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SELF-DRIVEN VEHICLES IN LOGISTICS: TODAY AND THE FUTURE

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Abstract

Nowadays autonomous driving technologies are developing rapidly. International concerns test self-driven vehicles in a real traffic and predict their appearance for commercial use by 2020-2021. This can change road transportation and the entire logistics industry in a significant way.

This thesis is dedicated to the present and the future of self-driven vehicles. The theory part covers the current development and possible application of autonomous transport for road transportation and material handling purposes. The goal of the research part is to investigate the public opinion on the matter of autonomous vehicles within logistics industry. In order to gather information, a survey was arranged and 62 people answered the questionnaire.

Autonomous driving is currently prohibited on public roads. Nowadays, self-driven vehicles are mainly used for material handling purposes due to more flexible legislative and liability requirements of this field. Nevertheless, IT giants and leading car producers are constantly working on overcoming the technological gap and other barriers on the way of self-driven vehicles to the common use.

The public opinion is quite uncertain. In general, people have a positive attitude to the appearance of self-driven vehicles and its impact on logistics. At the same time they understand possible risks and disadvantages it can bring to the market and society in a whole.

This work can be interesting for people who want to obtain understanding and perspectives of self-driven vehicles. Moreover, summarized theoretical information on the matter of autonomous driving, public opinion and other data can be found in this thesis and used for further studies.

Keywords: Self-driven vehicles, autonomously driven vehicles, logistics automation

CONTENTS

LIST OF ABBREVIATIONS

AGV	Automated Guided Vehicles
SDV	Self-Driven Vehicles
SCM	Supply Chain Management
LIDAR	Light Detection And Ranging
GPS	Global Positioning System
IMU	Inertial Measurement Unit
SLAM	Simultaneous Localization And Mapping

1 INTRODUCTION

1.1 Background

Transportation is a crucial part of logistics and supply chain. The efficiency of the whole chain depends on speed, cost and safety factor of a transportation modes used. That is why for several years the logistics industry contributes many resources into developing of self-driven vehicles. Logistics industry also provides good indoor environment for autonomous vehicles, for example secured warehouses and other facilities requiring routine labour.

According to McKinsey&Company and DHL, nowadays autonomous driving and electrified cars represent significant innovations potentially able to change existing business models and their logistics flows. Major automobile producers (Volvo, Tesla, Mercedes, etc.) are oriented on huge potential of autonomous driving and developing self-driven technologies. IT-giants (Google, Apple, Uber) also demonstrate their interest in the field of self-driven vehicles.

This thesis overviews two parts of logistics, where self-driven vehicles can be applied: transportation and material handling.

1.2 The purpose and the question

The purpose of this thesis is to provide understanding of current role and development of self-driven vehicles (SDV) and to estimate the importance of self-driven vehicles in logistics, including transportation and warehousing. As far as the public opinion represents an important factor of future development, it was also decided to research views and opinions of people with different background. The thesis answers two following questions:

1. *What is the current situation in the field of autonomous vehicles in terms of logistics?*
2. What *is the public opinion on future integration of self-driven vehicles into logistics industry?*

1.3 Structure of thesis report and research strategy

The thesis consists of two main parts:

1) Theoretical background. This part provides information concerning logistics background, transportation and material handling information, self-driven vehicles, their history, technologies and applications.

2) The research survey. This is a practical part aiming to collect information regarding public opinion on the matter of self-driven vehicles and possible further logistics integration. Results obtained during the research are analyzed and interpreted here.

The theoretical part overviews the main terms in logistics and transportation, self-driven vehicles history, technologies, applications and regulations. The public opinion was collected and processed during the research.

It was decided also to discuss the matter of autonomous vehicles with experts of logistics field. Professionals representing different positions went through a questionnaire and shared their opinions. This research was conducted in less scientific manner and was fully confidential. Nevertheless, this practical approach provided knowledge that allow interpreting the public opinion in a way that is more valuable.

2 TRANSPORTATION IN LOGISTICS

This chapter provides information of two main self-driven vehicles' operation zones: road transportation and material handling.

2.1 Logistics and transportation overview

The Council of Supply Chain Management Professionals (CSCMP) provides the following definition of logistics: "that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements." Logistics is an important part of a business process as a field, providing connection between point of origin and point of consumption with the flow of goods. It embraces following activities: transportation, material handling, production, packaging, inventory, warehousing, integration of information flow and often security.

Logistics appeared as a military activity to bring soldiers and munitions to the battlefront. The majority of researches came to conclusion that it appeared in ancient Greece and Rome, it is also closely related to the name of Alexander the Great, who developed military logistics and successfully used it in his conquests. Nevertheless, according to another view, the term appeared in Eastern Roman (Byzantine) Empire. In the court of Leo VI there were people firstly called "logisticians" who distributed food.

Genrich Jomini, French and Russian military writer, brought word "logistics" in the beginning of 19 century. According to his definition, "logistics is the practical art of moving armies". During Napoleon wars, logistics was used as never before.

Logistics was developed greatly during the Second World war. The global in size and scale conflict demanded fast transportation of soldiers and armament, especially from USA to Europe through the Atlantic Ocean.

In a business concept, logistics evolved in 1960's. In 1963, Council of Logistics Management was founded. Since then and until now, business logistics in its actual sense is continuously developing.

Transportation itself is a moving of goods with certain technology within supply chain. During the process of transportation, such important metrics as money, time and ecological resources are spent. Transportation field is the biggest consumer of energetic sources, 63,7 % of oil in the USA spent on transportation (according to IEA Key World Energy Statistics 2014).

Transportation can be considered as a connective element among the several steps that result in the conversion of resources into products. This is the planning of all transportation activities into a system of goods flow in order to optimize costs and service according to the concept of business logistics. Around one-third to two thirds of the expenses of enterprises' logistics costs are spent on transportation, as can be seen from the Fig.1 (source: Tseng, Yung (2005)).

