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## AUTONOMOUS TRANSPORT IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

### ABSTRACT

**Background:** The guidelines for the implementation of the sustainable development strategy will probably change over time, but it seems that if this is the case, the changes will be aimed at increasing the effect on social, environmental and economic values and alleviating tensions between them. The same applies to autonomous transport as an area of economic activity.

**Methods:** The research presented in the article uses a literature review and bibliometric analysis.

**Results:** The main problem areas in the economy of sustainable development in the context of transport and basic causes of the development of stable concepts of autonomous transport have been identified. The literature analysis was conducted in October 2019 on the basis of the Scopus database. Based on the keywords “autonomous vehicle” and “sustainable development”, a total of 79 publications (combining both issues) were identified. The results of pilot questionnaire studies carried out among 50 road transport operators in Greater Poland in 2019 were also presented. They concerned the perception of autonomous transport and the possibility of implementing autonomous vehicles in Polish road transport companies.

**Conclusions:** The interrelation of modern technologies and their impact on sustainable development is not a popular subject of research. It should be noted that in the most popular

topics of autonomous vehicles in combination with sustainable development are therefore dealt with from a technological perspective rather than in terms of economic analysis or economic efficiency. Representatives of Polish road transport carriers are skeptical about forecasts of 30 years for the implementation of autonomous vehicles. Respondents noticed more threats than opportunities.

**Keywords:** autonomous vehicle, autonomous transport, road transport, sustainable development

### INTRODUCTION

The sustainable development is being defined as "right to fulfill a developmental aspiration of the current generation, without limiting rights of future generations to meet their developmental needs". More widely –it is "process of changes, in which using resources, direction of investing, the sense of direction of the technological development and institutional changes are harmonized and are increasing both currents as well as future potential for satisfying the needs and human aspiration"[Short, 1992]. At implementing the concept economics in supply chains one should remember that economy of sustainable development permits in its assumptions a possibility of the market failure and a need for state interferences into various mechanisms of the activity of companies. The given attitude is aimed at stopping action which could be taken by the state and which would force market participants intended for the good for in order to resign from the benefit of future generations what is a superior principle of the concept of sustainable development [Rogall, 2010]. And it is very important when introducing such innovations as autonomous transport.

### PROBLEM AREAS AND BASIC CAUSES OF THE DEVELOPMENT OF STABLE CONCEPTS OF AUTONOMOUS TRANSPORT

A source of distinguishing sustainable development as the challenge of civilization is a phenomenon of the intensifying imbalance between the social-economic development and the state of natural resources what is bringing a major risk of the economic, ecological and social and political instability. A measure of this inequality is ecological footprint which is a synthetic indicator of the demand for sources of the earth. This track within last 45 years underwent the reduplication, leaning in 2007 from the level of the ecological balance about close the 50% [Pietrewicz, 2011].

## CHALLENGES AND MODERN SOLUTION IN TRANSPORTATION

Table 1. Problem areas in the economy of sustainable development

Ecological dimension	Economical dimension	Socio-cultural dimension
Destruction of landscape and species diversity and ecosystem	Inflation	Lack of strict respect for democratic principles and the rule of law
Global warming	Instability of the national economy (e.g. increase in unemployment, low wages)	Lack of social security, demographic risk (e.g. poverty, population growth)
Human health hazards (e.g. exhaust emissions, radiation, harmful substances, noise)	Non-economic imbalances, dependence on raw materials	Inequalities (e.g. gender, religious beliefs)
Depletion of non-renewable resources and overexploitation of renewable resources	Inequitable distribution of income and revenue	Armed conflicts, lack of internalisation and external security, competition for benefits.
	Inadequate coverage of basic human needs	
	State indebtedness	
	Insufficient provision of collective goods	

Source: own work [Rogall, 2010].

Let's look at environmental values. From a perspective of transport, the concept shows the sustainable development on economically justified, socially using acceptable and friendly to the natural environment resources in the destination of supporting its development in the long term [Witkowski et al., 2017]. A process of using the resources friendly to the environment and transforming them is found in a sustainable transport so that it is possible to improve their incidental properties or to affect the recycling in the existing environment without harming it [Brdulak, 2012]. Environmental values are for example following regulations associated with environmental aspects of the conducting business activities.

