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Safety of the Introduction of Self-driving Vehicles in a Logistics Environment

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Abstract

Thanks to the increasing speed of technological development brought by the 21st century, many of the processes in industrial production have been automated. The next big step in this progress of artificial intelligence could potentially be in corporate logistics, road haulage, and even private transport. Naturally, automation within corporations and in critical infrastructure raises ethical and trust-related issues, reflected in the attitude of emerging markets toward this form of development. This research aims to discover the current state of development of self-driving vehicles through comprehensive literary research and to present those ethical problems, the solutions to which are paramount for society to accept and to incorporate the concept of self-driving vehicles. As a result of the analysis of a knowledge-based system with the inductive inference method in primary research, the current strengths and weaknesses of automation in the field of logistics are revealed. The paper summarizes the results of the primary research and projects them for the future of automation.

Keywords

safety, self-driving, logistics, knowledge based-systems, inductive reasoning

1 Introduction

The continuous development of the automotive industry has allowed the average citizen to afford electric vehicles and even vehicles with self-driving features. Rapid technological advances have also contributed to the development of high-level logistics in companies. Warehouses are nowadays aided by self-steering forklifts and sorting machines, while automatic cruise controls, lane departure alerts, automatic braking, and automatic parking assistance are introduced on the roads. These features assist drivers, though still requiring their presence. Fully automatic, driverless vehicles, however, are still in the future, and their introduction to society is currently limited not only to further research and development. Ethical and trust issues frequently arise concerning self-driving vehicles and artificial intelligence in general. Humans often are reluctant to accept that a machine could make decisions for them. This distrustful social attitude is also influenced by culture, movies, and online media.

1.1 Methodology

Through an extensive literature review, we explore the development and current state of self-driving vehicles, afterward, we raise the most significant ethical issues, decisions, and trust factors reflected by society's attitude towards the spread of self-driving vehicles on public roads.

Based on the answers received in an in-depth interview with the head of a logistics company with decades of experience, the main advantages and possibilities of automated vehicles used in logistics and the current weaknesses of the technology are presented.

1.2 Objectives

The aim of the research is to provide insight into the current state of development of self-driving vehicles and to tackle the main ethical and trust-related issues, which divide society.

The advantages of automation and continuous technological development, along with the current weaknesses of self-driving vehicles are presented primarily in the area of logistics, warehousing and transport.

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2 Secondary research

2.1 Self-driving automobiles

In terms of their driving independence self-driving cars are classified into five distinct levels. These are the so-called levels of autonomous driving. The traditional driving experience regarded as the zero level of autonomy is defined when the vehicle is fully controlled by the driver without the availability of any driving aid (Pardavi, 2018). The first level of autonomous driving involves the presence of cruise control and lane recognition systems in the vehicle. These technologies have appeared in the late 90's and since have become an option in machine equipment in modern automobiles (Handy, 2004). In this case, the driver is fully responsible for the vehicle's operation, while the technology the vehicle is equipped with is only intended to be used to facilitate driving functions. The main purpose of cruise control, for instance, is for the driver to avoid having to keep the foot on the gas pedal continuously, which can be tiring (hvg.hu, 2019).

The second level covers the parking function and an augmented version of cruise control. From this level the automobile is able to park on its own, but the active presence and supervision of the driver remains mandatory and essential. Concerning the cruise control function, level two incorporates an intelligent chip capable of identifying if the vehicle is moving too fast before a turn and decelerating it if necessary. A further feature still belonging to the second level of autonomous driving involves the ability to detect the proximity of an object that is noticeable in the front of the vehicle and to brake automatically. On this level it is possible to minimally transfer the control of the vehicle, however only if necessary and for the duration of a short period, or a rapid action.

The third level of autonomous driving still requires the presence and the undivided attention of a driver. The driver must be fully aware and monitoring the road, while the vehicle can return control at any time. Any road traffic accident or damage caused to the vehicle is still under the responsibility of the drivers themselves. Many modern automobiles of the third level of autonomy can take control of driving for a significant amount of time, however, it is only possible on highways or roads with few intersections, zebra crossings, traffic lights, and other road signs (Chowdhury et al., 2021). In 2016, Tesla was the first to achieve the third level of autonomy in vehicles. With their cars, Tesla drivers can give full control to the car even for a long period. It is possible to entrust control to a vehicle with a third-level automated driving system to a greater degree. The vehicle is even capable of changing lanes automatically with the assistance of braking and lane clearance assessment. Human intervention still can't be ruled out while autonomous driving, as the road infrastructure, is often of poor condition and unsuitable. The average time of reaction of third-level self-driving vehicles is around 2 seconds, which in many cases is slower than that of humans (Pardavi, 2018).

The fourth level of autonomous driving is already very close to the concept of a fully independent transport. Here technological development is realized in the 3D visualization of traffic conditions. Therefore, the vehicle's software is important to be up to date with current traffic information. (Wong et al., 2020) We still can't quite regard this level as that of full driving autonomy, since the vehicles' reliable maneuverability highly depends on advanced critical traffic infrastructure, where 3D street mapping has been implemented. The earliest such vehicles could achieve widespread prevalence is 2022 (Liu et al., 2020).