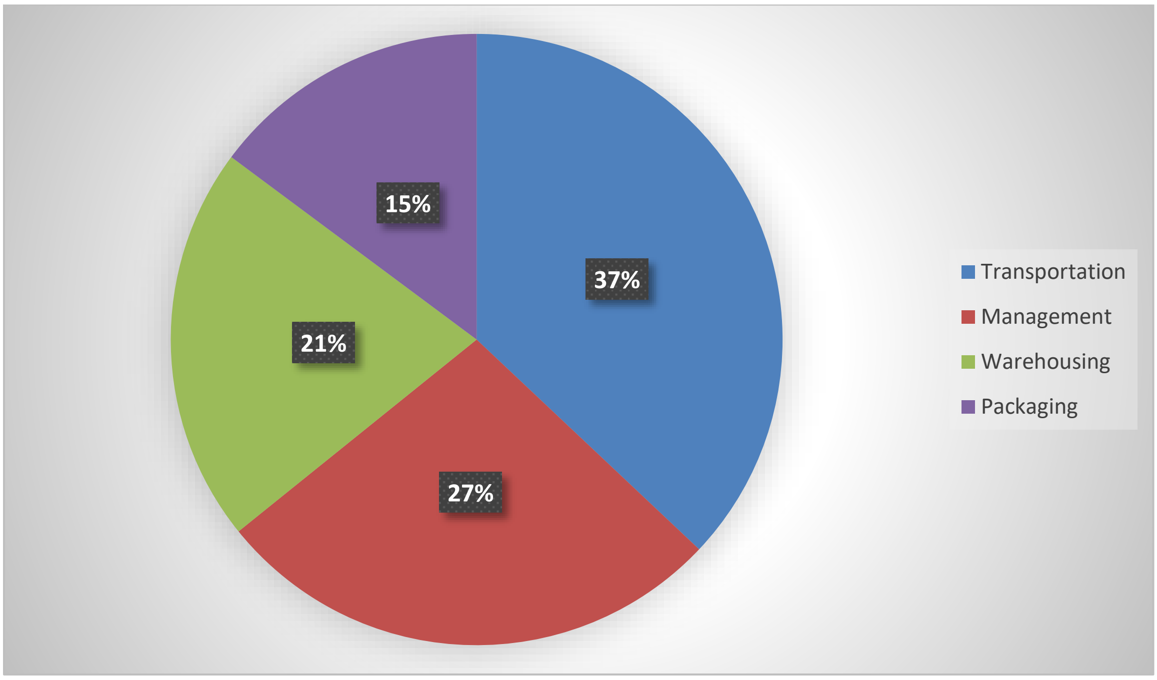

Fig 1. Cost ratio of logistics activities

2.2 Road transportation

Different types of transportation are in use within logistics field. The main ones are: trains, automobiles, ships and aircrafts. Every type of transportation has its own pros and cons, but the most flexible way is road transportation.

Transport on roads can be roughly grouped into the transportation of goods and transportation of people. A vehicle used for goods transportation depends on the type of goods transported, distance and size. For short distances and small shipments, a van can be used. For bigger shipments, trucks are more appropriate.

Road transportation has following advantages:

1) Less capital outlay. Compared to railways and air transport, capital investments are significantly less.
2) Mobility. Assuming the fact that roads are available almost everywhere, a door to door service is reducing loading and unloading costs.
3) Flexibility. Timing can be changed according to individual requirements.
4) Speed. Transportation within short distances by road is quite rapid.

All these advantages make road transportation very popular and common in use. Nevertheless, there are some substantial disadvantages:

1) The price of transportation is high due to using petrol, specific human labour and infrastructure
2) High ecological impact
3) Possible delays through accidents, traffic jams, etc.,
4) Security risks
5) Loading capability is low
6) Accident risk

The human factor during the driving process is another problem of road transportation. Moving by the road system assumes interacting with other traffic participants, and this multiplies the possibility of accident.

Due to new technologies and innovations, road transport is becoming more and more sophisticated. Such minuses as ecological impact, price and other are decreasing with newest developments.

2.3 Material handling transportation

Simply said, material handling is a short-distance transportation within a warehouse or between a warehouse and a transportation vehicle, also controlling, protecting and storing them.

It uses a wide range of manual, semi-automated and automated equipment: conveyors, cranes and industrial trucks. For transportation in variable paths, forklifts are used. A forklift is a powered industrial truck used to lift and move materials over short distances. Forklifts are available in many configurations. In an average warehouse, it has capacity of 1-5 tons. Toyota Core IC Pneumatic Forklift is presented on Figure 2 as an example (source: Toyotaforklift.com).

Fig.2. Toyota Core IC Pneumatic Forklift

As an automation solution, automated guided vehicles are commonly used within warehouses, yards, production facilities and other closed areas. The automated guided vehicle (AGV) is a portable robot using sensors to follow markers on the floor, magnets, visible markers or lasers. The AGV can move goods in autonomously attached trailers. AGVs are used almost in every industry where material handling automation is required.

3 SELF-DRIVEN VEHICLES FOR ROAD TRANSPORTATION

3.1 Understanding of self-driven cars

Although there is a number of different interpretations for the term “autonomous driving”, the common definition does not exist. According to the National Highway Traffic Safety Administration (USA), self-driven vehicles have been defined as “vehicles in which operation occurs without direct driver input to control the steering, acceleration, and braking”. In this type of vehicle, the driver is “not expected to constantly monitor the roadway while operating in self-driven mode”. But it should be noticed that this definition is not assuming that driver is absent.

The Society of Automotive Engineers (SAE) and the German Federal Highway Research Institute (BASt) created a 5-level classification of driving automation. Level 5 represents the full automation and means that the vehicle is able to make decisions and actions based on algorithms. Figure 3 demonstrates classification of self-driven vehicles by levels (adopted from sae.org).

