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PROSPECTS FOR THE DEVELOPMENT OF AUTONOMOUS TRANSPORT IN THE CONTEXT OF LEGAL, INFRASTRUCTURAL AND ETHICAL CONSTRAINTS

ABSTRACT

Introduction: Over the past several years, we have seen an unprecedented development of technologies related to autonomous vehicles. Various techniques of perception of the environment are combined here using popular sensors and algorithms. Global technological trends in the automotive industry clearly indicate that in the coming years it will be the most important direction of development of road transport - both passenger and freight, with an indication of the increase in the quantitative share of vehicles powered by electricity. The main goal of the paper is to organize and systematize the current knowledge in the field of the current state and development prospects and limitations of autonomous vehicles in interaction with the dynamically changing environment.

Methods: An analysis of scientific sources resulting from the adopted goal and assumed results.

Results: Description, systematization and conclusions resulting from the analysis of both the facts covered by the subject of the paper and forecasts concerning autonomous transport, covering the perspective of several or several dozen years.

Conclusions: The legal, organizational, technical and ethical standards regarding the operation of autonomous vehicles must meet the expectations of users, entrepreneurs and manufacturers, while devoting the utmost attention to physical and digital security issues.

Key words: autonomous transport, algorithms, limitations, development, telematics

DEFINITION AND CLASSIFICATION OF AUTONOMOUS TRANSPORT

Since the beginning of the development of the automotive industry in the construction of vehicles has changed practically everything. More and more new mechanical solutions were implemented, new construction materials, propulsion units and fuels were used, while the way

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the driver uses the vehicle has remained virtually unchanged [Skruch, Długosz, Cieśla 2015]. Currently, the presence of a driver while driving is necessary, but on the other hand, as statistics show [Buehler, Iagnemma, Singh 2009; Cheng 2011; Waldrop 2015], the driver is still his most unreliable element.

The last few decades in the development of the automotive industry has primarily been the search and testing of new technologies to facilitate driving. These efforts are directly related to the process of implementing autonomy. So what is it with regard to vehicles? It turns out that a clear explanation of this concept is impossible due to its different definitions in different parts of the world. Despite this, both the Europeans and the Americans are not yet fully autonomous vehicles. The highest level of automation (self-driving car) is a solution in which technology is completely in control of the car. Therefore, the driver does not even have to monitor the traffic situation. This kind of modernization should translate not only into driving without the active participation of the driver, but also have a safe and uninterrupted interpretation and response to changing conditions on the road.

In the general sense of the concept of an autonomous vehicle, it is a device that, thanks to highly advanced technological solutions installed, is able to move from point A to point B without having to take human action. Currently, there are many vehicle control systems, but none of them has achieved full autonomy. The variety of technologies used, however, means that it is not possible to clearly identify the definition that would apply to all vehicle categories [Szymeczko 2018].

Currently, the need for movement is becoming more common than the need to have own vehicle. Car sharing systems are being developed in cities. Car sharing on the one hand satisfies the communication needs, and on the other hand frees from paying high fees for parking your own cars in the city center. The near future will therefore bring a significant increase in this type of transport sharing systems with other city dwellers. Therefore, it is easy to determine the direction in which today's motorization goes: it will be based to a large extent on renewable energy and engines that do not emit pollution, as well as systems for sharing means of transport and autonomous modes of movement.

Autonomous cars, also called self-steering cars, are currently working not only with technology giants such as Google, Apple, Tesla and Uber, but also a number of automotive companies, including Mercedes, Volkswagen / Audi, BMW, General Motors, Volvo, Ford, a consortium of Renault-Nissan-Mitsubishi and Toyota. Nvidia and Intel also contributed to autonomous vehicle control systems by preparing a number of solutions used in many test solutions and vehicles without a driver. In addition, a large group of luxury car models available

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in car dealerships are characterized by a certain degree of autonomy, as exemplified by Mercedes E-class, coping even in city traffic, or Audi A8, which is able to drive independently on the highway. What's more, systems such as parking assistants have become commonplace, and it is also a mechanism necessary in an autonomous car [Bieńkowski 2019].