Reaching the fifth and final level of autonomous driving means that the industry will reach such a phase of technological development, where gas pedals and steering wheels will be abundant in cars. The ultimate goal is for the vehicle to be able to navigate from A to B with 100% autonomous operation, making completely independent decisions. Based on the reviewed literature, the introduction of these cars on public roads is expected in 2024. With fifth-level autonomous driving vehicles on the streets, for the first time ever, the blame for road traffic accidents will be put on the vehicles themselves, instead of the drivers. It is clear that the future is moving in this direction, but the introduction and widespread acceptance of these cars will require a number of legal permits and finding concrete answers to controversial moral issues (hvg.hu, 2019).

Nowadays, fully autonomous vehicles are operating on fixed tracks in many countries, in Hungary, for instance, it is the metro line 4 (Hamvas, 2018). The Austrian Navya buses, however, are transporting passengers on open circuits in Vienna. Similar driverless buses are operating in the US, Belgium, China, and even Japan. These fully autonomous bus services, however, for now, only cruise mostly in closed industrial parks, ports, where traffic conditions are much more predictable than on public roads (Trapp et al., 2019).

At the time of this research (2021), technological development stands at the third level of driving autonomy, with some level-four vehicles becoming more and more widespread on the roads. The biggest obstacles to the prevalence of higher-level autonomous vehicles include the question of mass production, the price of such vehicles, and the critical traffic infrastructure needed for this technology, not to mention the issue of trust.

2.2 Ethical and trust-related issues

Any innovative idea, or invention that challenges the status quo and radically differs from what has been the case so far is subject to a thorough and scrupulous scrutiny. So is the case with our research.

One of the most important question is the impact of self-driving cars on society. The issue of security can be both addressed from the perspective of human lives and the security of personal data of the owners of autonomous vehicles. The aforementioned issues are closely related, since the successful operation of a self-driving vehicle depends on an algorithm, the input of which is the information established between self-driving cars themselves. In contrast, however, people always value the security of their personal information very highly, and therefore, they may not necessarily prefer the idea that the system keeps track of every move they make with their vehicle. The central control system can be rendered useless by a cyber-attack. In this case, not only the data of the passengers in the car could be endangered, but also their lives. Furthermore, when a traditional and a self-driving vehicle meet on the roads, it may cause unpredictable behavior in the former and become a source of a problem. Traditional manually driven cars are not a part of the algorithm. Reactions originated by humans may differ significantly from what self-driving vehicles predict, and therefore roads may become less safe (Csizmadia, 2019). Naturally the technological shift doesn't happen at once. There are three different levels of self-driving cars on the roads nowadays. Self-driving cars must be able to assess their environment and react to road incidents that the system did not expect (Banyár, 2019).

Looking into the future, the ripple effect classifies the expected effects of a particular technological development into three chronologically ordered groups. Numerous studies examine the impact of self-driving cars on society and the direct and indirect consequences of their proliferation. Overall, based on the examination, it can be said that people tend to prioritize comfort, therefore over time, self-driving cars are expected to become widely accepted. With the gradual introduction of self-driving cars shortly, even those with no driving or car ownership experience will be able to be a part of the traffic and appear on the roads without the need for a driving license. So, the logical argument is that the increase in road traffic is inevitable, and people will prefer cars over public transport and be willing to take longer journeys by car as well (Fehér-Polgár and Michelberger, 2019). Based on this argument, when technological development reaches a fifth level of driving autonomy, self-driving vehicles could lead to an increase in road traffic of up to 14%. From the perspective of the environment, there is a clear danger of increased emissions, or in the case of electric cars, increased battery charging and disposal requirements, the long-term effects of which are, again, questionable at best.

It is also worth considering the possible impact of self-driving cars on employment. Today in Industry 4.0, robotization, digitalization, and interconnectedness have become essential in the operation and production process of factories and companies, which primarily replace the workforce. Within factories, autonomous machines and devices with artificial intelligence simplify everyday life. However, automated processes often lack precision, and the financial investments required are higher than those required by employing a human workforce in the long term. With the advent of self-driving cars, many other work areas can suddenly fall at the risk of disappearance. According to current research, taxi companies, chauffeur services, and areas for logistics supply are most at risk.

The social problems requiring examination come from a wide range, and the attitude towards this research area is frequently based on presumptions of the expected advantages and disadvantages that automatization may bring to society. Another question frequently stressed amongst researchers is the ethical question whether vehicles endowed with artificial intelligence are, in fact, able to make decisions that prioritize human lives. What happens when a conflict occurs between the driver and the artificial intelligence? Could the decision-making process be identical as if it was a conflict between two humans? Clearly, the ability of judging a situation solely from the perspective of emotions will not be achieved by an artificial intelligence, but the real question is whether it is possible for the machine to achieve a level of understanding equal to that of society's expectations (Csizmadia, 2019).