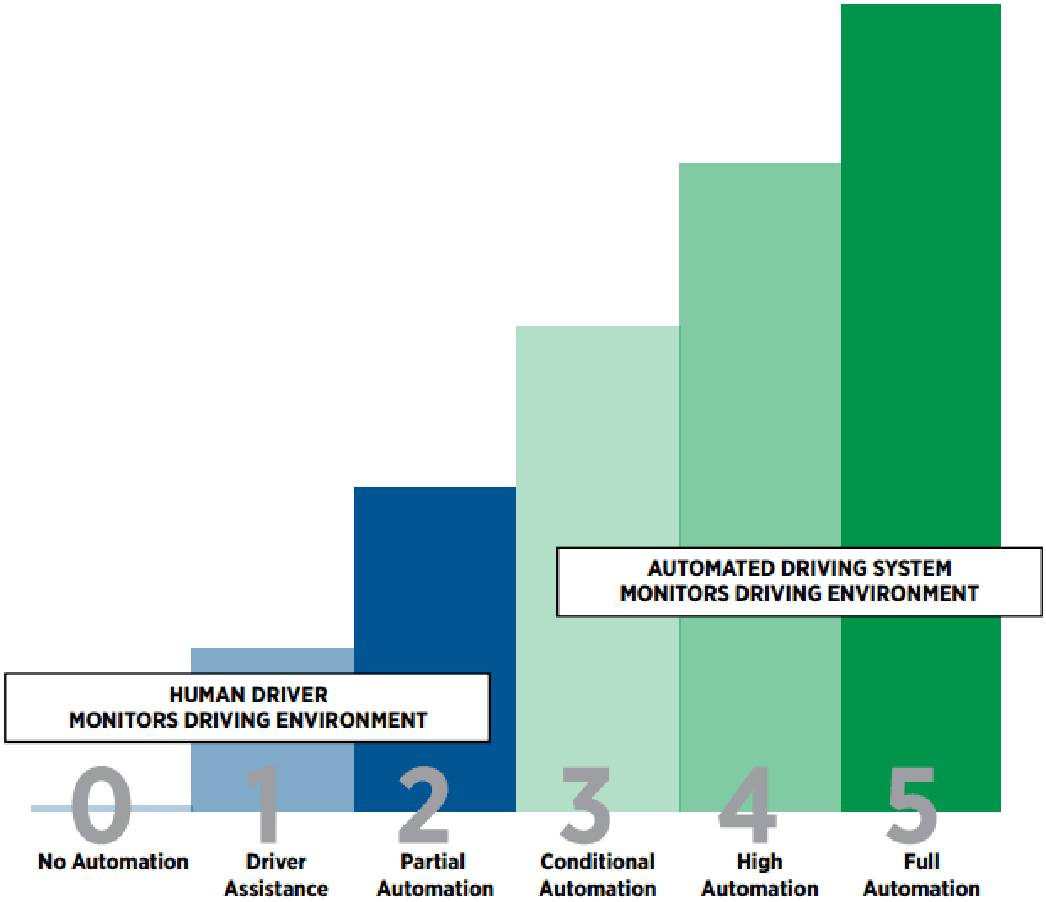

Fig.3. SAE Automation levels

Thus, Level 0 means fully human controlled driving. Level 1 of automation helps in certain situations, like in parking. Level 2 has certain modes, where it can take control on steering and acceleration. This is the level where Tesla's autopilot has been since 2014.

Level 3 assumes full control on a vehicle, but the driver is supposed to take control when the system asks for it.

Level 4 vehicle is fully autonomous, except in some situation. When the system cannot handle driving, it asks for human assistance, but parks car beforehand and puts the passengers in no danger. This is a true self-driven car, and this the level where Google/Waymo's cars are right now.

The level 5 self-driven vehicle represents a car that can handle any traffic situations by itself and does not require any human assistance.

From here further in this respect, by terms "self-driven vehicle" and "autonomous car" it is meant a vehicle with Level 5 of automation.

3.2 Brief history of autonomous vehicles

Experiments on self-driven cars started in early 1920's, but the first more or less autonomous vehicles appeared in 1980's when Mercedes-Benz created a vision-guided robotic van. Since that time, the major companies (Mercedes-Benz, General Motors, Toyota, Audi, etc.) have been developing their systems for autonomous driving. In 2013, in some states of USA (Nevada, California, Florida, Michigan) laws permitting self-driven vehicles were created for different levels of automation.

3.3 Key benefits

The hype surrounding self-driven cars and huge investments assume that there should be a practical advantage of using them in real life. Potential benefits are:

1) Improved safety. According to statistics, about 90 per cent of accidents happen because of human factor, including delayed reaction time, tailgating, rubbernecking and other form of distracted of aggressive driving. Moreover, autonomous vehicles can interact with each other, predict the behaviour of other objects, assuming such factors as traffic and weather. It all makes driving safer.

2) Costs. The automatic optimizing of fuel consumption and the absence of a driver can decrease costs. Improved safety leads to decreased transportation costs that can reduce transportation losses and insurance prices.

3) Traffic. Due to V2V communication, cars can “share” roads according to congestions and redistribute transport load on roads. Higher speed limits can be set up and that leads to increased road capacity. All these traffic factors lead to better road utilization as a result.

4) Environment. Decreased fuel consumption has also a positive influence on ecological situation on the planet.

3.4 Barriers

But still there are barriers and disadvantages distancing us from the common use of autonomous cars. The barriers are:

1) Technological barriers. Technology is not developed enough to provide safe driving performance yet.

2) Regulatory & Legislative barriers. Today SDVs are not legalized on public roads. The concept of autonomous driving is quite revolutionary for the law practice. To regulate the use of them, corrections in legislation have to be done. Only a couple of companies have permission to test self-driven vehicles in real conditions.

3) Social and Ethical barriers. An integration of self-driven vehicles into logistics industry can decrease the amount of workplaces related to driving. This can lead to changes in a labour market and society. Furthermore, some ethical questions related to morality of making a choice within traffic can emerge.

4) Liability Issues. As a driver is not responsible for driving, liability is shifting to manufacturers. It can increase quality control significance and raise the final price.

5) Security. Self-driven technologies require using of IT-infrastructure, which assumes a potential risk of privacy loss and hacking. There is also the risk of terrorist attacks.

6) Infrastructure. Current infrastructure (highways, V2V communication, etc.) need to be modernized in order to provide better driving conditions for autonomous cars.

3.5 Technology overview

Four basic interdependent functions are required to be capable of driving itself:

1) Navigation. Modern automobiles use GPS for route planning. Self-driven vehicles this function is extended with V2V communication system. This allows to receive and process road and safety information from other vehicles.

2) Situational analysis. This system monitors the environment to ensure the autonomous system is aware of all relevant objects and their movements.

3) Motion planning. This function is responsible for monitoring the vehicle's movements by using sensors.This course must ensure that the moving vehicle remains in its lane and continues in the correct direction as defined by the navigation system, so that the vehicle avoids collision with the static and dynamic objects that are identified by situational analysis.

4) Trajectory control.This function allows to plan changes in direction and speed and to keep driving stable.

From article “Autonomous car”, Wikipedia:

> “Modern self-driven cars generally use Bayesian Simultaneous Localization and Mapping (SLAM) algorithms, which fuse data from multiple sensors and an off-line map into current location estimates and map updates. SLAM with detection and tracking of other moving objects (DATMO), which also handles things such as cars and pedestrians, is a variant being developed at Google. Simpler systems may use roadside real-time locating system (RTLS) beacon systems to aid localisation. Typical sensors include LIDAR, stereo vision, GPS and IMU . Visual object recognition uses machine vision including neural networks. Udacity is developing an open-source software stack.”

This information based on article "Simultaneous localization and mapping" from IEEE Robotics & Automation Magazine, provides understanding of technologies used to obtain information from constantly changing road environment and to process it. Fig. 4 demonstrates LiDAR sensors on Ford Mondeo (Ford Velodyne LiDAR/YouTube).

