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The era of the unmanned vevicles is coming

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Abstract

Objectives: The use of Unmanned Vehicles in air, land and water transport is constantly increasing due to their technical and operational capabilities, along with economic advantages. They are used for recreational and commercial purposes by individuals, companies, organisations and state institutions. Particular types of vehicles are at different stages of technical, legislative and implementation advancement. Unmanned vehicles are at different phases of the process of the launch on the market for common use by the public. Railway transport will be the first to undergo widespread and, consequently, full automation, due to the fact that it is already in use and there is a possibility of its safe implementation, which must progress along with the development of technology, science and experience of producers and users. **Methods:** Scientific methods used in the paper are: analysis and criticism of written sources, analysis and logical construction. **Results:** The article presents issues concerning the possibility of implementing the use of unmanned vehicles in the air, land and water transport system. The state of advancement of the legislative and technical work has been described, along with the difficulties that can be encountered before the complete implementation of unmanned vehicles into operation. **Conclusions:** The process of implementing unmanned vehicles into the transport system has begun and it is irreversible. It is a matter of time before unmanned systems are used to transport people and goods. Their use is safer, more economically beneficial and brings benefits to society.

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Introduction

The dynamic technological progress in the engineering of every mode of transport is closely linked to artificial intelligence, the development and demand for new technologies and the improvement of the possibilities of using existing technologies. This development is the basis for the intensification of work on autonomous and unmanned aerial, marine and road vehicles, including automotive and rail means of transport. There is also a noticeable development and expansion of existing technologies and already used equipment and techniques thanks to which it will be possible to increase the potential of existing means of transport, improve the conditions of transporting both materials and people and strive to minimise the negative effects on the environment. Engineers are challenged to ensure that new autonomous units provide a high level of safety, that computer systems are able to gradually take over human activities and that adapted spaces can be used for transporting materials or transporting people.

In autonomous vehicles, the human driver will perform the activities consisting in checking the correct operation of the unmanned systems and auxiliary activities. Those are tasks of secondary importance, such as opening and closing doors, supplying the right products for the correct operation of autonomous systems and their further development. In the development of new technologies, great importance is attached to environmental protection with a trend towards zero CO2 emissions.

The level and guarantee of ensuring the smooth flow of transport, safety, timeliness, guarantee of the performance of a particular service, comfort with respect to environmental requirements is closely dependent on compliance with the legal regime. Due to the fact that the issues of autonomous and unmanned platforms, vehicles and ships are at different stages of ratification and implementation of legal regulations, it is important that they are the same for all those involved in the design, operation and implementation of possible changes to existing solutions. Differences in the implementation of autonomous solutions have a direct impact on where operations performed using unmanned systems are carried out in the air, on land and in water. Due to unfinished legal procedures, these operations are performed in air, ground or surface spaces selected for this purpose. Often, to ensure the safety of those not involved in the deployment or test, these spaces are closed to nonparticipants.

UNMANNED AERIAL VEHICLES

Flight operations using UAVs (*Unmanned Aerial Vehicle*) any aircraft used or intended to be used without a pilot on board (An et *al.*, 2017; *Commission Delegated Regulation* (*EU*) *2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems*, 2020) are steadily increasing (Darowska and Kutwa, 2019, p. 5). This is a process that has already started and will continue. Flights are made for hobby, sport, science, commercial purposes (in transport, construction, agriculture, forestry, inventories, energy, surveying and advertising) and of national importance (in air rescue and security services).

The lack of influence of the human factor on transport is an extremely important issue for the global transport system. This is particularly relevant in view of the widespread use of unmanned systems (Saeed *et al.*, 2021) in the context of the COVID – 19 virus pandemic (Kołodziejczak, 2020).

The technology used for manned and unmanned flights already ensures safe flight operations in shared airspace (manned and unmanned aviation). The integration of manned and unmanned aviation is being implemented according to a planned scheme which takes into account technological developments, the experience of air traffic management personnel, airspace users and the needs and expectations of industry (Bielawski *et al.*, 2020).

Flights with passengers on board and full integration of manned and unmanned aviation are feasible within the next few years. The timeframe envisaged for this is not due to the technological limitations of aircraft or air traffic management systems, or the capabilities of the pilots of manned and unmanned aviation. It is a consequence of passengers' attitude to UAV travel.