Social values are mostly related to social capital. Amongst social values mentioned in the transport it is possible to distinguish honest employee practice, fair rewarding employees, abiding by labor law and human rights, adherence to the principles of equality of rights, safety among others on-the-job, not-using for the child labor, not-applying the employee slavery as well as practice set for the cooperation with the local communities.

The overriding goal of any company is to make a profit. But in connection with economic values in the context of sustainable development, relations and cooperation with other companies are also important. It is possible to count to economic values fair conditions of contracts, timely paid to the amount due, not-using the economic majority towards partners in the supply chain, building the relations based on the confidence, applying fair trade rules, appropriate spread of risk and liabilities in the supply chain.

Basic causes of the development of stable concepts of autonomous transport are:

### ***New regulations***

Regulations are imposing more and more of high standards and financial penalties for the harmful impact on the environment. For example, influences limiting the level of the adverse impact of transport to the natural environment are included in the idea of sustainable transport. According to the OECD environmentally sustainable transport system (environmentally sustainable transport system) is "which isn't threatening the public health or ecosystems and is meeting the transport needs according to principles (a) of using renewable resources below the level of their ability to reconstruct and (b) of non-renewable stores below the level of development of their renewable substitutes" [Environmentally sustainable transport, 2000]. Next the White Paper of Transport 2011 clearly shows the modernization the transport to the plan in Europe to the year 2030/2050. European Federation is defining components of the sustainable transport for Transport and Environment. According to that it is possible to regard sustainable only when it is meeting four conditions of the environmental awareness, the economic optimum, social grounds and the political responsibility the transport [Wojewódzka-Król et al., 2016].

### ***The development of new technologies and the 4.0 industry***

In web-based global business arena witnessing Industry 4.0, has to be smart, innovative and socially responsible to form value-creating networks. It is possible to envision an autonomous transport of the future: The autonomous transport will be an incredibly complex and dynamic. Information will increasingly be machine-generated (instrumented). For example innovations in-vehicle sensors, processing power, and digital maps are driving the autonomous vehicles revolution. TomTom company is developing innovative technologies to power autonomous vehicles.

### ***Growing environmental awareness of the society***

Comprehending the environmental awareness is being considered in two dimensions. In a broader meaning, an entirety means acknowledged ideas, the value or also an opinion on the environment as the place of the life of man, together shared by particular social groups in the given period. In narrower meaning, it is a state of knowledge, views and conceptions of the role of environment concerning people in the life of man, [...], as well as state of the knowledge about ways and tools of managing the use, the protection and the forming of the environment [Poskrobko, 2007]. Enterprises that noticed the trend of the change of perceiving the environment by consumers are changing the manner of delivering goods and their production in more environment-friendly way. This means society need to build trust in innovation,

ensuring users believe in the technology and feel safe when using it. With autonomous transport, the challenge is to educate people to trust technology, to drive adoption.

***Purchasing and the conversion of the knowledge***

Knowledge is one of the most decisive factors capable of offering competitive advantages for companies that are engaged in autonomous transport. To obtain advantages from knowledge sharing, it is strategically important that firms understand the factors affecting partners' knowledge sharing behaviors [Cheng et al., 2008].

***Possibility of the cost-cutting***

Along with the need for seeking the cost-cutting new concepts are developing of business administration. However according to the J.K. Galbraith (Noble prizewinner) action connected with the environmental protection "by their nature are in conflict by force incentive of market economy" [Pietrewicz, 2011]. And so enterprises are implementing concepts of narrow management in order to eliminate the waste of the space, the stores of the production or the time of producing and delivering for the ultimate customer.

***The policy of image***

Autonomous transport is a result of combining environmental friendly management with cost-efficient solutions. It is particularly important in the case of energy-intensive and material-consuming parts of the industry in which a large quantity of waste is occurring [Brdulak, 2012]. In order to increase competitiveness companies are using many different tools influencing their environmentally-friendly image.