As self-steering vehicles developed, there were several ways of classifying them, but the most common are two of them, developed in the United States. In 2014, the classification of vehicle autonomy, published by SAE (Society of Automotive Engineers), was published: SAE J3016 Autonomy Levels. The classification takes into account six levels of autonomy and focuses more on the number of driver interventions and the need for attention while driving than on the technical capabilities of the vehicle [Neumann 2018]:

- Level 0 - is the lowest level of classification, this group includes all cars without any support, so the car is completely dependent on the driver.
- Level 1 - this group includes cars that have only some elements supporting the driver, e.g. maintaining the right distance from the next vehicle or emergency braking in a dangerous situation, but these are not functional enough to speak about the autonomy of the vehicle.
- Level 2 - more automation can be found here, which significantly affects the way the vehicle is controlled. The system requires continuous supervision, but the vehicle is able, for example, to move independently in a traffic jam, adjusting the speed and braking on time.
- Level 3 - there is already partial autonomy for cars in this group. It includes, for example, Mercedes E-Class or Audi A8 - they can overcome certain sections of the road without supervision, e.g. on the highway, but in the event of unusual situations the driver must take control of the vehicle, otherwise it will stop. It is therefore possible to talk freely while driving or to perform other activities not related to driving - but to a limited extent. It is still necessary to control the traffic situation.
- Level 4 - this level means cars of the future. It is assumed that driving them will be fully autonomous, however, in certain situations it will be possible to take control of the vehicle. Currently, there is no serially produced car that could be included in this group.
- Level 5 - specialists say that the emergence of fully autonomous vehicles on a massive scale, without a manual control system, is a matter of time. There will be no steering wheel or pedals - the user will only enter the destination point. Currently, the prototype of such a car is Waymo Firefly - a Google product.

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FOR AND AGAINST THE AUTONOMY OF VEHICLES

According to experts, fully automated fleets will significantly improve the functioning of the supply chain. Such cars do not need breaks at work, they can move constantly 24 hours a day, there is no need to pay them hotels or overtime. Efforts are already being made to order production materials in an automated manner. The software for carrying out such orders will work with autonomous vehicle handling systems, so that the role of man will be limited to accepting the actions proposed by intelligent algorithms. For example, self-driving forklifts and pallet trucks will probably be widely used in warehouses in the near future.

The great benefit of this solution will be lower costs of logistics operations. In addition, autonomous trucks will also contribute to an increase in liquidity of deliveries and their faster implementation, which will improve the dynamics of production plants and contribute to savings in the area of warehouse management. However, one cannot forget about the biggest advantage of this technology, which is the reduction of accidents. Today, autopilot on the road is doing better than man. Autonomous transport would also solve the problem of a lack of drivers. On the Polish and European roads, the transport market has been facing a deficit of professional drivers for years. It is estimated that currently 100-130 thousand people could find employment on the domestic freight and passenger transport market. The situation is similar in other European countries - the career of a truck driver has become a niche and fewer people entering the labor market are choosing it. As a result, the logistics and transport industry collided with a crisis of human capital shortage, the solution of which may lie in the legalization and implementation for the universal use of autonomous trucks.

The conclusions of the International Transport Forum [OECD / ITF International Transport Forum 2017] are also interesting. Widespread autonomy in commercial road transport would have serious consequences for road transport operations and costs. Although the purpose of the research is not to predict the level of cost savings, some tips are useful to understand the business imperative for the development and implementation of autonomous technology. In addition, this only applies to ongoing operating cost savings after transition costs (such as raising capital and paying exemptions for former drivers).

Although a fairly large number of drivers work for relatively low wages, labor costs still account for around 35-45% of costs in the road transport sector in Europe. Similarly, in the United States, driver wages and benefits represent about 35% of marginal (per mile) freight costs. Of course, not all of these labor costs would be eliminated through autonomous solutions, since there would probably be tasks that drivers would need to perform. However, even if half

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of these costs could be avoided by introducing self-steering vehicles, operational costs could be almost 20% lower in a number of supply chains.

Fuel performance is also expected to improve as the braking and acceleration commands (e.g. adaptive cruise control) are optimized and better aerodynamic performance is achieved. The estimated fuel savings for automatic functions are between 4 and 10% for automated "eco-driving" of trucks not connected to a convoy, and between 6 and 10% for partially manually driven truck convoys. The total effect of full automation and driving in a convoy can exceed 10%.