The use of manned aircraft by passengers guarantees travellers that, in the event of any danger, the crew, following the established procedure, will bring the flight operation to a safe conclusion. The crew will use modern electronics, Air Traffic Services, the personnel involved in the flight and all the procedures to ensure the completion of flight operations on the ground and in the air.

Passengers on board aircraft are mostly convinced that the crew is controlling the aircraft throughout the flight. However, flight operations are mostly carried out through the use of automatic systems which assist and replace the crew in controlling the aircraft. Automatic systems, ensure flight safety. They are mainly useful on long haul flights, in difficult weather conditions and where high accuracy is required and the operations are tedious, repetitive and require a certain accuracy and often the elimination of human error.

Air transport brings enormous financial benefits. Thanks to its use, other branches of industry also develop, newer technologies are developed, which reduce the negative impact on the environment. However, the presence of a crew on board is also an additional burden to carry for the flying vehicle, as well as the space and technical equipment that must be provided for the flight crew. By eliminating the crew on board an aircraft, weight is reduced and more airspace is available for passenger or freight transport.

UNMANNED TRAINS

Rail transport, in order to carry out its tasks, such as transporting goods or passengers, requires the involvement of appropriate personnel. The main professions involved in the transport process include the positions such as:

- the driver, who is responsible for ensuring the conditions required for the movement of the train , changing parameters, i.e. changing the speed of the train, adjusting the speed of movement to the existing restrictions and the current traffic situation, decreasing and gaining speed on sections that require it to ensure an appropriate level of safety, fluidity of the train movement and passenger comfort;
- the line dispatcher, who is responsible for deciding whether to run the train, supervising the timetable, identifying the possibility of potential conflicts, and in the case of their occurrence using all available means and procedures to prevent hazardous incidents;
- the traffic dispatcher, who, on the basis of the information collected about the traffic situation and the signalling equipment decides on the route setting, supervises the movement, releases the route and records the movement of the train.

Automation of selected functions of the railway transport process involves (Tan *et al.*, 2021), among other things, the automation of the above-mentioned tasks. Consequently, in order to ensure the movement of an unmanned train and cooperation at individual levels of the railway transport system, technical and legal requirements must be met. One of the methods of automation is to replace the tasks performed by the above-mentioned personnel, i.e. the driver, the line dispatcher and the traffic dispatcher, with appropriate automatic systems that will take over the tasks of these specialists.

On the basis of the information that there is a possibility of making a mistake that will result in a threat to human life and health or loss of human life and health, it should be concluded that the probability of an error being made by an automatic machine/robot is much lower than the possibility of a mistake being made by a human being. According to Figure 1 incorrect behaviour of a worker (irrespective of the industry) was the cause of 60.8% of accidents at work. Other causative factors individually did not exceed 10%.