In the 1960s the so-called Trolley Dilemma (Csizmadia, 2019; Foot, 1967) tackled exactly the question above. The research examines the question that when an accident is inevitable, and it's impossible to save all the vulnerable people involved, what are those factors that can be used to successfully assess the situation and make the decision that saves the most lives. This dilemma got its name from the original depiction of a trolley on a track.

The dilemma features a situation in which a tram is traveling at a high speed, unable to stop. On the tram route, there are five people doing maintenance, and there's only one worker on the parallel track. The test subject can shift the rails so that the tram goes to the parallel track. The test subject must therefore choose the least of two evils. The research is also enhanced by the choice of the subject, whether he wants to confront the events and take responsibility for the life of the worker on the parallel track or remain idle and wait for the inevitable accident with five people. Nearly 90% of the surveys conducted resulted in test subjects switching the rails, thus saving the lives of five workers in favor of the single worker on the parallel tracks. The choice is explained by the notion that people would be unable to live with the fact that they could have saved five people. A slight variation of the above dilemma was proposed by Thomson (1976), where the test subject stands on a bridge over the rails. An overweight person stands on the bridge beside the test subject. Further down the rail, there are five maintenance workers. The accelerating tram moving towards the five workers can, yet again, be moved to a different track if the test subject pushes the overweight person off the bridge. In this situation, however, the test subject must become a part of the incident itself to save the five lives.

A much greater struggle develops in this case between rational thoughts and human feelings, as the test subject needs to consider the option of directly intervening in the course of the experiment. When confronted with this choice, only 10% of the test subjects were willing to sacrifice the life of the obese person next to them (Bonnefon et al., 2016; Csizmadia, 2019). The basis of the decision, in this case, was the number of lives extinguished, as no other information was available at the time to the tests subject. Therefore, the more information is available to the decision-maker, the more it influences the decision, and the more confident the test subject can be with the outcome. For instance, in the case of the previous dilemma, personal information regarding age, occupation, culture, the religion of the obese person, and the workers below the bridge would have been useful to make a decision the subject would be sure about. Nowadays, an unethical decision solely made by artificial intelligence could lead to a global scandal within days (Csizmadia, 2019).

Safety is the first societal expectation towards drivers and motorists. People want to be sure that their families, friends, and themselves are safe on the roads. That's why it is worth highlighting the greater level of safety that self-driving cars have. According to the Hungarian Central Statistical Office, in 2020, the total number of road traffic accidents in Hungary was 16 627, of which 530 resulted in fatalities and 4834 in serious injuries. Overall, the number of road accidents and fatalities is declining on a year-on-year basis in the European Union. This is generally due to the rapid technological development of the automotive industry and advanced safety driving systems found in many modern vehicles (Hungarian Central Statistical Office (KSH), 2020). Systems installed in self-driving cars are now much more alert and able to react faster and in much more dangerous situations than humans (Howard and Dai, 2014). There were 35,000 fatal accidents in the United States in 2010, most of which were caused by drunk driving, minor inattention, and falling asleep. It is assumed that the number of these accidents caused by driver error will decrease significantly in the future due to self-driving cars.

Self-driving cars will also help to remove traffic jams and gridlocks. Thanks to the established connection and constant communication between the vehicles, potentially dangerous routes will be bypassed, and jams will be avoided. This will be made possible thanks to the (DSRC) dedicated short-range communications device, which can be used in a distance within 1 km of a similar device. Cars can communicate with each other and with traffic within this distance and alert each other if there is an accident or, for instance, if an ambulance is approaching and the way should be cleared. GPS-based systems also could aid in mapping what's happening on the road in real time. In addition, the inertial navigation system used is able to assess the speed, direction of travel and current position of the surrounding vehicles. The (LiDAR) light detection and ranging scanner helps to measure the distance between objects by creating a image with the emitted laser by measuring the speed of light, which helps the car to orient itself. As a result of increased traffic balance and the introduction of electric cars on the roads, fuel consumption is also expected to decrease, as smooth driving and consequence free braking, as well as the number of repeated accelerations will decrease. These changes will have a positive effect on our environment and will significantly reduce emissions (Dickson, 2020).

It's also worth to mention that those people born with disabilities, illnesses or health disorders who are unable to drive a car will be able to safely participate in traffic thanks to new technological developments. The amount of free time people possess will also increase, because the time spent driving will be freed up. The driver will now play the role of the passenger in the fifth-level autonomous vehicle (Csizmadia, 2019).

2.3 The impact of self-driving vehicles on logistics

Industry 4.0 is based on information technology. The essential condition for optimal operation is that the efficiency of the technology inside the factory must match that of outside the factory. Hence, the development of external and internal logistics must always be at the same level. Of course, today, logistics is much more than just storing and transporting products. The field of logistics is nowadays augmented with external and internal transport of products between companies, the movement of materials, their storage, and their loading as well. The success of logistics companies in Industry 4.0 is entirely based on digitalization and its adaptive organization. Special attention is focused on the data flow and network systems in addition to the coordination of information systems. The aim is to create a transparent, easily configurable system with an optimal flow by taking advantage of the technological developments brought on by Industry 4.0 (Szentmiklósi, 2019).