The report further states that the number of hours a driver can drive a truck is limited by both physiological capacity and government safety regulations such as Regulation (EC) No 561/2006 in the EU. In particular, in long-distance transport, restrictions on the length of the shift mean that vehicles can remain idle for a significant portion of the day (unless they are served by shift shifts). The introduction of fully autonomous vehicle technology would remove this severe restriction and potentially allow a much more intensive use of the car fleet (depending on other regulations such as night traffic bans in urban areas). Extended vehicle hours would bring significant cost savings because a given task can be accomplished using fewer vehicles. The extent of fleet reduction would obviously depend on the characteristics of transport tasks, but it is estimated that for those carried out over long distances, a fleet reduction of 50% is possible. However, the actual cost savings may be relatively small as vehicles would require more frequent maintenance, repair and replacement. In addition, there may be additional costs for equipping vehicles with technology enabling driving without the driver's participation.

The cited study estimates that over 90% of road accidents in Europe and the United States are caused by human factors, which for enthusiasts of autonomous solutions in transport is the prime argument that the widespread adoption of automated vehicles will reduce the number of accidents, deaths and injuries on the road. However, it is very difficult to determine what the real so-called collision performance of automatic systems, as new types of failures may appear, and other new threats, e.g. insurance, may generate serious additional costs (e.g. related to burglaries and theft of "unattended" cargo).

In summary, the above analysis suggests that reducing operating costs by accepting trucks without a driver is possible by up to 30% compared to the level of costs currently generated. For example, estimates of potential savings (in general) on the US road transport market are around USD 168 billion per year. In addition to reducing unit costs, extending the daily range of a freight vehicle would significantly improve delivery times offered by long-distance road

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transport. Such a degree of cost reduction explains the great interest of the transport industry in autonomous technology, despite many challenges that the industry will face in the future.

Interestingly, in 2004 two American scientists from MIT and Harvard published the results of research on the labor market. They provided a list of professions that would most likely be automated. As an example of work that could not be automated in the foreseeable future, they pointed to the profession of truck driver. They argued that the algorithms would not be able to drive trucks safely in heavy traffic conditions [Levy, Murnane 2004]. Just ten years later, Google and Tesla are not only able to imagine it, but are actually working hard to put this idea into practice.

The Goldman Sachs Group predicts that due to the impending entry of robo-taxi routes, by 2030, the value of the market of ride-sharing services will increase from 5 to 285 billion dollars. It is assumed that the increase in turnover will be accompanied by higher margins due to cost reduction. This is to be the result of automatic drivers who will not have pay expectations [Podsiadły 2018].

LEGAL RESTRICTIONS

Autonomous vehicles, artificial intelligence, the internet of things, robotics and 3D printing are the driving forces of the modern world. The fourth industrial revolution is a fact and is already affecting work, interpersonal relations, health, education and movement. This in turn is a huge challenge for the broadly understood practice of creating, implementing and enforcing the law.

There is no legal definition of an autonomous car so far. As mentioned above, according to the US National Highway Traffic Safety Administration, there are six levels of vehicle autonomy, from full driver control, through partial automation, to full autonomy, in which the driver's task is only to enter the destination address. According to this division, there are no truly autonomous vehicles yet, although the automation process is ongoing and dynamically developing. In the European Union, there is a similar classification of automation levels SAE (International Society of Automotive Engineers), distinguishing six levels divided into two categories: 0-2, in which the driver is responsible for monitoring the environment and must be ready to take control, and 3- 5, in which the driver no longer has to observe the surroundings and the vehicle takes control of all aspects of driving. However, in art. 8 of the Vienna Convention on Road Traffic says that "every vehicle in motion or group of vehicles in motion should have a driver" and "every driver should constantly control his vehicle".

New regulations are certainly necessary, but those that have been introduced so far (from a historical perspective) have not kept pace with progress. As it turned out many times - they

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strengthened the past, instead of shaping space and room for maneuver for the future. In the modern world, even more so than in the nineteenth century, this means for institutions responsible for the legislative apparatus the need to dynamically adapt to current challenges.

