Development of Road Transportation

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Abstract

Road transportation had been changing the whole time and recent changes were not exceptions. Appearance of autonomous driving technologies had questioned need for human labour in the sphere of transportation.

The chosen objective was to find out the direction of development in road transportation, peoples' opinion on the subject of autonomous vehicles and autonomous traffic.

Due to large amount of data a systematic literature review was chosen as a research method. It allowed to gather information from different sources and compare it to give a better, more complete analysis. Understanding peoples' opinion required a quantitative research, as statistical data was a more important than personal opinions. A questionnaire helped to get 476 answers from north-west part of Russia.

The data gathered from reviewing literature, articles, news and a questionnaire described possible outcomes of the development in road transportation. The sample of respondents was not large enough to clearly make a forecast on the speed and direction of autonomous technologies development.

Overall, based on the review data, automotive industry had to improve self-driven vehicles' safety issues, besides other problems, meaning that development of fully autonomous vehicles required significant amount of work to be done, thus postponed the possible labour issue by an undefined time.

Keywords/tags (subjects)
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Miscellaneous

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1 Introduction

Technology is developing fast nowadays. 15 years ago we could only dream of a fast mobile internet, almost full network coverage and almost everybody having a mobile phone. Technological development does not affect only mobile devices, but also transport. Development in transportation, as in any other field, is meant to make our lives easier, more productive, efficient and effective. Human kind has faced a technological revolution, a big step forward in progress, but nowadays that progress is still moving but at a slower pace.

We are, once again, in the middle of an industrial revolution, when technological development has the greatest force and impact on the life flow.The two previous industrial revolutions have changed the world significantly in the economic, demographic and political spheres.The third industrial revolution will have the similar effect on our lives in the future. Replacing human work force with machines is the most significant aspect nowadays. As it happened during the industrial revolution, many people had to give their jobs to machines. We will soon see the first completely autonomous vehicles meaning that people may lose their jobs in the future, because these vehicles will not need drivers.

The automotive history is a good source of information as it is quite long, has many points in time when the future of different technologies was decided. These factors helped me to see the turning points in the development of modern technologies.

The research aim is to give an answer to the following questions: what is the direction of progress in road transport industry; what is people's opinion on the topic of autonomous vehicles; are we going to see similar effect of a technological revolution on work places in transport sector as in previous revolutions.

2 Research Method

Thesis topic and research questions require a large amount of theoretical data, which, in case of the work, is historical data, current researches, news and people's opinion. Systematic review is the best way to make a research in this thesis work. The main idea of the research method is to analyze research evidence relevant to the research question. The method includes review both published and unpublished literature. Reviewing several sources relative to one topic provides the research with more complete data, without tolerances.

Carrying out and analyzing a questionnaire assists the systematic review method. To find out peoples' opinion on the matter of autonomous vehicles, quantitative research method is applied. Quantitative research method is focused on gathering numerical data and generalizing it across groups of people to explain a particular phenomenon. Research requires a research problem and a theoretical framework. The research expects following steps: population study (specifying a target group), data collection and analysis. Analysed data is then presented in a popular way and a summary of the research describes the possible solutions for the problem in question.

Participants were divided into groups sorted by relationship to the road transportation. Aim of the research was to find out specific groups' opinion of possible use of autonomous vehicles in everyday life, in professional use and company use. Respondents were asked if they would like to use and see autonomous vehicles on roads and what is the preferable level of vehicle autonomy. Given answers show possible will to use the technology. Next question was aimed to understand deeper the reason for selecting a particular answer to the first question. Comment to the question described the importance of human to vehicle interaction and its severe influence on road safety. Answers for the last question helped to define the feel of safety in an internet connected vehicle. Description to the question explained a possible threat of connected vehicles being vulnerable to hacking and, therefore, remotely piloted.

3 Industrial Revolution

The industrial revolution was a transition from manual labour to machine production, from agrarian society to industrial. It was also a complicated transformation of all social institutions and the way of living for all societies. According to research, industrial revolution started in the 18th century in Great Britain with the use of machines to speed up the production of fabrics. Machinery helped to massively exceed the past outputs of manual manufacturers. This had a serious positive impact on the economy as well as on the tempo of urbanization, when cities took a good pace in enlarging their population. (Bovikin 2015).