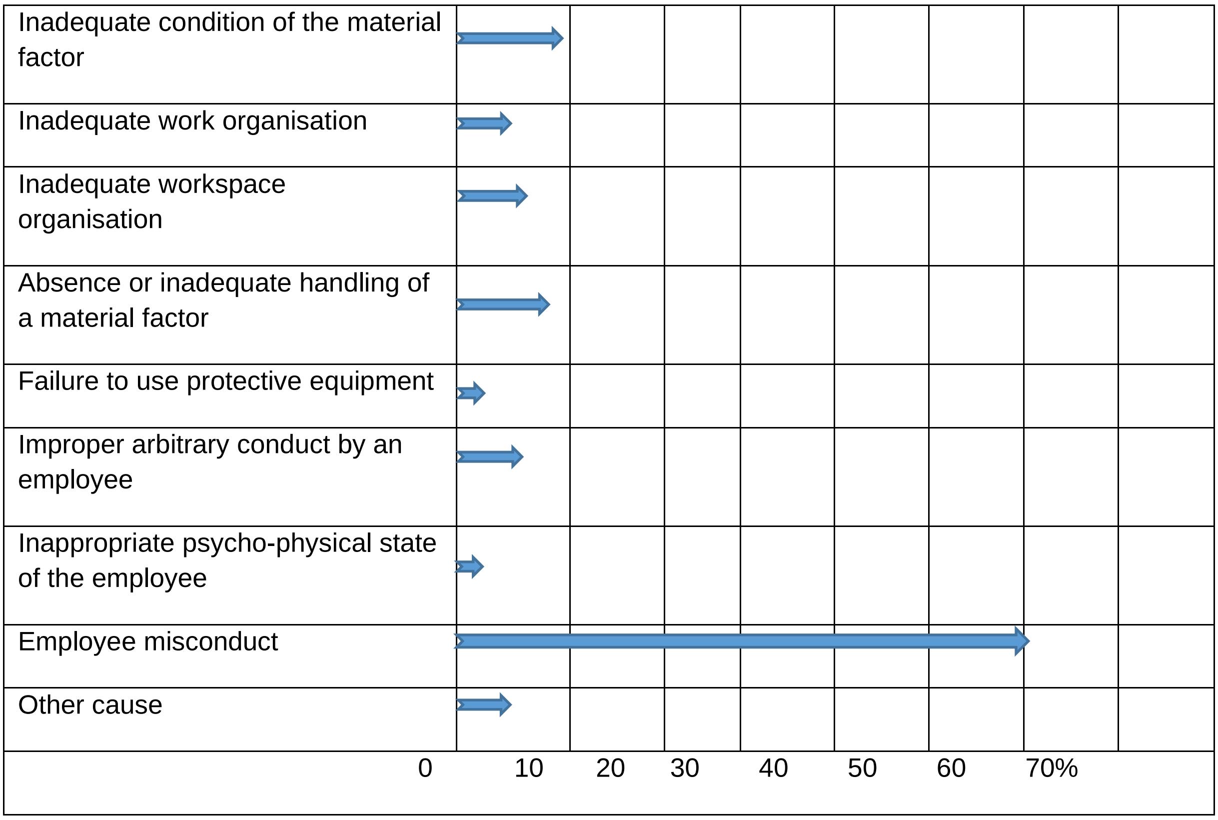

Figure 1. Causes of accidents at work in 2020 (*Accidents at work in the first quarter of 2020 - preliminary data*, 2020)

It should be assumed that the automation of processes will result in a reduction in accidents, increased comfort for travellers, optimisation of transport processes and thus a reduction in transport costs. The equipment, thanks to the use of appropriate software and algorithms, will more effectively control the execution of activities that are performed by a human being, taking into account train travel time, timeliness, limitations and the number of passengers.

Train automation is possible through standardised protocols described in the document on Train Management and Control Systems for Supervised Urban Transport, which defines the following categories of GoA (Grade of Automation) (Habib *et al.*, 2021), i.e., the automation of driving:

- GoA0 – On-sight [the driver drives on sight].

The driver is assumed to be fully responsible for driving the train. At the same time there is no requirement to install systems to supervise the actions of the driver. The position of switches and the control of unoccupied track sections may be partially supervised by the system.

- GoA1 – manual.

The train is driven by the driver based on indications from track-side signalling.
The first stage of automation involves vehicles controlled by the locomotive crew, mainly by the train control system, which may be supplemented by an on-board assistance system. In this case, the assistance systems, such as adaptive control, are only responsible for assistance functions, while the actual train management is entirely performed by the locomotive crew. The train passage is monitored by the ATP system (Automatic Train Protection). ATP has a protective function and uses automatic emergency braking to prevent accidents such as passing stop signals or speeding.

- GoA2 semi-automatic train movement.

In this system, trains run automatically from station to station, but the driver is in the cabin and is responsible for closing the doors, detecting obstacles on the track ahead of the train and handling emergency situations. A GoA2 train cannot run safely without a member of staff on board.

- GoA3 – driverless; train movement without a driver.

Trains run automatically from station to station. There is a staff member on board the train responsible for handling emergency situations. In the GoA3 system, the train cannot operate safely without staff on board.

- GoA4 automatic (unattended) train movement.

In fully automated train management, as in the GoA3 system, the ATO (Automatic Train Operation) system (Li et al., 2021) is responsible for managing the train. However, there is no longer personnel on the train, as the train responds independently to most incidents. For major incidents, either the control centre intervenes via remote train control, or there is stationary staff on site, dedicated to the intervention in case of incidents.

The IEC 62290-1:2014 standard (*Railway applications – Urban guided transport management and command/control systems – Part 1: System principles and fundamental concepts*, 2021) defines the above levels of automation, specifying the range of functions carried out by the vehicle operator, i.e. the driver and the system. In order to increase the degree of automation, it is necessary to increase the functions performed by the software, until the human factor is completely eliminated.