Fig. 4. Second generation of LiDAR sensors on Ford Mondeo

3.6 Public reaction, laws and liability

Nowadays, using of SDV on public roads is prohibited. According to the Vienna Convention of Road Traffic, a driver always should be present and control a moving vehicle all the time. Nevertheless, this convention was created about 50 years ago and transportation issues have moved since then. In May 2014, a rule permitting cars with levels 1-3 of automation. Rules are adopted according to developing of SDV.

Technological gap affects the adoption of new laws related to SDV and, in opposite, prohibition of testing in real condition affects the speed of development.
Public opinion has a significant impact on developing of SDV. Surveys show that people still worried about the safety, but 66 percent of respondents said autonomous cars are probably smarter than average human driver (PwC survey, USA, 2016).

Autonomous car liability is an actively developing field of law, and the main task of it is to determine who is liable in case a self-driven vehicle causes harms to persons or property. Liability is shifting from drivers to manufacturers, and there is a need of identifying the responsible party. Insurance companies are developing their rules according to autonomous driving conception.

3.7 Current development and perspectives

In 2017, mass-produced cars are available for common use with level 2 of automation. Cars mostly can stay in its line on the road, follow curves, keep the speed limit, and distance from cars ahead.

A couple of IT giants achieved level 4 in their developments. Leading car producers are constantly developing their technologies and have set a goal to start making mass-produced cars with full automation of level 5 by 2020-2021.

4 AUTONOMOUS VEHICLES FOR MATERIAL HANDLING

Although automated guided vehicles are quite efficient for warehouse transportation, there are some limitations in using them. That is why logistics industry is highly interested in developing of SDV for warehousing operations. In warehouses, autonomous devices have some other tasks except transportation, for example loading and unloading.

4.1 Material handling robots

Some companies produce indoor vehicles that are capable to replace a person and a forklift. They are fully self-driven and have a map of facility in their memory. These machines can handle up to 1500 kg of goods without drivers or supervision. Open Shuttle by KNAPP can be an example of self-driven transportation within a warehouse. This self-driven vehicle uses laser navigation technology and can transport and pick up goods within complex transport networks. It is able to plan routes, react quickly to any changes in a warehouse environment and make alternative ways.

For more complicated environments (e.g. crowded warehouse spaces), there are some more advanced robots. A device called Robocourier by Swisslog can be an example. It easily navigates through tight spaces, doors and between people within and is used mainly within medical purposes. It is even able to use elevator and move between few levels of a building.

4.2 Assisted order picking

Manual order picking is quite a routine and heavy task and a non-ergonomic cart handling slows the process down. To make this process automatized, order-picking assistants are in use. These autonomous assistants can follow the picker while she or he is moving through the shelves. When the full capacity of the assistant is reached, it goes to the drop-off zone and can be replaced with another assistant. This kind of assisting system greatly improves efficiency of order picking process. One example is the Kiva system, purchased by Amazon in 2012. The system operations are based on use of SDVs. An autonomous vehicle moves an entire shelf with items to the picker and that allows picker to stay in one place, while Kiva moves around.

4.3 Logistics operations in yards, harbors and airports

Closed infrastructure of such facilities as yards, harbors and airports allows to avoid such barriers for autonomous driving as legislative prohibition, ethical questions and public acceptance. That is why all modern developments can be used there for a wide area of logistics operations. Usual forklifts were used for decades, and it was very dangerous for pedestrians and other process' participants. Now self-driven forklifts and robots are starting to integrate into this logistic network. Harbor Container Terminal Altenwerden in Germany is one of the most innovative container handling facilities in the world, where container handling is almost fully automated. 84 autonomous vehicles are used there to transport containers between the warf and the storage area via fastest possible ways.

4.4 SDV vs. Automated guided vehicles

As mentioned before, AGVs are commonly used for material handling. AGV can be considered as a predecessor of SDV. Fig. 5 shows differences between AGV and SDV.

Fig. 5. AGV's and SDV's comparison

Parameter	AGV	SDV
Flexibility	Fixed with predesigned paths of markers	Can be used within any facility
Need of infrastructure	Require special facility planning and training	-
Intelligence	-	Machine learning is used to collect new data and adapt to new environments
Usability	A simple task to be set up every time	Able to perform complex transportation tasks

5 RESEARCH SURVEY

As mentioned before, public opinion can be one of the barriers on the way of self-driven vehicles breaking in to the logistics market. That is why it was decided to study public opinion on future integration of self-driven trucks into logistics industry. In order to collect opinions of people from different countries, with different background and education, a survey was conducted.

5.1 Participants

62 people took participation in the survey during the period 12.12.2017 – 26.12.2017. Participants were found due to personal contacts and social networks. Although there were no selection criteria for respondents and the link was available for everyone, people with logistics background were more interested and actively participated in survey. As a result, 48% of respondents mentioned their logistics experience (see Fig. 6)

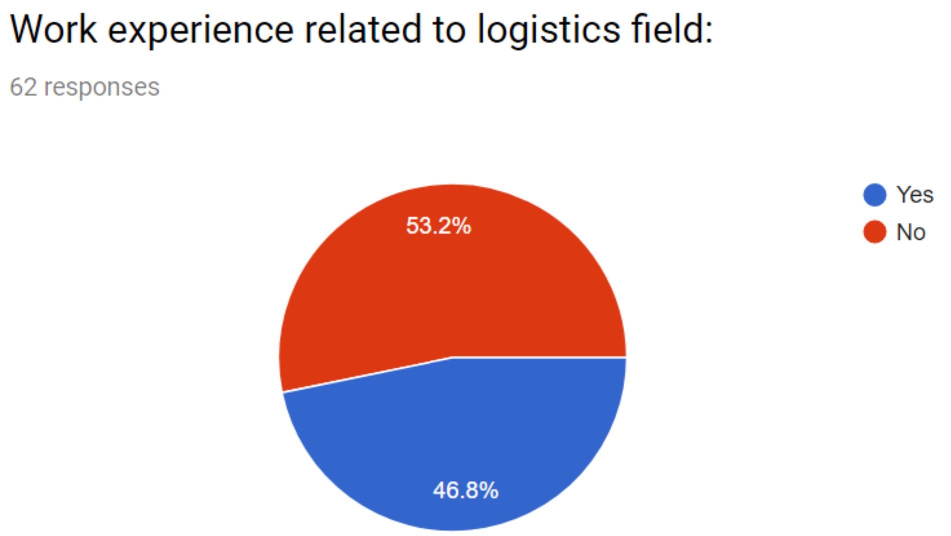

Fig. 6. Logistics experience graph

As shown in the Fig. 7, 36 respondents (58.1%) stated that they have a bachelor degree and 15 (24%) have a master degree. Moreover, some respondents gave information on their background during the personal conversation.