**AUTONOMOUS VEHICLES AND SUSTAINABLE DEVELOPMENT – IN THE LIGHT OF A LITERATURE REVIEW**

The interrelation of modern technologies and their impact on sustainable development is not a popular subject of research. The literature analysis was conducted in October 2019 on the basis of the Scopus database. Based on the keywords "autonomous vehicle" and "sustainable development", a total of 79 publications (combining both issues) were identified. Most of these publications are on Engineering (58) and Computer Science (47), followed by Social Sciences (15), Environmental (11) and Mathematics (9).

It should be noted that in the most popular topics there are neither economic nor management sciences. The topics of autonomous vehicles in combination with sustainable development are therefore dealt with from a technological perspective rather than in terms of economic analysis or economic efficiency. Of these 79 publications, 18 were published in 2019, 23 in 2018 and 12 in 2017. This means that almost two-thirds of publications on the subject

have been published over the last three years. Apart from these two slogans, the keywords of the discussed publications include, among others, “Vehicles”, “Intelligent Systems” or “Transportation”. These publications were prepared by scientists from different countries, most of whom were from National University of Singapore (4 publications), University of Michigan, Ann Arbor (4) and Massachusetts Institute of Technology. The leading scientists are from United States (22), China (8), United Kingdom (8), Canada (7), Germany (6) and Italy (6).

The authors of selected publications indicate the special role that modern technologies play (and will play) in the development of sustainable transport systems. As Ginley [2014] notes: “The future is bringing increasing demands for greater efficiency and for more sustainable designs in cargo handling technologies. Moreover, the scarcity of land is forcing port companies to realize higher area utilizations. Terminal operators have the same objectives but they are also looking for cost reduction through decreased life cycle costs, energy consumption, maintenance, etc. This is forcing terminal operators to invest in more sustainable, environmentally friendly and cost-effective cargo handling equipment. The challenge is how to balance service requirements, costs and demands for sustainability”. The attempt to balance transportation needs with the possibilities of the environment is, of course, not only about maritime transport.

Automated transport systems also play an important role in the creation of urban mobility and have an important influence on the shaping of urban space. Cities are now facing the challenges of the 21st century: sustainable development, the transformation of the digital economy, climate change, with the support of smart mobility tools. “However, this innovative technological advancement is also speculated to bring a major disruption in urban transport, land use, employment, parking, car ownership, infrastructure design, capital investment decisions, sustainability, mobility, and traffic safety” [Yigitycanlar et al. 2019].

So the research question is, is there a place for sustainable mobility based on autonomous and shared vehicles in urban space today? Recommendations for the implementation of such concepts should be indicated: implementation of implementations based on benefits associated with convenience of use at reasonable costs, taking into account the interests of stakeholders, taking into account the diversity of mobility needs, based on multidisciplinary research projects, taking into account engineering and economic perspectives, but taking into account “psychology, sociology, history, anthropology, innovation studies, and public policy as well as the arts and humanities” [Sovacool and Axsen, 2016]. It should also be born in mind that the future of transport remains highly uncertain. Although we are talking today about car ownership models and changing the way cars are used, it should be remembered that electronic

communication can lead to a partial replacement of mobility needs. Thus, transport policy instruments (car-free streets, charging infrastructure, parking policies, etc.) should be implemented taking into account the need to reorganize urban space for self-propelled vehicles [Vleugel and Bal, 2017].

Attention should also be paid to the safety of autonomous vehicle traffic (AV) as part of both intelligent transport systems and sharing economics. “AV privacy has crucial implications for smart and sustainable development. Amidst the growth of ICTs and the sharing economy, the protection of personal data and the security of communication networks are vital to ensure society capitalizes on the gains from increased connectivity” [Si Min Lim and Taehagh, 2018]. The authors of this publication point that information security management is critical to protect the users of autonomous vehicles. Security of data against unwanted access to one and the other element, according to the authors, is the building of user’s trust, which is (and will be) necessary for the further development of autonomous vehicle technologies and their market success.