Small automated railways are already operating in urban agglomerations. Short, light trains without a driver on board are used for this purpose. They perform their function asthe Fast City Railway or as an underground line in competition with trams and Metros, which are expensive to build, limited by tunnel cross-sections and havehorter stations, which results in lower capacity.

It should be emphasized that the automatic rail technology, is developing faster than other automatic technologies, including car technology. This process is most evident in the case of the metro, where unmanned trains are becoming a standard, eliminating human labour through appropriate software and algorithms.

When taking part in the transport process, one should take into account several parameters, which include economics, technical development, cooperation with other modes of transport and safety. Consequently, the reduction of human labour should take place gradually. First of all, automatic systems check whether the train path is clear and, if they detect an obstacle, they immediately inform the driver and apply the brakes automatically. Other processes should also take place in such a way as to gradually eliminate the need for drivers and on-board staff as technology and experience develop.

The transport of goods from Asia in containers is cumbersome and limited in the case of non-standard dimensions that are difficult or impossible to divide into smaller pieces. To meet this challenge, the German Space Agency (Deutsches Zentrum fir Luft und Raumfahrt, DLR) presented a project called 'Next Generation Train Cargo', which, within 25 years, will be able to transport goods from Asia, among other places, while coping with technical difficulties such as non-uniform wheelbases and, at the same time, ensuring the autonomy of the train.

UNMANNED VEHICLES

The Autonomous Vehicle (*AV*), remotely Connected and Automated Vehicle (*CAV – Connected and Automated Vehicle*), self-driving car (*Self-Driving Car*), autonomous car (*autonomous car*), driverless vehicle (*Driverless Vehicle*), unmanned land vehicle (*Unmanned Land Vehicle*) – a motor vehicle fitted with systems which control the movement of the vehicle and enable it to move without the driver's interference.

Wherever an autonomous vehicle is mentioned in this section, it refers to a motor vehicle equipped with systems which control the movement of the vehicle and enable it to move without the intervention of the driver, who can take control of the vehicle at any time.

Unmanned motor vehicles are subject to numerous difficulties, hazards and inconveniences. These hazards can occur at intersections, during turns and right of way changes. There is also a high likelihood of pedestrians intruding into lanes on the road, not going off the road when the traffic lights change, or suddenly entering the road.

As shown in the table in 2020, 20,999 accidents took place in Poland due to the fault of vehicle drivers (which is 89.2% of the total). As a consequence of these incidents, 2,020 people died (81.1%) and 24,123 were injured (91.2%) – Table 1.

Table 1. Road accidents and their consequences by perpetrator

Causation of accidents	**Accidents**	**%**	**Killed**	**%**	**Injured**	**%**
Drivers' fault	**20 999**	89,2	**2 020**	81,1	**24 123**	91,2
Pedestrians' fault	**1 385**	5,9	**301**	12,1	**1 115**	4,2
Passengers' fault	**100**	0,4	**2**	0,1	**100**	0,4
Co-guilt	**228**	1,0	**27**	1,1	**254**	1,0
Other reasons	**828**	3,5	**141**	5,7	**871**	3,3
TOTAL	**23 540**	**100,0**	**2 491**	**100,0**	**26 463**	**100,0**

Source: (Report on Road Safety Information Systems Development for Poland Diagnosis and High Level Action Plan, 2020).

One of the goals of introducing autonomous vehicles onto the roads is to reduce road fatalities. In 2019, fewer people died on the roads in the EU than in previous years. From data published by the European Commission in Europe – 51 people per 1 million inhabitants are killed on the roads every year. Europe is the region with the highest road safety in the world. The safest roads are in Sweden and Ireland, the most dangerous ones are in Romania, Bulgaria and Poland.

Autonomous cars can help reduce the number of accidents. In the Strategic Action Plan on Road Safety presented by the Commission, and the 2021-2030 policy framework set a road safety target to eliminate road fatalities by 2050 (Vision Zero).

In 2014, the American Society of Automotive Engineers (International Society of Automotive Engineers SAE) elaborated the J3016 standard which divides automatic driving into 5 levels of autonomy, where level 0 means no driver assistance at all. Operational are only safety systems, such as the ABS (Anti-Lock Braking System)[1] and the ESP (Electronic Stability Program)[2] , emergency braking and ice warning systems.