The logistics field already incorporates automatic vehicles in day-to-day operations and supports the workforce. Self-driving vehicles are used on short distances and in closed areas, while self-driving trucks are used over long distances outside the factory.

Many logistics companies around the world use vehicles with self-driving technology within warehouses. Material handling tasks are automated with transport equipment thanks to technological advances. Again, it can be argued that the cost-effectiveness and the precision of the activities performed by the machines are proportionally better than those performed by humans. Naturally, the above can only be stated for the processes that require minimal pre-programmed decision-making in an enclosed space. Technological development, therefore, is only replacing mechanical, monotonous work, therefore, the need for human labor in these areas declines. Of course, there are still so many decisions and activities where self-driving vehicles are incapable of decision-making here humans must intervene. There is an increasing need for qualified competent technicians with expertise who will be able to monitor the performance of autonomous vehicles (Ferenczi and Németh, 2020). Companies have to create and develop plans that would allow them to operate autonomously and become a so-called "smart factory". This, however, means automating a significant part of the production line. In many cases, the procurement of automated vehicles is insufficient to build a proper closed system, it is also essential for the storage infrastructure to be unhindered, and free of obstacles (Toldi et al., 2020).

The condition for the successful implementation of autonomous vehicles in the warehouse is for them to be capable of orienting themselves in space. It must also be able to recognize a pallet it was instructed to, transport it, and then deliver it physically to the desired location undamaged in an as efficient and shortest way as possible. Self-driving forklifts are already in use today performing the above-specified tasks. In-warehouse automation can be divided into four separate levels, illustrated in Table 1.

At the time of the research, we can mention the successful implementation of third-level autonomous vehicles, specifically in enclosed areas. However, many warehouses implement the technology of the fourth or even fifth level of autonomy (Ferenczi and Németh, 2020). One of the most prominent implementations of third-level autonomous technologies can be found in forklifts. The autonomous movement of this equipment is thanks to laser technology. In the early stages of the development of autonomous forklifts, an attempt was made to build a track the forklift could follow automatically by carefully positioning magnetic plates on designated routes in the warehouse. The forklift was able to follow the route while keeping constant contact with the network. The aforementioned technological solution involving lasers can determine the exact position of forklifts using mirrors mounted at specific distances (Fükő et al., 2020). This technology is referred to as the LiDAR system. Here a laser scanner manufactured by Sick assists the determination of the spatial location of the forklift (Michelberger and Kemendi, 2020). The scanner rotates while emitting a laser beam and can calculate the current position and direction of the vehicle from the signals reflected from mirrors. This allows the vehicle to be moved according to specified coordinates (Sick AG, 2020). The sensors are located in the front and rear of the forklift and map the environment around the vehicle.

Table 1 Levels of automation of machines used within the warehouse

Levels	Tasks performed.
Level 0	Tasks performed entirely by human labor
Level 1	The task is performed by people with the help of smaller tools and machines.
Level 2	The labor is completed by machine, but it is handled by humans.
Level 3	A machine performs the task on its own, it is controlled by a human, but some tasks are already performed automatically, e.g. forklift.
Level 4	The whole task is performed by the machine according to the instructions sent to them, no human intervention is required.

Source: created by the authors, based on Ferenczi and Németh (2020)

The operation of the sensor is divided into two separate functions. It must be noted that the sensor can't cause the forklift to stop it rather warns it, however, as a result of failure to avoid danger, it interrupts the power supply, and the forklift stops. Naturally, autonomous forklifts are capable of communicating with each other, furthermore, there is also a possibility to connect to the forklift via WIFI if it is justified by management (Cservenák, 2019). Thanks to the constant connection and flow of information, the forklift can pass on the task assigned to it to another one in case the former is running low on fuel or battery. At low battery levels, the forklifts can withdraw from an operation and return to the charging station. By transferring the tasks to another forklift, the process is resumed (Fükő et al., 2020). Floor-mounted strips or magnetic plates are no longer required for the accurate orientation of autonomous forklifts (Cservenák, 2019).