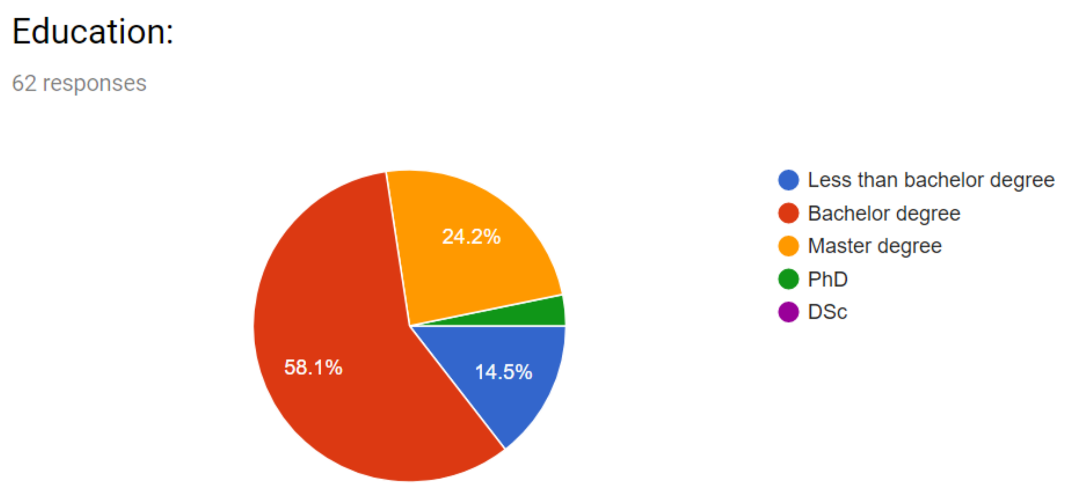

Fig. 7. Education graph

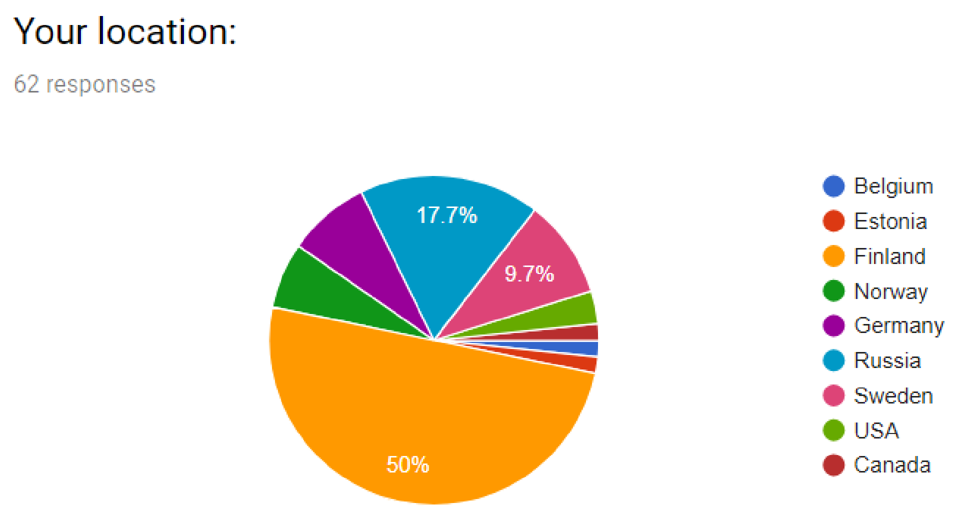

Fig.8. Respondents' location graph.

Finland was a primal location of the research (57,6% of participants), but respondents from other countries including Russia, USA, Sweden, Norway and Germany were also invited to go through the survey, as far as it allows to assume possible cultural effect on results.

5.2 The structure of the survey

The survey represents a questionnaire collecting answers as a multiple choice, short answer and evaluation of veracity with 1-5 scale. The survey was conducted via Google Forms and it is available in the appendix of this thesis.

The survey had four parts:

1) Introduction. In this section, a respondent was asked to provide some basic information about himself, including country of residence, education and logistics experience information.

2) Understanding of self-driven vehicles. Here information about SAE levels of automation was provided in order to ensure the right understanding of terms “self-driven vehicle” and “autonomous car”.

3) Road transportation. In this section, general attitude and views on the matter of road transportation were collected. It was suggested to evaluate the importance of following transportation metrics with 1-5 scale: cost, safety, speed, environmental impact, flexibility, availability and reliability. Together with introducing part, it creates a brief portrait of an interviewee.

4) Opinion on self-driven vehicles. In this chapter, participants shared their opinions and views regarding self-driven vehicles and their possible logistics implication.

5.3 Data gathering process

In order to obtain more participants, the survey was shared through the social networks (Facebook.com, VK.com). Additionally, some of respondents were approached with a personal letter. The efficiency ratio was evaluated as 12%, so about 520 potential respondents have seen the survey invitation letter and 62 agreed to participate.

5.4 Results

5.4.1 Importance of transportation metrics

Figure 9 demonstrates an average attitude to different transportation metrics.

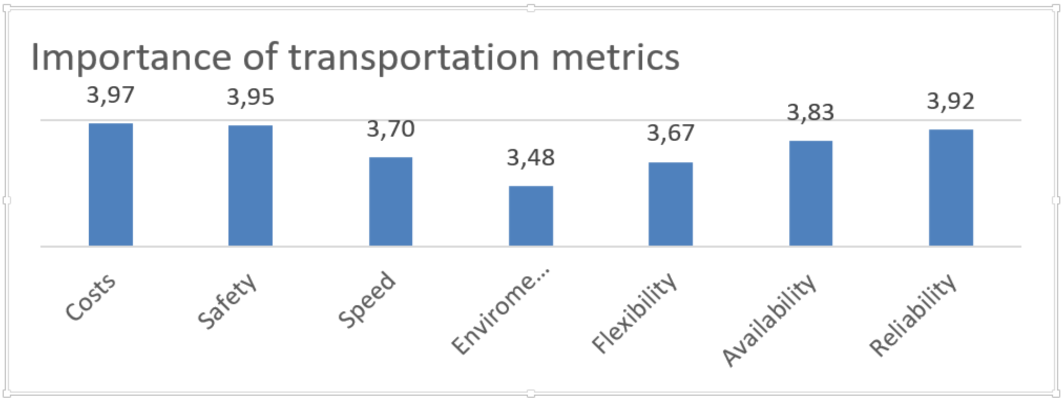

Fig. 9. The average importance of transportation metrics

As seen from the figure, the transportation cost is the most important metric for 28 (46,6%) respondents. Then reliability (23 people or 37%) and safety (24 people or 38,7%) were mentioned as important too. 20 people also evaluated an importance of availability metric like “more likely important”.