First level – Single unit automation

A vehicle fulfilling the conditions of the first level of driving automation means that it is able to perform a single action under the constant supervision of the driver, yet autonomously. The most common is ACC (Adaptive Cruise Control)[3] , which, in addition to maintaining a constant speed, controls the space in front of the car using sensors, braking if there is a car in front of it. It is also able to adapt its speed to that of the preceding car and return to the set speed when the obstacle disappears.

Adaptive Cruise Control maintains the speed and a set distance from the preceding car. The vehicle's electronics are able to make certain adjustments to the ride - gently accelerating, braking and slightly turning.

Level two – two activities at once

An equipped car, under certain conditions, makes it possible to automate more than one element necessary for driving. At all times, however, all tasks require the participation of the driver. The purpose of such automation is not to take over driving by the system, but to increase safety in case of incorrect driver’s behaviour, such as failure to perform a turning or braking manoeuvre.

The car can do what Level One systems do, but it can combine them. For example, it can accelerate and brake while simultaneously turning the steering wheel. The driver must be ready to take control of the vehicle at any time.

Level three – conditional automatic driving

The car is able to travel on its own in certain situations. For example, on a motorway or in a traffic jam, it will accelerate, brake and turn on its own for a long time. Continuous driver supervision is required, because when the system decides that the situation is too

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[1] ABS – Anti-lock Braking System – a system that senses wheel slip and automatically modulates pressure, producing braking forces at the wheels that reduce the degree of slip. Source: own elaboration based on available sources.

[2] ESP – Electronic Stability Program – a system that, based on readings from various sensors, brakes the appropriate wheels and reduces engine torque, which stabilises the car in case of skidding. Source: own elaboration based on available sources.

[3] ACC – Adaptive Cruise Control, Intelligent Cruise Control – a device that maintains adequate spacing between moving motor vehicles when traffic is in the same lane. Source: own elaboration based on available sources.

complicated for it, the driver must immediately take over. Therefore, although you can let go of the wheel, your attention should remain on the traffic situation at all times. The system can take over completely on a wide and relatively straight motorway with clearly marked lanes. the autopilot performs functions such as accelerating, turning, decelerating and avoiding certain obstacles.

Level four – independent driving, but not everywhere

Vehicles may have no steering wheel or pedals. The car will not require human supervision. Under certain conditions and in a certain environment, the vehicle will complete the entire route without any assistance. The driver has the possibility to take control of the vehicle, but this is not necessary. Except in exceptional situations, such as very bad weather conditions or an intense snowstorm, the car will cope on the road perfectly on its own. Even if the driver ignores signals that he is to take the wheel - the car will stop safely at the side of the road.

Level five – fully automatic driving

The vehicle is capable of autonomous driving in any situation - anytime, anywhere. There are no instruments to steer it, and there is no need for driver intervention. Only the destination must be indicated.

It should certainly be said that an autonomous vehicle will be safer than a manned one. The main obstacle to this is the ratification and implementation of all the processes that need to be fulfilled in order to integrate the cars safely into the road transport system. There are other issues affecting unmanned car transport, which include:

- A change in the mentality of the public.

Road traffic participants need to be convinced that driverless vehicles are safer, travel is more comfortable, timely and predictable.

- Drivers' reluctance to changeattitudes.

Here the age of the drivers can make a big difference. While the younger population is more willing to change, the older generation will have technical and mental difficulties and it may take it a long time to get used to a new mode of transport.

- Infrastructure.

The quality of infrastructure will have a huge impact on safety. Depending on the quality and equipment of the infrastructure, the level of safety will increase and, conversely, the worse the infrastructure, the lower the level of safety. Providing regulatory framework is a task facing politicians, but the public needs to be convinced beforehand.

- Liability in the event of a collision involving an autonomous vehicle.

Until now, the driver, the human being, has been responsible for any damage. Legislators are therefore wondering what to do if this responsibility is assumed by a machine. The Swedish manufacturer Volvo has recently made headlines by announcing that the brand would take full responsibility for its autonomous models. The answer to this argument is the question of what if an unmanned car hits a human being while avoiding an obstacle, the case goes to court and who will be prosecuted in such a situation.