History shows three different industrial revolutions:

- Introduction of machine fabrication, textiles and metallurgy
- Production of quality steels, transport and conveyor production
- Digitalization, transition from an industrial society to service society

3.1 The first industrial revolution

It is still argued, if transformation of society in the 18th century could be called a revolution, as the process went slowly in some sectors of production. However, in some sectors it went fast, and overall, the process was uneven. The reasons for the first revolution were: the growth of population in Europe, increased demand in certain areas, for example, in agriculture and textiles where the products were in short supply and where there was an inability to fulfil the demand. A larger population required more food, meaning that farmers had to improve their technology to meet the demand. It also meant that farmers were becoming wealthier and could start factories. Manufacturers of goods used manual labour in those days and had to start using machinery to increase the output of their goods significantly. Early inventions were ahead of the time and did not find any demand for a long time. Nevertheless, some inventions played a significant role in history. These inventions were: the loom, cast iron and steam engine. (Bovikin 2015.)

Summing up the first revolution, it played a genuinely significant role in history. It became the engine for inventions and innovations around the world. It is noticeable how the world stepped from the agrarian to the industrial era, not by just reviewing the statistics of population engagement, but based on the facts that food began to be produced in factories, clothes had standard sizes and were not made-to-order, wood was being replaced with metal. Society changed as well. Peasants became less important, and hired labour emerged.

3.2 The second Industrial Revolution

The second industrial revolution began in the 1860’s and finished in the 1920’s. In history books, it is described as evolution of the previous revolution, refining and improving technologies. Unlike the first revolution, this was powered by science and scientific progress. An impulse to the development was given by mass electrification and the invention of the electric motor. Moreover, it was boosted by the birth and development of the oil industry, which led to the appearance of kerosene and petrol. It was also the era of the invention of a cheap way to produce steel, the invention of telegraph and telephone as well as the automobile. Finally, the construction of railroads of steel, cut significantly costs in transportation and boosted trade. (Вторая промышленная революция [Second industrial revolution] 2009-2018.)

Electrification started soon after the invention of the generator in 1867 by E. Siemens. Thomas Edisson invented the electric lightbulb. In 1888, M. O. Dolivo-Dobrovolskiy invented an efficient and simple way of transmitting electrical energy for long distances. This invention facilitated the provision of electricity for factories, transport and home use.

Transformations in the energy production sphere were tightly connected with changes in fuel production. Discovery of oil in the middle of the 19th century led to the development of oil extraction and oil conversion. Oil started to slowly replace coal. Gas was started to be used for heating and lighting homes in the 1870’s.

Transportation had a boost with the appearance of a cheap way to produce steel. More modern ships were built of metal, and they had engines in them. Voyage time across the Atlantic Ocean using those ships took 4 times less than by sailing. This meant that new markets were now open for the food industry. In addition, shorter travelling time meant lower costs, which was beneficial to other traders as well.

Steel production also made the construction of railroads significantly less expensive and pushed the railway transportation further. Remote villages were not remote anymore, meaning that farmers could sell their goods in cities. Tourism had a boost as well.

The invention of the automobile revolutionised personal and public transportation. The invention of the internal combustion engine secured further development of the automotive industry. The development of internal the combustion engine gave birth to a new way of transportation, namely, aviation. (Причины второй промышленной революции 2-й половины 19 века [Causes for second industrial revolution in the 2nd half of 19th century] 2016.)

Summing up, second industrial revolution was an era of the most rapid economic growth of industrial countries. As a result of increase of labour efficiency and decrease of prices for mass consumed goods, level of life noticeably increased. At the same time, because manual labour was replaced with machines, unemployment rate increased, and social stratification became more visible. Improvements in transport sphere and acceleration of goods turnover helped to stop hunger in different areas in case of low crop. Increase in production volumes of production plants lead to further urbanization and appearance of middle class, a group of qualified and relatively highly-paid workers.