5.4.2 Opinion on autonomous transport in logistics industry

40% of respondents said that they have heard before about SAE classification of driving automation.

As seen from Fig.10, 20 people (32,3%) are ready to use autonomous transportation services, and only 1 person (1,6%) stated that they do not trust self-driven vehicles.
10 people answered this question as “maybe”, 12 said “more likely no” and at the same time 19 said “more likely yes”.

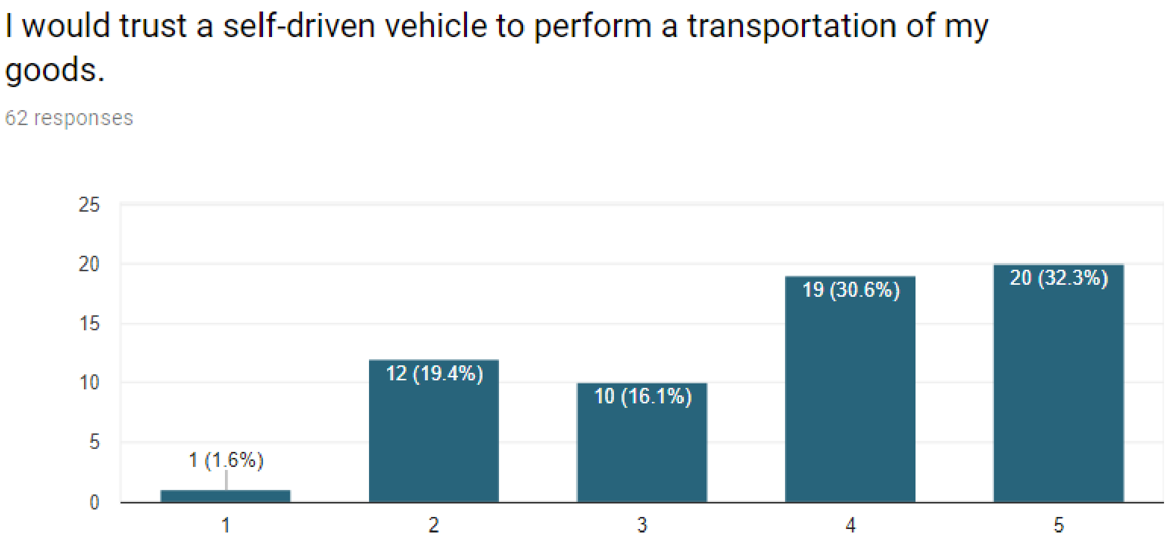

Fig. 10. Willingness to use self-driven vehicles.

The scale used on the Fig.10: 1=No; 2=More likely no; 3=Maybe; 4= More likely yes;5 =Yes.

13 respondents believe that self-driven cars will be able to act completely without a driver, and at the same time, 5 said that it is impossible. Other participants answer as following: 3 said “more likely no”, 4 stated “maybe” and 12 said “more likely yes”. So here the overall positive attitude is seen (75% for “yes” and “more likely yes”). At the same time people are not sure, if there is any difference (for themselves personally) who perform transportation, a human driver or artificial intelligence.

The next question (Q13) was aiming to find the role of safety and environmental impact. The majority (26 people or 41,9%) stated that maybe, safety and ecological points are more important, so these opinions were quite uncertain. 13 (21%) answered that more likely more important and 12 (19,4%) said that safety and environment are definitely more important.

The majority of interviewees agree, that appearance of self-driven vehicles will lead to significant turnover of logistics market (27 people or 73% voted for “yes” or “more likely yes”). The respondents agree that the quality of transportation services will become better and that ethical issues are not a problem for further use of self-driven vehicles.

The respondents say that developing of self-driven vehicles will decrease amount of workplaces within logistics industry. They expressed this opinion by voting “yes”, “more likely yes” and “maybe” on the statement dedicated to this matter and by leaving the comments on the negative impact of SDV. This issue was evaluated as the main disadvantage of autonomous logistics, but some say this also will lead to increased employment in this area for IT-specialists, service staff etc. Few respondents also said that small companies will not be able to afford self-driven trucks because of huge initial investments. In this way, they can lose their business niche.

The respondents also provided some opinions as additional comments in the last open question. Some mentioned that small companies will not be able to afford initial investments. Some said that integration of self-driven vehicles into logistics industry might increase the gap between developed and poor countries, since this process, cars in poor countries would be delayed down by lack of financial resources, a bad condition of a road system and an opinion of a conservative population. The liability problem was also determined.

6 ANALYSIS AND INTERPRETATION

6.1 Background impact on attitude to self-driven vehicles

To find out what can influence the opinion of a respondent, it was decided to compare the overall attitude to self-driven vehicles against such background metrics as location, experience and education. The attitude ratio was based on evaluating the following statements evaluation:

1) I would trust a self-driven vehicle to perform a transportation of my goods.
2) Artificial intelligence for autonomous driving will be able to replace drivers completely.
3) There is no difference for me who performs transportation, a human driven vehicle or autonomous vehicle.
4) The quality of transportation and logistics services will become higher due to use of self-driven vehicles.

These statements are considered as positive regarding the matter of using SDV. The respondents were supposed to evaluate them with 1-5 scale, so the overall attitude was calculated as a sum of these answers. The points varied from 6 to 20.

Figures 11 and 12 demonstrate the average attitude of people with different location and educational background. It was found that people from different groups have same attitude points. As seen from Fig.11, people with no degree, a bachelor or master degree have equal attitude. PhD participants have a bit higher points, but it cannot be assumed as a significant difference, as far as only 3 participants possess this degree.