Since the operation of forklifts is intertwined with artificial intelligence, they work with a higher degree of precision and more carefully than, for instance, a specialist with many years of experience. Still, they are only used in warehouses in enclosed areas where the traffic is manageable. Forklifts use additional sensors for collision avoidance and path clearance. It is therefore essential that the path of motion of autonomous forklifts be optimally designed to maximize the efficiency of the vehicles and minimize the chance of accidents. Any form of obstacle or perceived danger will cause the forklift to halt. Forklifts are not yet able to assess the situation at the level of human perception, but instead, wait for an obstacle to disappear and for the ambiguous situation to be resolved. Human intervention on the path of the forklift can interfere with its operation. Hence, the most suitable area of use for autonomous forklifts is warehouse buildings, which, thanks to their intricate design, can be used to transport a given load from point A to point B without obstacles. Autonomous forklifts are nowadays used in warehouses of companies where the materials arrive in a manner, which the vehicle can manage, for instance, a pallet, a box, or a package. Some possible improvements can still be pointed out, for instance, it is evident that self-driving forklifts are still not enough to fully automate the supply chain itself. Processes leading up to and flowing from the warehouse management cycle require human labor, such as the process of sorting or accounting. Without automatizing the former, we can't talk about a fully automatic logistic chain. While building the infrastructure and assembling a fleet of automated forklifts is indeed a significant investment for companies, more and more of them are choosing to go through with the change management process given the possibility to save costs and move hand in hand with the latest technological developments (Fükő et al., 2020).

Seegrid an autonomous mobile robots service provider, is an example of a company that uses autonomous forklifts. This company is also involved in automation within warehouse material handling. The company offers state-of-the-art sensors, software, and autonomous vehicles with safety equipment. Seegrid develops forklift fleet management software for companies that maximize the efficiency of warehouse operations (Seegrid, 2020). The company manufactures industrial vehicles and is known for the so-called GP8 Series 6 autonomous forklift. The vehicle is operating at the fourth-level of autonomy. The AGV forklifts are operating on cutting-edge self-driving principles and don't require any changes in the infrastructure of the warehouse (Sentech, 2020). The forklift uses 10 cameras and an image recognition algorithm to orient itself in the warehouse. The GP8 Series 6 model is still in the pre-purchase stage, which means it's not used in factories or warehouses, but the technology is already available as is the vehicle (Abegaz and Shah, 2020). Seegrid forklifts are used by market-leading companies such as General Motors, Jaguar, Land Rover, Amazon, and Whirlpool. The company is constantly working on the development of self-driving vehicles in the area of logistics, and its corporate goal is to ensure that organizations can operate autonomously, reliably, and accurately at all points of the supply chain (Dormehl, 2017).

The freight market has also undergone significant change in the past years. Autonomous freight transport holds great promise in the exploration of self-driving technologies. In today's fast-paced world, there is an unprecedented need to transport goods to meet customer needs (Rosen & Ohr Law, 2020). The development of trucks and freight transporting systems aid drivers during long shifts and helps them to avoid potential incidents. Practically, every modern truck already has functions of cruise control, lane recognition systems, as well as automatic braking. It's not a coincidence that most trucks are already level-three autonomous vehicles since they are regarded as the most dangerous vehicles on the road due to their size and weight. Hence, there is a strong and justifiable need for their development and security (Hungarian Central Statistical Office (KSH), 2020). What's more, carrier companies have to face the issue of the employees' mental health and needs. The driver's daily driving limit and mandatory rest periods are regulated strictly. Modern trucks are already able to drive on the highway regardless of the supervision of the driver (Origo, 2019). Still, the problem of maneuvering in cities or on smaller, less mapped roads remains, thus the active presence of the driver is still required. In a closed and controlled area, it is possible to even for vehicles as large as trucks to establish V2V communication. At the time of writing the paper, all truck drivers must remain in control of the truck at all times, especially when driving off the motorway and entering towns and cities (Torontáli, 2019).

In 2018 an autonomous truck from Embark traveled 3863 miles from Los Angeles to Jacksonville on a test drive without human intervention. Embark uses data from sensors and applies machine learning techniques to map the environment in real-time. The test drive, of course, was conducted in the presence of drivers for safety reasons (Kolodny, 2018).

In Hungary, the development of self-driving trucks and truck-driver support is facilitated by Knorr-Bremse. The company-developed truck was first introduced in 2016. The truck can drive on its own on test tracks and enclosed sites, simultaneously though, it is also showing promising results in driving on highways. Still, the weaknesses of the current level of development of self-driving technology on the roads are evident in the case of automobiles and trucks altogether. Self-driving trucks will not be able to communicate on the roads with older, unequipped vehicles. Thus, self-driving trucks must be able to handle the surrounding traffic by only using the sensors mounted on the vehicle (Torontáli, 2019).

The Platooning method was first introduced in 2019. Its essence is to assemble a convoy of trucks in a chain, where the leading vehicle guides the fleet to the destination. In this military-inspired transportation technique, the need for overtaking is eliminated, and it is possible to maintain a safe braking distance. With this technique, drivers will be able to put significantly less effort into the driving process, while thanks to the tow, fuel consumption would also decrease (Aranyi, 2019). Continental and Knorr-Bremse have announced that they will cooperate on creating a platooning demonstrator. It is crucial that in the future, trucks from different manufacturing backgrounds could communicate with each other in an as efficient and as fast manner as possible, form a chain according to the platooning technique, and thus, optimizing the transportation process. Based on results from experiments, some trucks were already able to connect at a distance of 50 meters and line up independently. When V2V communication is established, when the first truck suddenly brakes, the following will start braking at the same speed simultaneously, thus avoiding a collision (Knorr-Bremse AG, 2019). The program can perform automatic acceleration and deceleration of the convoy if, for instance, an automobile would move from the offside to the outside lane. Even in this case, at the press of a button, the driver can reposition the convoy in a manner, so that the automobile would fit right in between the trucks (Aranyi, 2019).