3.3 Third Industrial Revolution

Third industrial revolution is also called Digital revolution. It is a general transition from analogue technologies to digital. Also, it is a transition from industrial society to post-industrial, meaning that services are going to be the key economic support, not manufactory.

Digitalisation started with appearance of personal computers and the Internet in 1960’s. By 2011, approximately 2,25 billion people or one third of the Earth’s population had access to the global network. Today, not only our computers and mobile phones are connected to the Internet, but our homes and cars are among other devices in the Net. Internet of Things is growing with appearance of household devices, such as thermostats, lights and appliances as well as concepts of connected infrastructure. In ideal future our cars will interact with each other and with traffic infrastructure to make transport flow safe and optimized on efficiency and effectiveness.

The crown of the third industrial revolution will be the invention of Artificial Intelligence. A robotic mind, able to think and make decisions as a human. As nature of human intellect is still disputed and undefined, appearance of artificial mind is unlikely in the nearest future. (Romanchuk 2012.)

Some sources also define a fourth industrial revolution or Industry 4.0. The purpose of the latest revolution is to wipe out the borders among physical, digital and biological spheres. In other words, invention of artificial intelligence, development of cybernetics and creation of every possible smart systems means stepping out of the informational revolution and into Industry 4.0. (Промышленная революция 4.0. На пороге новой эпохи [Industrial revolution 4.0. On the edge on a new era] 2017.)

4 Transport

Motorized road transport was a significant part of the second industrial revolution and it will also play a vital role in the third one with total computerization. Therefore, automotive history requires a deeper introduction.

Automobile is a motorized means of transport designed to transport loads and passengers on non-railed roads (Ozhegov 1999, 27). It is common to think that first automobiles were built in the late 19th century by Karl Benz. In some way it is true, because the development pace had risen significantly with appearance of Benz's motorized vehicles, but the history goes much deeper to the past, than reader might think.

First automobile prototype with a steam engine was built as early as 1678 for Chinese Emperor. Unfortunately, it cannot be named an automobile as it was unable to transport anything but itself (Kirpichev 2011, 117).

First motorized vehicles had steam engines installed as a power unit. These vehicles were designed in the late 18th century to move heavy weaponry in France. Steam engine uses heat from burning wood, coal and other flammable materials to boil water in a large container. Container is pressurized, so that steam, while going through the system, could move a piston in a cylinder. The piston is rotating a flywheel which was connected to a driven wheel via a belt or a chain. Steam engines were used to power automobiles until 1930. By that time internal combustion engines became more fuel efficient and powerful than steam engines. (История автомобилестроения [Automotive history] 2010.)

First motorized vehicle to transport people was designed in Great Britain in 1784. It was a coach with a steam engine instead of horses built by William Mardock. In 1789, Oliver Evans got the world's first patent for an automobile in the United States. More interestingly, Evans' invention was also the firs amphibious automobile. (ibid.)

Later, in 1828, an electric motor was invented. It was used to power a scale model of an automobile as it was not yet powerful enough to move a full-size vehicle with load and required a source of electricity. 10 years later first electric locomotive appeared. Its top speed was unbelievable 6 km/h, but it was the first vehicle that led to invention of a tram and using rails as electric conductors to power locomotives. Electric vehicles along with steam powered vehicles were dominating the automobile market during the first quarter of the 20th century. (ibid.)

First internal combustion engines were designed in 1806. At that time, petrol, diesel and other liquid fuels haven't yet been invented, so development went slowly and different gases were used to power them. Internal combustion engine uses a mixture of flammable gas or liquid with air. That mixture is pumped into a cylinder and then ignited. Burning mixture expands and pushes a piston, which is rotating a flywheel. First operating engine used a mixture of hydrogen and oxygen as fuel. In 1860, an automobile with an internal combustion engine powered by hydrogen travelled a 9 km journey in 3 hours. Later version of this particular engine worked on coal gas. (ibid.)

Only 10 years later, an engine running on liquid fuel, petrol to be precise, was built and installed on a carriage. So, 1870 may be counted as the beginning of rapid development of internal combustion engines. Since then, engines got new ignition systems, fuel feed systems, varied sizes and layouts. (ibid.)

