safety systems take on the further important role of protecting the vehicle occupant.

As already mentioned earlier, the basic devices protecting the driver and passengers are:

- seat belts;
- child seats and seat belts;
- headrests;
- front, side and curtain airbags (currently as many airbags and curtains as possible are used).

Passive safety is also ensured by the body structure of the vehicle. It should contain:

- reinforced side doors (specially designed to absorb as much energy as possible during a side impact);
- additionally reinforced and stiffened body frame equipped with crumple zones;
- locks in doors designed so that they do not open during impact, but after the collision they are easy to open to exit the vehicle or remove the injured person.

In addition, the front part of most new vehicles has the ability to absorb the impact force, while the passenger compartment, the so-called safety cage, is rigid and highly durable [5]. Achieving the optimal vehicle design is possible thanks to numerous crash tests, as well as computer simulations. Vehicle interiors are designed so that they do not contain any sharp elements, toxic or flammable materials that would be dangerous to passengers in the event of a collision. Additionally, vehicle bodies are designed in such a way as to ensure proper movement of the engine (prevent its contact with people in the cabin), steering wheel, pedals and all elements that could breach the passenger compartment structure in a collision. The engine is equipped with immobilizer systems that shut it down and cut off fuel supply, because contact with the catalyst is enough to ignite the fuel. The design of the windows also affects safety, currently the windshields are bonded and mounted in a way that makes them easier to push out by a person trapped inside the vehicle as a result of an accident [5].

In addition to the vehicle crew, passive safety also concerns protecting pedestrians or other users outside the vehicle. Therefore, rounded external vehicle shapes are used, without protruding handles and sharp edges. These measures are intended to minimize injury that a pedestrian may suffer from being hit by a car. It should be emphasized that during a car-pedestrian collision, the head is most at risk of injury.

In some vehicles, a system is installed which, when hitting a pedestrian, lifts the vehicle's hood to mitigate the effects of the incident. To improve pedestrian leg safety, specially designed bumper and front hood structures are used so that the leg is hit quite low, as far from the knee as possible, and the impact force does not concentrate at one point, but is distributed over the entire leg length. The bumpers are made of materials that deform in a controlled manner during impact with a person, absorbing the impact force [5].

Additionally, a very rarely used pedestrian protection system involves activating airbags hidden under the hood, triggered using special sensors mounted on the front bumper [11].

The design changes introduced in motor vehicles in recent years have significantly contributed to increasing their level of both active and passive safety. This is evidenced primarily by statistical data on road accidents and their consequences.

Therefore, despite the development of motorization and the increase in the number of registered motor vehicles, a decrease in the total number of accidents can be noticed (with active safety having a fundamental impact on this condition) and their victims (thanks to passive safety).

Unfortunately, based on statistical data, it can be concluded that the driver is the most unreliable part of the system: "human - technical object - environment". Therefore, the goal is for manufacturers to equip their vehicles with systems that will at least partially relieve the driver of certain actions. These systems are already appearing in new passenger cars. Their operation is based on a set of sensors, lasers, radars and cameras that monitor the road situation, especially in the immediate, although not only, vicinity of the vehicle.

The driver's condition and reactions are also recorded. Namely, the assessment of his psychophysical condition and detecting whether he is able to react independently to dangerous situations is very important.

## CONCLUSIONS

In recent years, huge progress can be noticed, thanks to which many solutions that were unrealistic have become possible to implement and are becoming more and more common. Of course, there is always room for improvement, so new ideas and solutions should be promoted that will allow reducing the number of fatalities and the effects of collisions and accidents to an even greater extent.

Although significant importance is attached to the safety of people traveling by car, there are still few pedestrian safety systems. Research on such systems is already underway and automotive concerns should be expected to compete in the future in introducing vehicles equipped with increasingly innovative pedestrian safety systems to the market.

Vehicle safety is critical and includes both active safety (accident prevention) and passive safety (injury minimization). This applies to special vehicles like military, police, fire, prison transport etc.

In the case of vehicles used in the prison service that are used to transport detainees, solutions are necessary to ensure the safety of the crew and detainees in these vehicles. This includes structural reinforcements, window grilles, partitions, as well as appropriate ergonomics.

Special vehicles require additional safety considerations due to their unique purpose and operating conditions. Risk management should be implemented throughout their design and use.

Key safety factors for special vehicles include crew protection, firepower, armoring, and mobility. An optimal balance between these is needed.

Active safety systems like ESP and advanced driver assists are now widespread in civilian vehicles and should also be adapted for special vehicles where applicable.

Passive safety requires energy-absorbing structures, restraints, airbags etc. Special vehicles have unique requirements here as well.