The use of the 5 G network will increase the speed of car-to-car communication, as well as that between the car and its surroundings. For this purpose, vehicles use in-vehicle devices in the form of special sensors.

The timeframe for the launch on the market of the first autonomous vehicles is very short. There will be tests of autonomous taxis and automation of road transport for carrying goods over longer distances. The right infrastructure seems to be the determining factor for the success of these projects.

UNMANNED SEA VESSELS

An autonomous sea vessel is a craft controlled and supervised by an on-board computer system. The ship does not require a crew on board in order to operate it. More than 90% of world transport is carried out by sea. Transport on long intercontinental routes as well as on short distances, often within the confines of a port, a sea or between continents is provided by means of specialised ships, e.g.: passenger ships, RORO vessels, container ships, gas tankers, tankers, general cargo ships and bulk carriers.

It is envisaged that the first unmanned ships will be container ships, supply tankers, short-haul passenger and car ferries, research vessels or port and technical vessels. In order to carry out maritime operations, they must have, among other things, clear sea lanes, navigational equipment, fireprotection and fire–fighting equipment, port safety support systems, an Automatic Identification System device and determination of the ship's status.

The use of unmanned ships will bring many benefits, the main ones being

- Environmental advantages. due to vessels being powered by electricity, emissions into the atmosphere will be minimised.
- Economic benefits.
  - ✓ Lower costs associated with the employment of the crew by shipowners.
  - ✓ Repurposing of space previously used by the staff for the carriage of goods.
- Safety benefits.

- ✓ Statistics show that the human factor is a frequent cause of accidents and disasters at sea. The use of unmanned craft results in a reduction in the number of accidents in maritime transport,
- ✓ Not having to put the lives and health of seafarers at risk. Piracy against vessels is still a real threat to maritime transport. The possibilities for criminals range from seizing a vessel or cargo to placing explosives on it.
- Development of new technologies.

The autonomous ship is the future of maritime transport and, thanks to the rapid development of technology, it will be possible to transport people and material more safely, more quickly and more cheaply, and to integrate other modes of transport and industries.

Difficulties include the following areas:

- Legislation and its implementation.

Regulations should take into account maritime traffic involving both autonomous units and traditional crew-controlled vessels.

- Operational benefits.

In the first stage, it seems reasonable to create separate routes dedicated to autonomous vessels.

- Technical advantages.
  - ✓ The exchange of information at sea between ships. To this end, it is necessary to implement a secure and reliable computer system which will ensure the management of navigation and the avoidance of possible obstacles and dangers.
  - ✓ Gradually reducing the number of crew on board. Due to the possibility of unforeseen situations in maritime space, it is reasonable, as technology, infrastructure and experience develop, to gradually reduce the number of crew on board with the aim of achieving no crew on board at all.
  - ✓ The risk of an attack on the software of a potential autonomous craft.

MODERNISATION OF EXISTING TECHNOLOGIES

The process of automating unmanned vehicles is as important as upgrading existing technologies. In an effort to reduce operating costs, KLM Airline has modernised the cabins of 14 Boeing 737–800 aircraft (de Man *et al.*, 2010).

The aim of the upgrade was to increase the comfort and functionality of the aircraft cabins. However, the modernisation also helped to reduce the weight of the aircraft by 700 kilograms, saving 58 tonnes of fuel and thus reducing CO_2 emissions by 184 tonnes per year.

By operating 14 aircraft, they save around 812 tonnes of fuel per year which contributes to a reduction in carbon dioxide emissions of 2,576 tonnes.

In addition to being more comfortable, the cabins will be more functional. The lighter seats will be more ergonomic and there will be Internet access. The upholstery of the seats has been mostly made from recycled products, the luggage compartments will be equipped with LED lighting that automatically adjusts to the time of day. It will also be possible to access the Internet with a USB port, which will increase the comfort of travelling and make the time spent on the aircraft more productive.

CONCLUSIONS

The modern world is wondering when people will commonly shift to autonomous vehicles and when they will be used to transport cargo. Considering the above issues, it is fair to say that the biggest obstacle to the automation process that will result in unmanned transport with the use of air, land and water vehicles is not technical. The time span for achieving full automation is postponed mainly due to people's attitudes regarding travel in unmanned vehicles.