From February 22, 2018, provisions regarding testing of autonomous cars appeared in Polish regulations. In Chapter 6 on the use of roads for the purpose of research on autonomous vehicles, Art. 65k says that "Whenever this chapter refers to an autonomous vehicle, it should be understood as a motor vehicle, equipped with systems that control the movement of this vehicle and enable its movement without the intervention of the driver, who can take control of this vehicle at any time [Act of 20 June 1997 Traffic Law].

Before fully automated vehicles begin to travel on our roads, it is necessary to resolve, for example, liability for damages resulting from accidents and collisions. According to current regulations, this responsibility is borne by one of the road users. But what if the autonomous vehicle moves without human intervention? Is the autonomous system guilty or is it the person who designed and programmed this system? And how to calculate the amount of contributions? What criteria will replace the current factor related to the driver's experience? Previous tests of autonomous vehicles in normal road traffic show that the cause of almost every collision is a human error, because these vehicles move only within the limits of software invented by man [https://www.prawo.pl/prawo/prawo-a-nowe-technologie-autonomiczne-samochody-sztuczna, 453609.html 2019][*].

As there are no fully autonomous vehicles on the market yet, and those equipped only with certain automation elements, such as the parking assistant, are subject to the same insurance rules as all previously produced cars. So far, the standard liability insurance policy is mandatory for all cars available in serial production, but the less obvious issue is insurance for cars from level 4 and 5, which are still being tested. Examination of their possibilities means, however, that they travel on public roads and as such are subject to insurance obligation. In February 2018, a new version of the Road Traffic Act entered into force, which ordered and adapted the provisions on motor insurance to new needs. It includes, among others, information on the obligation to insure the civil liability of the autonomous vehicle test organizer. It is true that every vehicle, including the tested one, is subject to the obligation to have a civil liability

* History shows that crucial moments in the history of mankind aroused as much curiosity as fear. The desire to minimize or avoid risk has often led to absurd situations and left excessively cautious far behind. One of the most spectacular examples is the British Locomotive Act of 1861, and its proper amendment of 1865, colloquially called the Red Flag Act. It assumed that the motor vehicle had to be driven by three people, one of which was obliged to run with a red flag or - at night - a lantern in hand about 55 meters in front of the vehicle and thus warn other road users. The speed limit in cities was 2 miles per hour (about 3 km / h), and outside the city up to 4 miles per hour (about 6 km / h), probably due to the condition and health of the man running in front of the vehicle. The most restrictive provisions of the Act were repealed 31 years later, but the development of motorization in Great Britain was successfully stopped.

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insurance policy, but the legislator extends this obligation to additional protection when testing on public roads. So far, however, the details of the conditions that the policy should have or the amount of the guarantee should be concluded are unknown.

It should also be noted that new technologies are associated with a huge disproportion of consumer knowledge about technology and its expectations. The legislator will face the dilemma of how to regulate consumer protection when using tools based on artificial intelligence, taking into account this disproportion, e.g. by introducing mandatory training, instructions, but also limiting the producer's liability in the event of unrealistic consumer expectations towards technology. According to Y. N. Harari, in the near future, systems based on artificial intelligence, i.e. self-learning and having the ability to analyze and interpret information at a much faster speed than the human brain, will be able to react to unforeseen situations (also occurring on the road) and communicate with each other [Harari 2018].

INFRASTRUCTURE RESTRICTIONS

Nowadays, vehicles have extensive communication capabilities, often connected together in a network. Different networks differ in the degree of sophistication of security systems with regard to, for example, the risk of cyber attacks and data protection. As you know, the distinguishing feature of autonomous vehicles is internal and external software and the appropriate "tool room". These solutions are dynamically developed, implemented and situation-managed by vehicle manufacturers. The connection between the system in vehicles and the central server must be secure in such a way that the data flow is protected against unauthorized access. Uncontrolled access to data by third parties directly and indirectly threatens both the safety of the vehicle and road users. The problem of security against cyber attacks has been increasing in recent years. Autonomous vehicles can generate data such as travel mileage, travel time, meeting goals, etc. Such data is sensitive and is particularly vulnerable to being used by others for harmful purposes. In particular, trucks that carry valuable cargo that can be stolen will be more likely to attack. Autonomous vehicles equipped with a number of technologically advanced solutions enabling safe driving in the event of an attack are exposed to the intentional accident caused by the person making the attack. In such a situation, it seems necessary to apply appropriate legal conditions to protect the data of users of this type of vehicles as well as to constantly develop methods of protection against new threats [Pillath 2018].