1888 is the year when automobile era begins. Karl Benz establishes the world's first automobile production. Benz's automobile was technically a tricycle, but it was the first serial production motorized vehicle. (ibid.)

In 1889, Wilhelm Maybach and Gottlieb Daimler built a new type of vehicle, which was, from ground up, designed as an automobile, not a carriage or a coach with an engine suspended on it. (ibid.)

In 1901, Olds Automobiles, more known as Oldsmobile, with its Curved Dash was the first mass producer of automobiles using a first conveyor.

Further development of automobiles I'd like to divide in several areas:

- Engines and fuel types
- Safety
- Assistive technologies
- Organization of road transportation and road safety

4.1 Engines

Automobile industry has used several types of engines in its history. They are internal combustion engines, electric motors, steam engines, fuel-cell hydrogen engines, hybrids and even jet engines.

4.1.1 External combustion engine

Steam engine was the first power unit to replace a horse in a carriage. A steam engine consists of a boiler, pipelines and a cylinder with a piston inside. Boiler evaporates water and creates pressure inside itself to make steam doing a job of moving a piston possible. Pressurized is then pumped into cylinder via pipes and moves the piston. Valves control the steam intake and exhaust. A rod was converting translational movement into rotating. It was connected to the piston on one side and to a flywheel or a directly to a driven wheel on the other side. (Когда автомобиль будет иметь паровой двигатель? [When would an automobile get a steam engine?] 2016).

Benefits of steam engines are that the can run on any flammable fuel, for example coal, wood, gas, vegetable oil and so on. Also, it develops quite a lot of torque and can move heavy objects. On the downside, steam engines need a lot of water. Water means lots of extra weight to carry around and time to evaporate it. (ibid.)

Efficiency of early steam machines was from 1 to 8 percent due to the fact that used steam was exhausted into the atmosphere. Later, steam engines were equipped with condensers and modified evaporating part of the boiler and reached efficiency of up to 35% and used only a few liters of water per 100 kilometers of travel. (ibid.)

Steam powered automobiles had 40% share amongst all road vehicle on roads of the United States by 1925. Dropping price for petrol and increasing power output of internal combustion engines played its role on defeating steam power. (ibid.)

Nevertheless, steam power trucks and heavy-duty vehicles were used in the United States until 1960's.

4.1.2 Gas powered engines

The most widespread engines nowadays are internal combustion engines. These engines can be powered by petrol, diesel, biodiesel, ethanol and natural gas. Early versions of combustion engines ran on hydrogen or coal gas as petrol was not invented yet. First patent for a gas engine has been given to a French engineer Phillippe Lebon in 1801. He was the first to describe the work principle of a 2-stroke gas internal combustion engine. Unfortunately, he didn't have a chance to build one. (История Автомобилестроения. Двигатель [Automotive History. Engine] 2009)

4.1.3 Petrol powered engines

Jean Etienne Lenoir was the first one to build an engine that was capable to compete with steam machines. By 1864, over 300 units were built by Lenoir. Due to the intoxicating influence of money, Mr. Lenoir discontinued development of his engines and, unsurprisingly, his invention was not anymore able to compete with Nicolaus Otto's creation. (ibid.)

Otto got a patent for his invention in 1864. Visually it was more a predecessor of Lenoir's engine, but it was 5 times more economical to the fuel and more efficient. In fact, it was more efficient than the best steam engines of that time. Predictably, demand on that engine was great. Otto continued development and in 1877 he introduced a 4-stroke combustion cycle, which is still used in modern automobiles. (ibid.)

All these engines had 2 problems: poor ignition and poor fuel vaporising.

Engines had a unit that was responsible for creation of vapor, as liquids themselves do not burn. To get rich petrol vapor, fuel had to be heated to start evaporating quickly. Unfortunately, it was not enough to make the engine perform better. (ibid.)

Also, ignition was done either by open fire or a heated pipe. Open fire was too dangerous and could be used only indoors and heated pipe did not provide proper continuous ignition. (ibid.)