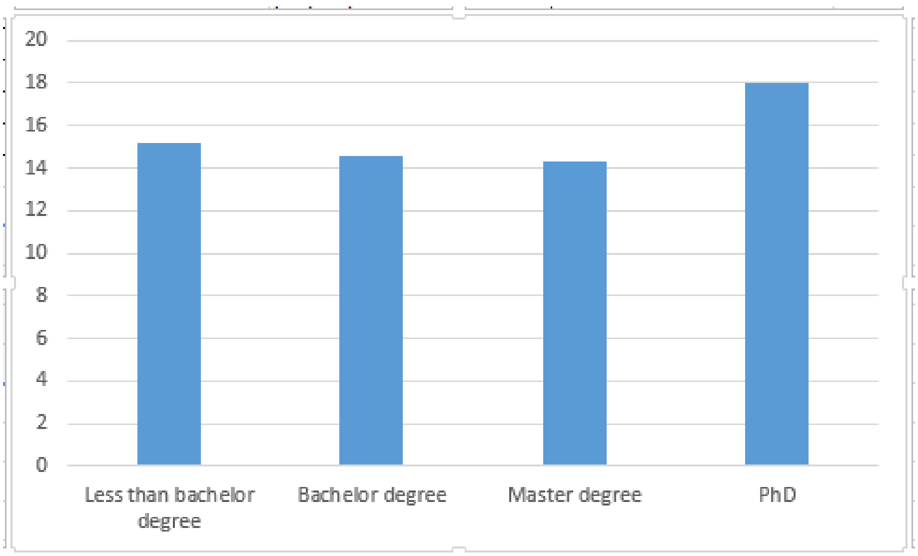

Fig. 11. The Impact of education on average attitude to SDV

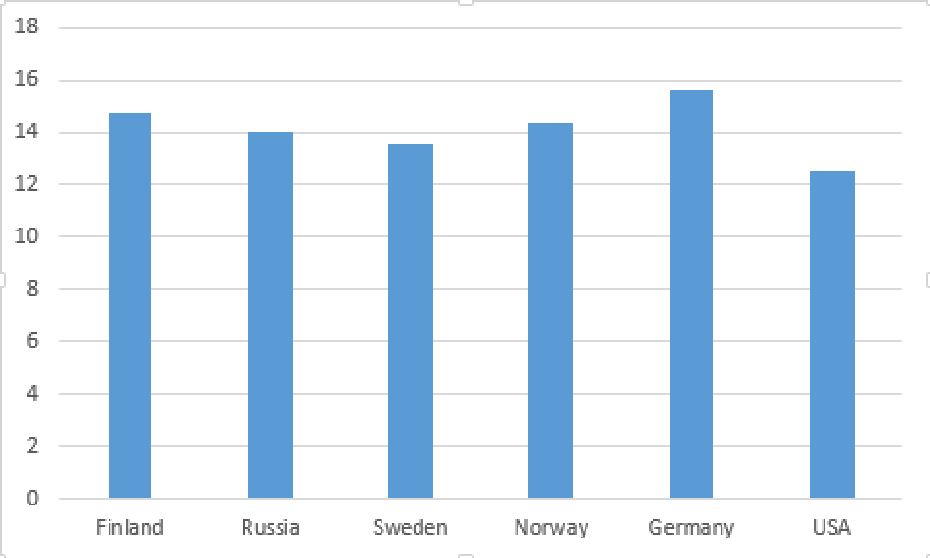

Fig. 12. Impact of location on average attitude to SDV

The same tendency was found regarding the impact of location background. Figure 12 shows a minor difference of attitude: points vary from 13 to 16 depending on the country. The same comparison was done for experience background proving that it does not affect the attitude.

These observations allow to say that matters of nationality, education and experience have no impact on overall attitude and can be ignored within further interpretation.

6.2 Interpretation

Although the attitude is uncertain, the average can be calculated and it is equal to 3,61 out of 5. This means the attitude in general is more likely positive. The respondents understand advantages of self-driven transport and believe that it can make logistics more efficient. The respondents believe that appearance of self-driven vehicles will change logistics and adjacent spheres a lot and more in a good manner.

Nevertheless, the respondents also consider some negative impact on logistics and society in a whole. They are afraid of global unemployment that can possibly lead to changes society. The respondents also confirm that unaffordable investments needed to enter the market of self-driven transportation can be critical for small companies. As a result, the competition in the market can become tighter and not all companies will be able to survive. The respondents also mentioned that IT giants can come and monopolize the logistics market. IT giants are the main source of SDV development now. With the help of other companies, they develop IT infrastructure for self-driven vehicles.

On Figure 13 positive and negative features determined by participants can be seen.

Advantages	Disadvantages and barriers
1) Reducing transportation costs 2) Improved safety 3) Less harm to environment 4) Increasing of services' quality	1) Possible global unemployment 2) Significant initial investments 3) Liability issues 4) Possibility of software failures 5) Ethical issues 6) Possible competition against IT giants

Fig. 13. Positive and negative features of autonomous driving features

7 CONCLUSION

As it was mentioned in Chapter 2 of this thesis, transportation is an important part of logistics. Self-driven vehicles are going to replace many common technologies of transportation and become an important part of logistics. This will also lead to changeover of logistics market in a whole. Many business aspects of logistics services providers and their customers will be changed as well.

The goal of the thesis was to answer two following questions: *What is the current situation in field of autonomous vehicles in terms of logistics?* and *What is the public opinion on future integration of self-driven vehicles into logistics industry?*

The answer to the first question was given in Chapters 3 and 4. Nowadays, self-driven vehicles are in use mainly for material handling purposes, as far there is no need to solve legislative and liability problems. Although autonomous cars and trucks are not permitted for usage on the roads, many companies are developing self-driving technologies for public roads. It requires plenty of work and resources. Besides technological gap, they also have to regulate legislative, liability and ethics issues, in order to turn self-driven vehicles into reality on public roads.

The second question regarding the public opinion on self-driven vehicles in logistics industry was researched and answered in Chapters 5 and 6. The data obtained during the survey include a different opinions and views on this matter. People understand that self-driven vehicles will change the logistics market in a great manner. They see advantages this can bring to the market and everyday life and realize disadvantages.

To summarize and to express my opinion, I can say that when self-driven vehicles come to public roads, this will be one of the significant modernization of logistics in the last few decades. This area still needs huge amount of investments and labour, but I personally believe that in the nearest future self-driven vehicles will become a reality in spite of all possible barriers.

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APPENDICES

I. THE SURVEY FORM

Self-driven vehicles: today and the future
This survey is conducted as a part of research of the bachelor thesis "Self-driven vehicles in logistics: today and the future", made by Nikita Tarutin, student of Savonia University of Applied Sciences (Kuopio, Finland).

Major car producers predict appearing of self-driven trucks available for commercial transportation by 2020-2021. There is no doubt, it will change the logistics industry and the whole supply chain management in a significant way. Although there are still some barriers (technological, legislative, ethics, etc.) on the way, many companies are continuously developing autonomous driving technologies.