Autonomous trucks are currently able to analyze their surroundings and communicate effectively with each other using sensors, cameras, and other V2V communication methods. Within the cooperation agreement, Continental will be developing the automatization systems, while Knorr-Bremse will be working on the driving assistance systems (Knorr-Bremse AG, 2019). Based on the latest research, the platooning system has the potential to become the first-ever widespread autonomous truck driving system.

3 Primary research

In the primary research we examined the propensity to introduce self-driving vehicles by analyzing a 221-item sample. The analysis was performed using an inductive inference method using the DoctuS knowledge-based framework.

3.1 Knowledge-based framework

The decision-making tools needed to solve complex problems are computer-aided decision support systems that address decision-making dilemmas in the strategic implementation of computer-aided decision-making.

The most qualified forms of decision making support systems are expert systems based on knowledge-based technology, in which the mutually beneficial characteristics of human and artificial skills are combined. The knowledge base of knowledge-based/expert systems contains the essential knowledge and connections related to a certain special field. In this way, it is excellent for solving specific problems related to this specialist field. Their application can be extended to both the "soft" social sciences and the "hard" natural and technical sciences, i.e. it can be used to prepare and support any type of decision (Szeghegyi and Velencei, 2003).

Decision making, problem solving is a human activity. Creating alternative, possible solutions is the task of human creativity. The knowledge-based system can be considered as a set of problem-solving tools that can be used in the "evaluation of alternatives" phase of the problem-solving process. It does not want to replace the decision-maker. The DoctuS knowledge-based system was developed many years ago by combining the knowledge elements of decision-making, artificial intelligence and cognitive psychology (Baracskai, 1994; Velencei, 1998).

More than a hundred knowledge bases have already been established with the decision-makers of domestic and foreign companies. This software is also present in education. It has been purchased by several domestic and foreign universities and is used in education (Velencei and Szeghegyi, 2018).

One of the advantages of knowledge-based systems is that they can also handle concepts. This is an important factor, because many decision aspects, decision criteria and case values can only be placed on conceptual scales. As well as a user-friendly system, you do not need IT skills to understand the thinking of the software and to follow its logic, its thinking trail.

In recent years, development has shifted to "experience mining". The importance of this was strongly supported by the November 2013 issue of the Harvard Business Review, which focused on "smart" decision making (Velencei and Szeghegyi, 2018). The article on tools used in decision support (Courtney et al., 2013) also included expert systems, confirming that experts involved in decision-making do not only believe in hard methods. The DoctuS knowledge-based framework concludes from the stated cases and rules, this is a pre-chain implementation of deduction (Velencei, 2017).

If the decision-maker has appropriate knowledge and experience, he/she can look for "if … then" rules that describe the course of his/her thinking well enough.

If the expert does not want or is not able to define rules, but has many processed cases and has a decision for each of them, then these can be used to reproduce the decisions already made.

If the decision, the decision criteria and their values can be used to describe a sufficient number of cases, it is not necessary to specify the structure of the decision criteria or the rules, but on the contrary, the tacit rules resulting from the classification of the cases can be revealed. So the generated rules come from the cases and their properties. Some of the tacit knowledge can be revealed from the spoken cases of the experienced decision-maker (Quinlan, 1986). This is the induction that results in a model graph (Baracskai and Dörfler, 2003). Only the informative, i.e. viable properties are included in it. Existing knowledge and knowledge being developed in the process may outline typical patterns of thinking that describe the experiences of decision makers.

By recognizing these patterns, decisions become transparent and explanatory (Szeghegyi and Langanke, 2007).

Through the application of the inductive method, it is clear that in reality the weight of the decision considerations is different. In this regard, the degree of informativeness provides a numerical value that reflects the gain from that information. The degree of informativeness can be between 0 and 1 (Szeghegyi and Velencei, 2003).

The generating algorithm selects from all possible distributions of all properties the ones that derive the greatest gain from the content of the information.

As Kahneman writes, "The model of intuitive decision-making as a pattern recognition further develops the ideas previously published by Herbert Simon" (Kahneman, 2013:p.273).

3.2 Research process

Based on secondary research data, we summarized the decision aspects, which reflect the intention and opinion about the introduction. All decision criteria and the values of each decision criterion are listed in the Attributes table. Part of this is Table 2, which shows all the decision aspects and each element of their value set.

The cases were then entered. The target group of respondents consists of professionals involved in the selection, operation and sale of such systems. The values of the intention to introduce and the decision criteria for each case are given in the Cases table, the details of which for the first 10 cases and the first 5 decision criteria are shown in Table 3 (Cases).