To solve the first problem, Donat Banchi invented a carburettor. Carburettor is a device used to prepare a fuel-air mixture before the engine. Piston in the engine was now used as an air pump to suck the mixture into the cylinder. Carburettor's job was to spray petrol into the air that was passing through it inside the engine. Spayed fuel meant that more petrol will get inside the cylinder. As the mixture is travelling to the cylinder it will be partly vaporised. Also, 4-stroke cycle has a compression stroke, during which, the rest of fuel will be vaporised. Carburettor brought more power output to the engines and increased their efficiency. (ibid.)

Second problem was solved by inventing an electromagnetic ignition coil. Coil provided electric current to ignitor and electric sparks ignited the fuel. That type of ignition meant that internal combustion engines became more stable at operation as well as even more fuel efficient. (ibid.)

To get more power engineers increased the capacity of cylinders and, later, their number. Doing that endlessly was not possible due size of the finished product, it would not be able to fit in a vehicle. One solution was to switch from inline cylinder arrangement to V-type. V-type engines are more compact than an inline engine with the same number of cylinders, but again, there were no reasonable pros for enormous engines in road transport. (ibid.)

To get more power out of the engine, more fuel needs to be injected. Unfortunately, 1 volume unit of fuel vapor needs 14 volume units of air and in a naturally aspirated engine air volume is limited. Respectively, volume of injected fuel is limited. Thanks to motor racing, forced induction was introduced. It is divided in to 2 types: compressor (or supercharger) and turbocharger. Purpose of forced induction is to increase the amount of air coming into the engine, so that more fuel can be burned. Most of the automobiles produced nowadays have turbochargers installed. That solution allows to decrease engine capacity at the similar power output and improve fuel economy. (ibid.)

Invention of fuel injection lead to increase in fuel economy and power. Injectors replaced carburettors in 1990s. Fuel injector is a unit operated mechanically, later electronically, to spray a required amount of fuel into the air intake system or, like nowadays, straight into combustion chamber. (ibid.)

Introduction of ecological norms in 1980's made manufacturers find ways to decrease emissions. The most harmful of them all are carbon monoxide, nitrous oxides and hydrocarbons. To decrease the value of these gases exiting the engine, a catalytic convertor was invented. A convertor is installed right after exhaust collector in hot area of exhaust system. Converter is a metal case with catalytic component inside. Catalytic component is more often made of platinum, rhodium and palladium. Convertor is divided into 3 sections, each containing one of the elements to neutralize harmful exhausts. Catalysts are elements that accelerate chemical reactions but are not taking part in it. So, passing through the converter, harmful gases are mostly neutralized and turned into carbon dioxide, nitrogen, oxygen and water vapor. (ibid.)

4.1.4 Hybrids

Lowering emissions was assisted by appearance of hybrid electric vehicles. Hybrid electric vehicle is an automobile which has an internal combustion engine working together with one or more electric motors. Wheels need to be driven by an internal combustion engine. Hybrid EV's are divided into several categories depending on level of hybrid activity: mild hybrids, hybrids, plug-in hybrids. Mild hybrids have a 48-volt system onboard. Starter motor is used to make the initial move of the vehicle after standstill, when normally most of the fuel is used. These vehicles cannot run on electric power only. A regular hybrid has an internal combustion engine and an electric motor working simultaneously. These hybrids may run several kilometres on electric power only on speeds up to 45 km/h. Recharging of batteries happens only under braking. Plug-in hybrids work the same way as regular hybrids, but have extended electric range, often of 30-40 kilometres, may run on electricity only at speeds up to 120 km/h and be recharged using a regular power point. (ibid.)

4.1.5 Diesel powered engines

Rudolph Diesel got a patent for a new type of internal combustion engine in 1892. That engine did not have an ignition system, the fuel was ignited by sudden compression provided by the moving piston. Early engines worked on vegetable oil. Later, with development of crude oil purification, heavier fractions were used for that. These fractions are called diesel fuel. (ibid.)

At the moment of early production of diesel engines, these engines were not popular as they were much heavier, larger and significantly more complicated. Later, after some years of development, diesel engines found their place as marine engines and in heavy-duty vehicles as trucks and special purpose vehicles. Benefits of installing a diesel engine are following: smaller fuel consumption, higher torque, longer lifecycle. Due to the combustion cycle and type of fuel diesel engines are significantly less environmentally friendly, than their petrol rivals. Diesels produce more nitrous oxides as well as soot. Soot appears in exhaust gases if fuel is not burnt completely, for example, during low-speed runs or idling. (ibid.)