The purpose of this survey is to research the public opinion on the matter of self-driven vehicles and their possible further logistics implication.

CONFIDETIALITY: Your names will not be published or shared with third parties. Survey requires your full name in order to prove your opinion.
INSTRUCTIONS: In the first chapter, where you are supposed to provide some information about yourself, all the fields are required to be filled in. Answer questions from chapter 2,3 and 4 using your own opinion on the matter. You can skip a question if it is not applicable for you.

*Required
1. Introducing
In this section, I would like to get more familiar with you and your background. Please, introduce yourself.
Q1: Your full name*:

Q2: Your location*:

Q3: Education*:

- Less than bachelor degree
- Bachelor degree
- Master degree
- PhD
- DSc

Q4: Work experience related to logistics field*:

- Yes
- No

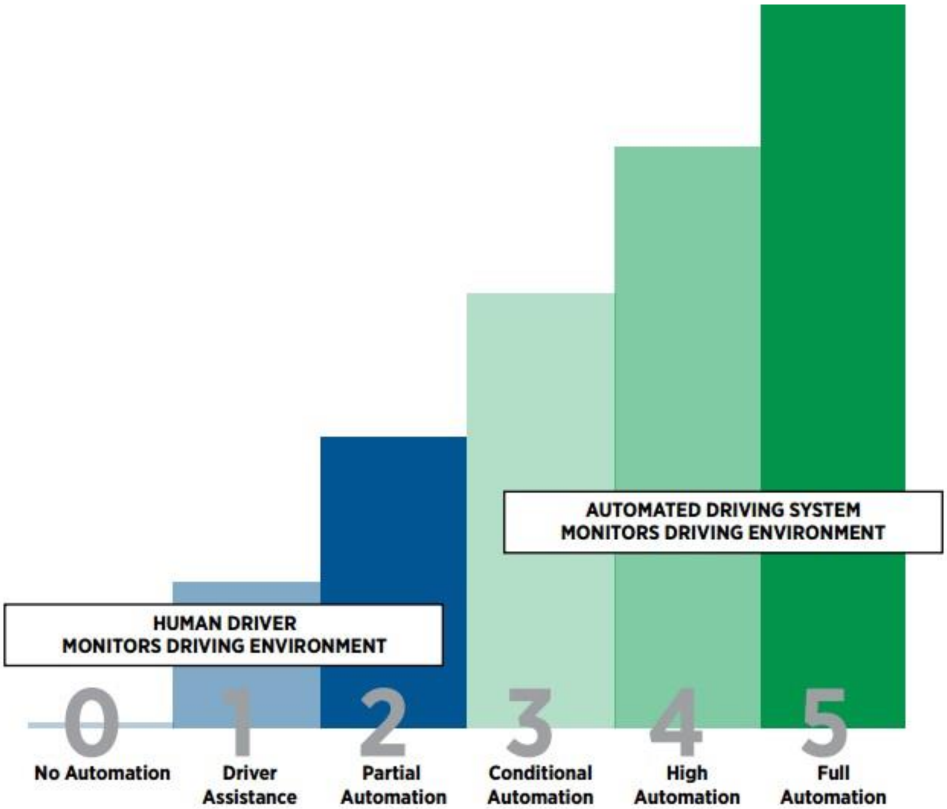
2.Understanding of self-driven vehicles.

Basically, there's no common definition for the term "self-driven vehicle" or "autonomous driving". For my research, I used SAE classification of driving automation. Please, read the following information about SAE classification carefully before you go through the questions.

Q5: Have you heard about SAE classification of driving automation before participation this survey?

- Yes
- No

Levels of automation in driving (adopted from SAE.org)



Level 0 means fully human controlled driving.

Level 1 of automation helps in certain situations, like parking.

Level 2 has certain modes, where it can take control on steering and acceleration. This is where Tesla's autopilot has been since 2014.

Level 3 assumes full control on a vehicle, but driver is supposed to take control when the system asks for it.

A level 4 vehicle is fully autonomous, except some situations. When the system cannot handle driving, it asks for human assistance, but parks car beforehand and places the passengers in no danger. This is true self-driven car, and this is where Google/Waymo's cars are right now.

A level 5 self-driven vehicle represents a car that can handle any traffic situations by itself and does not require any human assistance.

Since here and further, by terms "self-driven vehicle" and "autonomous car", a vehicle with level 5 of automation is meant.

3.Road transportation

In this section, I would like to know your opinion and views on some issues of logistics and road transportation.

Q6: Do you drive a car?

- Yes
- No

Q7: Do you use delivery services of transportation companies?

- Yes, for my personal needs
- Yes, for a business
- No

Q8: Please, describe with 1-5 scale which metrics of road transportation are important for you (1=Not Important, 5=Very Important)

	1	2	3	4	5
Costs	○	○	○	○	○
Safety	○	○	○	○	○
Speed	○	○	○	○	○
Enviromental impact	○	○	○	○	○
Flexibility	○	○	○	○	○
Availability	○	○	○	○	○
Reliability	○	○	○	○	○

4. Your opinion on self-driven vehicles

Some researchers say that using autonomous vehicles for road transportation will have such features as improved safety, decreased costs, less harm to environment and decreased traffic. In spite of this advantages, there are still some barriers including technological gap, public opinion, legislative and liability issues.

Here I would like to gather your opinion on self-driven vehicles. Please, evaluate the veracity with the scale 1-5 how the following statements fit your opinion.

SCALE:

1=No

2=More likely no

3=Maybe

4= More likely yes
5 =Yes

Q9: I would trust a self-driven vehicle to perform a transportation of my goods.

Q10: Artifical intelligence for autonomous driving will be able to replace drivers completely.

Q11: There is no difference for me who perform transportation, human driven vehicle or autonomous vehicle.

Q13: Safety and enviromental impact of transportation plays a greater role for me than price.

Q14: Appearing of self-driven vehicles will lead to significant turnover of logistics market.

Q15: As soon as self-driven vehicles are available, the application of them for logistics purposes will become common.

Q16: IT giants can enter logistics market with self-driven technologies.

Q17: The quality of transportation and logistics services will become higher due to using of self-driven vehicles.

Q18: Developing of self-driven vehicles will decrease amount of workplaces within logistics industry.

Q19: Ethical issues of autonomous driving represent an insurmountable barrier for self-driven vehicles.

Q20: Do you see any negative impact of self-driven vehicles on logistics market? Please, describe.

Q21: Here you can write any additional comments on the matter of self-driven vehicles and its possible logistics impact.