Astarita, Giofre, Guido and Vitale [2019] pay attention to the definition of “floating car data” (FCD): “New technologies such as “connected” and autonomous” vehicles are going to change the future of traffic signal control and management and possibly will introduce new traffic signal systems that will be based on floating car data (FCD)”. The use of such data to regulate traffic in real-time gives, among other things, the potential to create sustainable transport in terms of energy efficiency (but also road safety). The authors point out, however, that there are no studies today on how “unconnected” (to the global network), vehicles could benefit from participation in such a system [Astarita, et al. 2019].

One of the challenges for the development of autonomous mobility remains traffic management tools. Among the interesting directions of research are, therefore, those related to new traffic control tools. Comparing traditional traffic control tools with new communication tools and technologies, these technologies have great potential for reducing pollution and energy consumption at junctions [Li et al., 2015].

Traffic management at junctions is just one of the challenges. Another is the supervision of the maximum speed of vehicles. These technologies are present in the literature under the name Variable Speed Limit - VSL. “Most of the VSL control algorithms in the literature have been based on aggregate traffic data and ignored the fact that drivers have different preferences and compliance behavior” [Khondaker and Kattan, 2015]. The authors point out that it is very interesting to use a microscopic approach and analysis of individual driver’s behavior combined with tools to predict traffic changes and assess road throughput. Multi-criteria optimization will give you the ability to balance three elements: mobility, safety, and sustainability. The proposed

model (and algorithm) will allow the evaluation of travel with the use of Total Travel Time (TTT) or Time To Collision (TTC) indicators to measure safety [Khondaker and Kattan, 2015].

The potential of autonomous vehicles to implement sustainable development can also be seen in the wider context of linking autonomous vehicles to sustainable supply chain development. The transition from traditional supply chains to digitised networks and supply chains supports sustainable investment, integration and coordination of processes, which in turn creates tools and opportunities for the use of autonomous vehicles in sustainable supply chains [Bechtsis et al. 2018].

### **AUTONOMOUS TRANSPORT FROM THE PERSPECTIVE OF ROAD TRANSPORT ENTREPRENEURS**

According to the results of the PwC "21st CEO Survey", as many as 68% of the CEOs and directors of global companies in the transport and logistics industry expect changes in key service technologies to have a breakthrough in their business. According to practitioners [PwC, 2019], autonomy in the form of fully autonomous vehicles is key to filling the labor supply gap in the market will enable a reduction of transport costs by 28% after 2025 by replacing the costs of labor (drivers) with the costs of software, telematics, and remote control. Most economic, social or political and legal factors will most likely lead to an increase in costs in the industry, and autonomy can, therefore, be one of the few ways to reduce them. However, you will have to wait 5 to 10 years for technological solutions in this area to mature. As many as 78% of representatives of global transport and logistics companies plan to take action to automate tasks and positions to ensure effective implementation of the company's goals. In turn, 31% of them plan to invest in automation by 2020 [PwC Digital IQ Survey, 2017]

Automatization will require legal adjustments, which in turn requires achieving broadly understood social consent for the use of autonomous vehicles in road traffic. This process requires not only the active involvement of legislative and executive authorities of countries implementing autonomous solutions, but also representatives of the NGO sector, representing the interests of citizens, and the media, which play an important role in communicating modern solutions and ways in which they can be used in practice. Currently, unfortunately, it is difficult to talk about a healthy balance in the field of communication of innovations related to autonomous transport - the public space most often receives reports about accidents involving autonomous or semi-autonomous vehicles. From this perspective, the introduction of autonomous vehicles is very closely linked to the social aspects of sustainable development.

The quoted PwC research presented the opinions of managers of global companies. However, in Poland, most road transport companies are small and medium-sized enterprises. That is why it is worth looking at autonomous transport from their perspective. The results of pilot research carried out among road transport operators in Greater Poland in 2019 for the purposes of the thesis will be presented below [Różniewicz, 2019].