Common use of the road infrastructure of autonomous and traditional vehicles will also be one of the major problems. The different perception of the infrastructure they travel on is

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particularly important. Drivers focus most of their attention on what they see. Good surface conditions and favorable weather conditions are often more important than information on road signs. In turn, autonomous vehicles are based on information collected from the environment and analyze it in accordance with the guidelines. This situation may give rise to some conflicts when using roads simultaneously. The solution to this problem may be a partial separation of autonomous and conventional vehicles. This would allow smooth and gradual deployment of vehicles for everyday use. However, the implementation of the idea of self-steering vehicles would have to be preceded by a large number of tests to get a full view of the possibilities of their use in Polish conditions. Another requirement is to improve the technical conditions of the roadway and other road components, because some imperfections such as large road defects may be misread by the systems as an obstacle that must be avoided [Neumann 2018]. Especially in Polish conditions, improving the quality of roads is associated with huge expenses.

ETHICAL RESTRICTIONS

Currently, the vast majority of people are responsible for road accidents. Self-driving vehicles could eliminate human error or help people with disabilities, but looking at this from a safety perspective, it must be ensured that the balance does not ultimately prove negative. Another issue is the issue of liability for any accident. Will the vehicle or software manufacturer be responsible for it? What pattern would the vehicle take in a critical situation - hit another vehicle or drive down to the pavement where people are located?

However, it seems obvious that after the introduction of autonomous vehicles into traffic, accidents will continue to occur. The lawmakers will primarily decide how the machine should behave in morally difficult situations. Therefore, before we allow our cars to make ethical decisions, we need to conduct a global discussion and make our preferences reach companies developing moral algorithms, and decision makers responsible for regulations.

SUMMARY

The benefits that the autonomous transport sneaks into the carriage are considerable. Drivers will not be restricted by statutory working hours, there will be no need for mandatory breaks, and the company's performance may increase several times. Let's not hide, however, that it also has some disadvantages. First of all - it causes a lack of control over the goods. The driver (who is an employee of the company) knows the traffic situation, can look after the goods and is responsible for delivering them. Unmanned car tests have confirmed that they are not trouble-free and any damage to shipments may be charged directly to the accounts of transport

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companies. The inability to work over long distances will make professional and experienced drivers lose their jobs. The profitability of the courses on small sections is much lower, which will result in their rearrangement. American specialists estimate that up to 15% of professional drivers may lose their jobs.

Allowing algorithmic technology to function in society - including on the road - we must be aware of our own responsibility. The challenge is big and the questions are difficult. Sooner or later you will have to face them. Their list is long, and those listed below should definitely be treated as one of the most important:

- Should managers of cities, country, district where tests take place have permanent and full access to data on the behavior of the autonomous vehicle on the road during test drives (stopping, switching off the system, reaction to objects on the road, human interference)?
- Should the number of kilometers that the vehicle will drive test before being authorized be specified?
- Should clear quality standards be developed for vehicle-mounted sensors?
- What is the protection of data that is collected and generated by an autonomous vehicle?
- Is the buyer of the car, along with the purchase, supposed to receive the maximum amount of information about how the car will behave in extremely difficult situations?
- Do unambiguous regulations regarding the protection of the driver's rights and personal rights in the event of an accident have to be set before vehicles are allowed on the road?
- Should full vehicle autonomy (the driver has no influence over the car's decisions) be prohibited?

Over the next few years, the cars will be equipped with increasingly advanced technologies supporting the driver's work. They will use artificial intelligence, as is the case today even with active cruise control or augmented reality solutions, a substitute for HUD displays. Finally, it is worth quoting one of the many forecasts prepared by Allied Market Research [https://www.marketresearch.com/Allied-Market-Research-v4029/Transportation-Shipping-c95/1.html; 2019], where the autonomous vehicle market is expected to reach over USD 54 billion by 2026, and is expected to grow at a rate of nearly 40 percent in the coming years. per year.

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