Modern diesel engines are equipped with different technical solutions to decrease harmful exhausts. Soot filters designed to catch soot particles in the exhaust system. Filters clean themselves actively or passively. Passive cleaning or regeneration is natural, when engine runs with high load and exhaust gases burn the soot in the filter. Also, some additives may be added to fuel to decrease the burning temperature of soot and the process may be possible at lower loads. Active regeneration means using some hardware modifications to increase the temperature in the filter: fuel injection before the filter, electric heating of gases before the filter, microwave heating of the filter itself. (ibid.)

Additional hardware for catalytic convertors were introduced already in 21st century to decrease nitrous oxide emissions. That hardware unit injects urine or AdBlue as it is more known. Additive is injected into hot part of exhaust in catalytic converter. Urea transforms into ammonia and carbon dioxide. Ammonia then reacts with nitrous oxides in the exhaust gases. As a result, nitrogen and water vapor exit the convertor. (ibid.)

Petrol engines were least popular until the end of the first quarter of the 20th century. By that time motor racing helped to develop more powerful and efficient engines and, respectively, vehicles than their steam and electric cousins. (ibid.)

4.2 Electric Vehicles

Electric vehicle is a means of road transport, driven by one or more electric motors, powered by onboard battery pack or fuel cells.

Electric vehicles appeared on the market earlier than vehicles with internal combustion engines. Early EV's had approximately the same power output and range as vehicles running on fossil fuels. By 1925, 38% of all motorized vehicles were electric in the United States. Only 22% ran on petrol. Decreasing price on petrol and complexity in charging EV's played its role and internal combustion dominated the automobile market. Electric vehicle tried a comeback during the oil crisis in 1970's, but it again went down in 1982. (История автомобилестроения [Automotive history] 2010.)

1990's was the turning point to development of EV's as ecological situation was deteriorating. Volkswagen's diesel gate scandal boosted significantly appearance of electric vehicles. More and more manufacturers introduce their EV's every year as well as completely new manufacturers appear on the market producing only electric vehicles. (ibid.)

EV's nowadays struggle of low range and long recharging time. Most of the currently produced electric automobiles have a range of less than 300 kilometres. That range is good enough for city runs, but not for long journeys. Fortunately, Tesla Motors is working on extension of range. Some other manufacturers like Fisker, General Motors and BMW install internal combustion engines on their vehicles to generate electricity to charge the batteries or to provide is straight to electric motors. (Golovanov 2017.)

4.3 Other types of power sources

4.3.1 Fuel cells

Hydrogen as energy source for automobiles has not been forgotten. First motorised vehicles used hydrogen gas, which was mixed with oxygen and ignited in combustion chamber. Hydrogen gas was contained in gas tanks. Hydrogen was then replaced with natural gas, later with petrol, as both were less expensive. (Golovanov 2015.)

First automobile designed to run on hydrogen was built in 1959. It was the first vehicle to have fuel cells onboard. Fuel cell is a unit, that generates electricity from chemical reaction. Use of hydrogen in fuel sells is more efficient than burning it in a combustion chamber. Efficiency increases from 35% to 57%. (ibid.)

Hydrogen is known to be an ecologically friendly energy source, as after the chemical reaction, the only exhaust product is water.

Unfortunately, hydrogen is not a panacea in fighting emissions and finding an ideal energy source. First, electricity is used to produce most of hydrogen. Second, it is still more expensive, than petrol and natural gas. Third, storage of hydrogen requires special containers, which are significantly larger, than a fuel tank of same capacity. Infrastructure of hydrogen fuel stations exist, but there are not enough of them to make fuel cell vehicles mass used. Most importantly, hydrogen is dangerous in case of damaging a fuel cell. Hydrogen steps into explosive reaction with oxygen. (ibid.)