The resolution is based on technical parameters as decision criteria, with the exception of price as an economic parameter.

The distribution (Fig. 1) shows that 26% of respondents are determined to introduce, 21% consider it just a good idea, 33% are uncertain, and 8% have strong doubts and 12% oppose it. So, there is a strong division among experts.

Fig. 2 shows the model graph. The model graph shows the opinion based on the dominant decision criteria.

Table 4 shows the degrees of informativeness in the model graph that determine the decision.

The qualifying property is the "type of IT system" of the self-management system, the degree of informativeness of which is 0.6056. Based on its value, it can be concluded that it is a rather dominant decision-making criterion for judging the intention to introduce.

Table 2 Attributes (extract)

Name	Value 1	Value 2	Value 3
Opinion	Rejection	Strong doubts	Uncertainty
Fuel	Electric	Gas	Petrol
Access (programming, setup)	Remote control	Local control	Device access
Price	Very overrated	Value for money	Overrated
Self-driving system level	1	2	3
Protection	180°	270°	360°
IT system	Integrated	Semi integrated	Not integrated
Load capacity	400–600 kg	1000 kg	1600 kg
Side protection (laser based)	Yes	No	Partially
Personal security scanner number (FTS)	0	1	2
Sensor system cleaning	Self-cleaning	None	Mechanical cleaning
Upgradable self-steering system	Yes	No	Partially
Rechargeability	Fixed point	Continual	Mixed
Risk area protection	5	3	2
Navigation Track	Defined	Not defined	Split
Size	>5 m	>3 m	>1 m
Sensor system	Laser operated	Magnetic line	None
Manufacturing	Series Production	Custom manufacturing	Mass produced
Steering wheel	Yes	None	Partially
Brake	Yes	None	Partially
Control	Remote access	Local	Same internet network
Seat	None	Standing	Seated
Site	Pre-programmable	Indoors	Outdoors

Source: own research

Table 3 Cases (extract)

	Opinion	Price	Self-driving system level	IT system
1	Rejection	Very overrated	1	Semi integrated
2	Strong doubts	Value for money	2	Not integrated
3	Uncertainty	Value for money	4	Not integrated
4	Good idea	Overrated	3	Can be remotely operated
5	Uncertainty	Overrated	4	Integrated
6	Rejection	Very overrated	1	Semi integrated
7	Strong doubts	Very overrated	1	Semi integrated

Source: own research

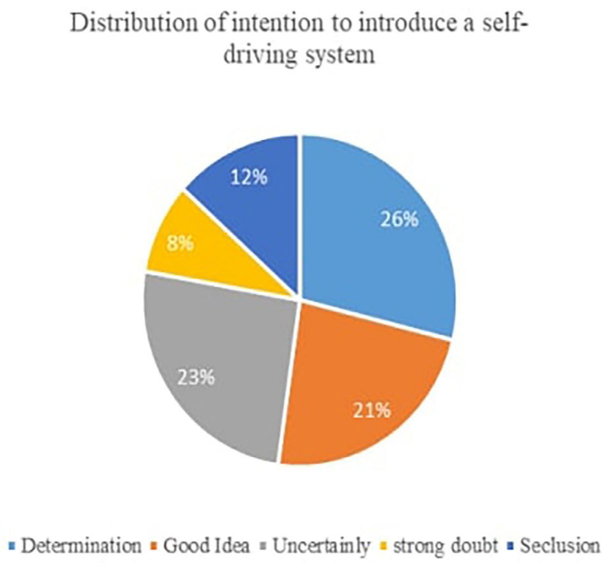

Fig. 1 Distributions (Source: own research)

However, different types of IT systems justify the consideration of additional decision aspects depending on the type of IT systems, as can be seen in the model graph. The other features are price, protection, load capacity, level of self-steering system. If the IT system is integrated, then price is an additional decision criterion. If the price is commensurate or undervalued, the experts are determined to introduce it. If the price is overvalued, experts are uncertain about the issue, as the introduction of such a system involves risks. The technology is new, so it can easily become obsolete.

Also, although the IT system of the self-management system can be integrated with any system, prices have not yet been established in these markets (package prices), but prices are determined according to an individual agreement.

The other two notable graph branches are the branches of stand-alone and non-integrated IT systems. In the case