Pedestrian safety is starting to get more focus. Innovations like deployable hoods, bumper design and exterior padding can help protect vulnerable road users.

Ultimately drivers remain fallible. Driver monitoring systems are emerging to assess fatigue, impairment etc. and partially automate vehicle operation if needed. Fully autonomous special vehicles may be possible someday. Despite progress in the field of security, there is still room for improvement and the need to implement new solutions. In particular, there is a need for continuous improvement of technical solutions in this area.

**WYBRANE ASPEKTY BEZPIECZEŃSTWA W POJAZDACH SPECJALNYCH**

Artykuł prezentuje analizy w zakresie bezpieczeństwa pojazdów specjalnych, które są kluczowe dla życia i zdrowia ludzi. Omawia zagadnienia bezpieczeństwa czynnego, mającego na celu unikanie wypadków, oraz bezpieczeństwa biernego, minimalizującego skutki zdarzeń. Przedstawia rozwiązania techniczne stosowane w celu zapewnienia bezpieczeństwa załogi i innych użytkowników ruchu, takie jak: systemy stabilizacji toru jazdy, systemy monitorowania martwego pola, poduszki powietrzne, wzmacnianie konstrukcji nadwozia. Podkreśla znaczenie ciągłego rozwoju technologii dla poprawy bezpieczeństwa pojazdów. Zwraca uwagę na potrzebę ochrony nie tylko pasażerów pojazdu, ale także pieszych. Artykuł pokazuje, że mimo postępu w zakresie bezpieczeństwa, nadal istnieje obszar do poprawy i potrzeba wdrażania nowych rozwiązań.

**Słowa kluczowe**: pojazd specjalny, bezpieczeństwo pojazdów, bezpieczeństwo czynne, bezpieczeństwo bierne, rozwiązania techniczne.

## REFERENCES

[1] Barcik J., Czech P. (2014). Prawne aspekty bezpieczeństwa w ruchu drogowym kolumn specjalnych obcych Sił Zbrojnych na terytorium RP, *Logistyka*, 5(2014), 44.

[2] Niziński S. (2002). *Eksploatacja obiektów technicznych*, Wydawnictwo ITE Warszawa - Sulejówek - Olsztyn - Radom. ISBN 83-7204-284-5.

[3] Simiński P. (2012). Problematyka ruchu nowoczesnych transporterów specjalnych, *Postępy Nauki i Techniki*, No. 14.

[4] Simiński P. (2011). Metodyka określania wpływu wybranych zmian konstrukcyjnych na bezpieczeństwo ruchu specjalnych pojazdów kołowych, *Rozprawy*, 152, Wydawnictwo Uniwersytetu Technologiczno-Przyrodniczego, Bydgoszcz.

[5] Simiński P. (2013). Wpływ niesprawności układu hamulcowego na zachowanie się pojazdu specjalnego w czasie hamowania awaryjnego w ruchu krzywoliniowym, *Prace Naukowe Transport*, 96.

[6] Wicher J. (2004).*Bezpieczeństwo samochodów i ruchu drogowego*, WKiŁ, Warszawa. ISBN 978-83-206-1854-9.

[7] Reński A. (2011). *Bezpieczeństwo czynne samochodu. Zawieszenia oraz układy hamulcowe i kierownicze*, OWPW, Warszawa. ISBN 978-83-7207-904-6.

[8] Starkowski D., Bieńczak K., Zwierzycki W. (2010). *Samochodowy transport krajowy i międzynarodowy*, *Kompendium wiedzy praktycznej*, T. I, Systherm, Poznań. ISBN 978-83-61265-32-0.

[9] Mazal J., Rybanský M., Bruzzone A.G., Kutěj L., Scurek R., Foltin P., Zlatník D. (2020). Modelling of the microrelief impact to the cross country movement. Proceedings of the *22nd International Conference on Harbor, Maritime and Multimodal Logistic Modeling & Simulation* (HMS 2020), 66-70. https://doi.org/10.46354/i3m.2020.hms.010.

[10] Janos R., et al. (2017). Conceptual design of a leg-wheel chassis for rescue operations. *International Journal of Advanced Robotic Systems*. 14(6). https://doi.org/10.1177/1729881417743556.

[11] Prochowski L., Żuchowski A. (2006). Właściwości nadwozia w zakresie pochłaniania energii podczas uderzenia samochodu w sztywną przeszkodę, *Zeszyty Naukowe Politechniki Świętokrzyskiej. Mechanika*, 84.

[12] Rymaszewski R. (2014). Systemy bezpieczeństwa - standardowe i innowacyjne, *Nowoczesny Warsztat*, 11.

[13] https://www.who.int/health-topics/road-safety#tab=tab_1 (access date: 09/01/2024).