Considering air, rail, road and sea transport, it seems that rail transport is the easiest to drive autonomously as opposed to road transport where there are junctions, poorly marked road edges, sudden turns and the possibility of people intruding on the road. Rail autonomy and the technology it uses is years ahead of other modes of transport. In the case of subways, driverless trains are slowly becoming the standard and this is where we should expect to see full autonomy in the near future.

The introduction of autonomous vehicles into general use must be preceded by a number of tests. The problem of the lack of legal analyses in the field of international aviation, maritime and land law concerning the possibility of using unmanned autonomous units is also one of the obstacles to be taken into account during the automation phase of unmanned vehicles.

The question will always arise whether, in critical or unforeseen situations, the technology will prove to be effective and will cope with difficulties without human intelligence, knowledge and experience. Another issue to be considered is the attribution of responsibility, who will be legally, financially or materially liable in the event of unforeseen incidents arising from the error of an unmanned vehicle carrying out operations using new technology, appropriate algorithms and full automation.

Regulations must be introduced into the transport system gradually, along with the development of experience, technological development, the capabilities of manufacturers and carriers and, above all, the expectations of society. This is a long-term process that will encounter many problems, but given the development of modern technology it is only a matter of time.

The ongoing changes must be combined with the application of new technologies that will be able to convince potential buyers of transport services. What is more, financial issues, the comfort of travellers, environmental protection and the fluidity of transport cannot be more important than the safety of transport users.

It is certain that the development of unmanned vehicles will result in an increase in economic and social development and will have a positive impact on the development of science, technology and environmental protection, while ensuring safety and high economic indicators through the use of new technologies.

REFERENCES

Accidents at work in the first quarter of 2020 – preliminary data (2020). Available at: file:///C:/Users/RADEK/AppData/Local/Temp/accidents_at_work_in_the_first_quarter_of_2020_-_preliminary_data-1.pdf.

An, W. *et al.* (2017) 'Agriculture Cyber-Physical Systems', *Cyber–Physical Systems*. Elsevier, pp. 399–417. doi: 10.1016/B978-0-12-803801-7.00025-0.

Bielawski, R. *et al.* (2020) 'Safety of aircraft structures in the context of composite element connection', *International Review of Aerospace Engineering*, 13(5). doi: 10.15866/irease.v13i5.18805.

Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems (2020).

Darowska, M. and Kutwa, K. (2019) *Biała Księga Rynku Bezzałogowych Statków Powietrznych. U-space – rynek – wizja rozwoju*. Polski Instytut Ekonomiczny.

Habib, L. *et al.* (2021) 'Towards Tramway Safety by Managing Advanced Driver Assistance Systems depending on Grades of Automation', *IFAC–PapersOnLine*, 54(2), pp. 227–232. doi: 10.1016/j.ifacol.2021.06.027.

Kołodziejczak, M. E. (2020) 'The Emergency States Guarantee the Functioning of the Country during the COVID–19 Pandemic: The Case of Poland and the Republic of China (Taiwan)', *European Research Studies Journal*, XXIII(Special Issue 3), pp. 239–252. doi: 10.35808/ersj/1880.

Li, S. *et al.* (2021) 'Integrated train dwell time regulation and train speed profile generation for automatic train operations on high–density metro lines: A distributed optimal control method', *Transportation Research Part B: Methodological*, 148, pp. 82–105. doi: 10.1016/j.trb.2021.04.009.

de Man, A.–P. *et al.* (2010) 'Managing dynamics through robust alliance governance structures: The case of KLM and Northwest Airlines', *European Management Journal*, 28(3), pp. 171–181. doi: 10.1016/j.emj.2009.11.001.

Railway applications – Urban guided transport management and command/control systems - Part 1: System principles and fundamental concepts (2021). Available at: https://webstore.iec.ch/publication/6777.

Report on Road Safety Information Systems Development for Poland Diagnosis and High Level Action Plan (2020).

Saeed, F. *et al.* (2021) 'Smart delivery and retrieval of swab collection kit for COVID–19 test using autonomous Unmanned Aerial Vehicles', *Physical Communication*, 48, p. 101373. doi: 10.1016/j.phycom.2021.101373.

Tan, Y. *et al.* (2021) 'Automatic inspection data collection of building surface based on BIM and UAV', *Automation in Construction*, 131, p. 103881. doi: 10.1016/j.autcon.2021.103881.