According to 58% of respondents, by 2030 autonomous cars will normally functioning on Polish roads, only 16% were skeptical about such implementation prospects. 76% of respondents declared their willingness to participate in courses enabling better understanding of the topic of autonomous vehicles. 82% of respondents are willing to replace trucks and vans in their own fleet with self-steering ones. Among the benefits that the respondents saw in the introduction of autonomous cars, cost optimization was 58% first. It was to consist of getting rid of the costs of drivers' salaries, faster covering the route - without mandatory breaks in accordance with the Act on the driver's working time, timely delivery. 32% of respondents noticed the benefit of being able to constantly monitor a vehicle, its location and, technical parameters. Only 14% of respondents saw the benefit of eliminating a significant number of accidents caused by drunk drivers.

Questions about the potential benefits of using autonomous vehicles as well as threats were multiple-choice questions. Respondents perceived threats more often. They considered the biggest threat to the lack of trust in the 36% system, they are also afraid of software errors and the inability to respond to such obstacles from vehicles. 64% of respondents indicated that autonomous vehicles were not adapted to the psychological aspects of other road users - for example, the behavior of drunk pedestrians. Another threat is what has also been indicated as an advantage, i.e. reduced employment of drivers - 44%, also in the context of retraining or acquiring new skills, piloting an autonomous vehicle.

The number of technological solutions used in enterprises employing respondents may also affect the perception of automation. The vast majority of respondents declared that their enterprises use the most popular solutions, i.e. GPS (Global Positioning System) - satellite navigation system, working time controller and driving speed controller. 23 people indicated that they worked with the help of cargo tracking, and three people less - with a fuel consumption meter. The least respondents got acquainted with the functioning of the tire pressure sensor and temperature sensor. Awareness and ability to use individual tools also results in answering previous questions. People who worked with the fuel consumption meter, work time controller, GPS indicated that they are in favor of the introduction of autonomous cars because it will facilitate their work because the above devices will cease to need them.

96% of respondents would like to use the latest technologies at work. 60% of respondents believe that autonomous transport is an expensive solution. In this issue, the most important were the responses of employees who use the latest technologies at work. They are the ones who have the greatest awareness and have broader knowledge than others. After careful analysis, it was this group of people who fully opted for autonomous transport. And 40% of those surveyed believe that an investment in autonomous rolling stock will pay off and begin to bring benefits in a few years.

### CONCLUDING REMARKS

Modern autonomous transport models are the result of many compromises, not least because of the need to provide value in environmental, social and economic terms –as indicated above. This is one of the main reasons why their implementation has been so slow. Another reason is the lack of mechanisms for the integration of sectoral policies implemented in self-government administration bodies, as well as systematic identification of cooperation, especially between sectors.

From a bibliometric analysis it follows that:

- the future is bringing increasing demands for greater efficiency and for more sustainable designs in cargo handling technologies;
- automated transport systems also play an important role in the creation of urban mobility and have an important influence on the shaping of urban space;
- attention should also be paid to the safety of autonomous vehicle traffic (AV) as part of both intelligent transport systems and sharing economics;
- information security management is critical to protect the users of autonomous vehicles;
- the potential of autonomous vehicles to implement sustainable development can also be seen in the wider context of linking autonomous vehicles to sustainable supply chain development.

Representatives of Polish road transport carriers are skeptical about forecasts of 30 years for the implementation of autonomous vehicles. Respondents noticed more threats than opportunities. This is due to a lack of confidence in the technology. Autonomous cars that are slowly entering public use in many countries are not surprising. In Poland, this topic is innovative. Until now, respondents had knowledge about autonomous transport. For the most part, they expressed their willingness to participate in training in this field, and also positively supported the possession of self-steering cars in the transport fleet in the enterprises employing them. Respondents' responses were competent with the work performed. People working with

the latest technologies see vehicle automation as a beneficial phenomenon and want to work with them. More often it was this group of respondents who marked this as an opportunity and continued to show interest in this topic. Therefore, it should be stated that from the perspective of sustainable development, the introduction of autonomous vehicles to Polish roads will be associated with a group of sociological factors, to a lesser extent economic.

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