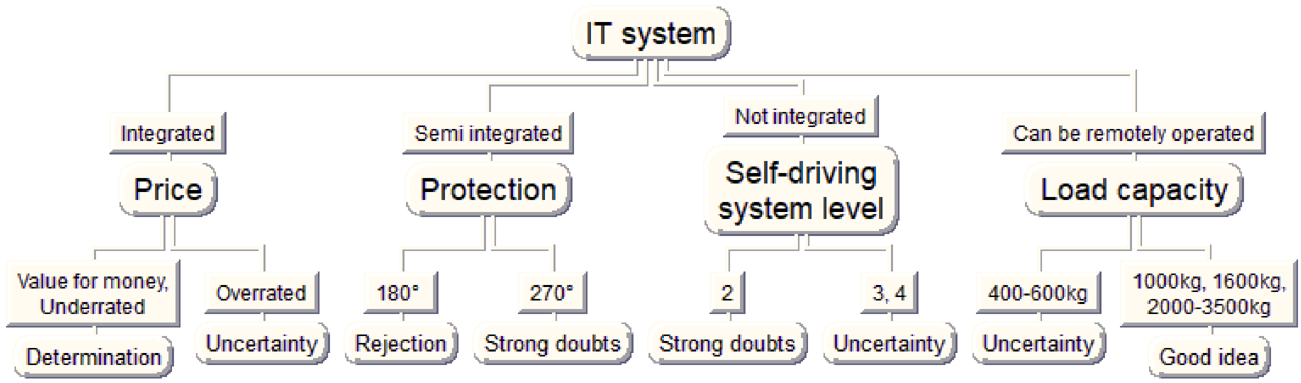

Fig. 2 Model graph (Source: own research)

Table 4 Degrees of informativeness

Attribute	Informativity
IT system	0.6056
Self-driving system level	0.5406
Price	0.3795
Protection	0.4915
Load capacity	0.2177

Source: own research

of an independently operating IT system, i.e. a system that cannot be integrated into any system, the load capacity is the further decision-making aspect. As the value of the load capacity increases, the opinion about the introduction also changes in a positive direction. In these cases, in addition to the independence of the system, the experts will see the basic technical parameters that would appear when implementing a normal system.

In the case of a non-integrated IT system, although the level of the self-management system is the highest, the interviewed experts are uncertain about the implementation, and at the self-management level 2 they have strong doubts.

By analyzing all the branches of the graph, the mindset of the experts can be modeled. A correlation can be observed between the questions of the questionnaire, which was examined by Pearson's correlation analysis (Table 5). The analysis was performed for all questions. Its presentation has been limited to where at least a moderate relationship can be observed. To perform Pearson's correlation analysis of the research, each text response was converted to numerical values. Thus, we examined the correlation between each question and answer. The strength of the correlation was determined as follows:

Table 5 Pearson's correlation analysis

	1. question	13. question	13A. question	13B. question	13C. question
1. question	1				
13. question	0.42	1			
13A. question	0.23	−0.47	1		
13B. question	0.48	0.15	0.08	1	
13C. question	0.21	0.3	0.17	0.11	1

Source: own research

- Above 0.55: Strong correlation
- 0.4–0.55: Moderately strong correlation
- 0.3–0.4: Medium correlation
- 0.2–0.3: Weak correlation
- Below 0.2: No correlation.

Questions:

- 1. question: How much would you spend on a scale of 1–5 to implement a self-driving system?
- 13. question: Type of information system
- 13A. question: Integrated IT system (Scale range: 1–5)
- 13B. question: Non-integrated IT system (Scale range: 1–5)
- 13C. question: Stand-alone IT system (Scale range: 1–5).

The following conclusions can be drawn from the correlation analysis. One of the determining factors in choosing an IT system is price, as there is a medium relationship between price and the type of IT system. That is the type of self-managed IT system we choose is affected by the price. It can also be observed that when choosing between IT systems, the availability of several types has a negative effect on the decision in favour of an integrated type of self-management system. It is also noticeable that in the case of a non-integrated system, there is a medium-level relationship between the type of IT system and the price. Therefore, it can be said that the price has a significant effect on the choice of the level of the self-management system. The results of the research may be motivators for further research. As we know the mindset of the experts, we know what technical developments and economic incentives are needed to encourage the introduction of self-driving vehicles. For example, in order to reduce the proportion of indecisive people who make up a surprisingly significant proportion (33%) of respondents, it is worth exploring the causes of uncertainty as a topic for further research in order to move the intention to introduce in a positive direction.

4 Conclusion

In the literature review, we analyzed the self-driving systems and, in addition, narrowed them down to the introduction of self-driving systems for logistics vehicles. We then based the primary research on secondary research, as the decision criteria were summarized based on the existing literature. In the course of our research, we determined the most important properties of the introduction of logistics and vehicle self-driving systems and their relationship system using an inductive inference method (Model graph). In addition, we have introduced several important parameters for the intention to introduce, which describe the current market trends and may help the manufacturers to operate with a greater understanding of the expert/consumer side. With the familiar parameters, the model can be used and utilized at any time by professionals familiar with the self-driving system, as this was a narrowed area using the 22 most important parameters considered by the experts. In the model, the outputs can be modified by adding new decision criteria and by adding supplementary decision criteria.

It remains an eternal question, when will it be enough? When will we reach the limit of our reasoning? Or we accept Gladwell's assertion that grasping the point often leads to better results than a more detailed, thorough, exhaustive thought tour (Gladwell, 2005).

The big question of our time is whether we will be able to replace man. More and more research is calling for radical changes in the workplace and work of the future, primarily due to process intelligence based on artificial intelligence and industrial cyber applications (Velencei and Szeghegyi, 2018).

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