4.3.2 Jet Engines

Invention of automobile allowed travelling longer distances on land in considerably shorter times, than using horses. Appearance of jet powered automobile was obvious and in 1928 the world saw the first example. It was an Opel with 12 hard fuel rocket engines. Creator had big hopes for it to be fast, but it only topped 75 km/h. It was slow even by 1920's measurements. (Le 2010.)

Paul Heilandt created an automobile with liquid powered jet engine. It was capable of reaching 140 km/h and was planned to take on the market. Unfortunately, thrust from a jet is not even remotely suitable for road use with other vehicles and people around as it was blowing them away. (ibid.)

Later, jet engines were used in automobiles that were designed to break speed records and not to be driven on public roads. The fastest of them all is Thrust SSC with a reached speed of 1228 km/h in late 1990’s. Another vehicle, Bloodhound SSC, is to be tested in the nearest future and aims to break 1000 miles per hour (1609 km/h). (Prihodko 2014.)

4.3.3 Compressed air engines

Emissions problem of cities has given manufacturers an idea of using compressed air as an energy source for powering a car. Principle of work is similar to internal combustion engine cycle, but without burning, and exhaust gas is the same fresh air that we normally breathe. 2009 showed us a perspective vehicle with compressed air engine. Franco-Italian MDI showed an automobile that could top out 75 km/h and had a range of 100 or 250 km depending on the air tank volume. It is road legal and can also use cycle roads. (Score 2016.)

Air powered vehicles are very cheap to run, have no harmful exhaust and are quiet. A workable solution to reduce emissions in cities. Refilling tanks would only take a few minutes and cost 0.50 euros per 100 km. It would be a dream, if there were no drawbacks: there is absolutely no infrastructure built for this type of vehicles, air needs purification from water moisture, so that it won’t damage the engine. (ibid.)

4.4 Emissions

Every internal combustion engine is producing harmful greenhouse gases, like CO and NO_x. These emissions are result of a process of fuel combustion. Diesel fuel exhaust fumes have more nitrous oxides due to chemical contents of this type of fuel. Since 1992, with introduction of EURO emissions standards, manufacturers were obligated to follow these standards to be able to sell new vehicles in EU. Each following standard was stricter than its predecessor. (Евро нормы выбросов вредных веществ для автомобилей [Euro norms for automobile emissions of harmful substances] 2017.)

Stage	Date	CO	HC	HC+NOx	NOx	PM	PN
		g/km					#/km
Positive Ignition (Gasoline)							
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	-	-
Euro 2	1996.01	2.2	-	0.5	-	-	-
Euro 3	2000.01	2.30	0.20	-	0.15	-	-
Euro 4	2005.01	1.0	0.10	-	0.08	-	-
Euro 5	2009.09[b]	1.0	0.10[d]	-	0.06	0.005[e,f]	-
Euro 6	2014.09	1.0	0.10[d]	-	0.06	0.005[e,f]	6.0×10^{11} [e,g]
Compression Ignition (Diesel)							
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	0.14 (0.18)	-
Euro 2, IDI	1996.01	1.0	-	0.7	-	0.08	-
Euro 2, DI	1996.01[a]	1.0	-	0.9	-	0.10	-
Euro 3	2000.01	0.64	-	0.56	0.50	0.05	-
Euro 4	2005.01	0.50	-	0.30	0.25	0.025	-
Euro 5a	2009.09[b]	0.50	-	0.23	0.18	0.005[f]	-
Euro 5b	2011.09[c]	0.50	-	0.23	0.18	0.005[f]	6.0×10^{11}
Euro 6	2014.09	0.50	-	0.17	0.08	0.005[f]	6.0×10^{11}

* At the Euro 1..4 stages, passenger vehicles > 2,500 kg were type approved as Category N_1 vehicles
† Values in brackets are conformity of production (COP) limits
a. until 1999.09.30 (after that date DI engines must meet the IDI limits)
b. 2011.01 for all models
c. 2013.01 for all models
d. and NMHC = 0.068 g/km
e. applicable only to vehicles using DI engines
f. 0.0045 g/km using the PMP measurement procedure
g. 6.0×10^{12} 1/km within first three years from Euro 6 effective dates

Table 1. EU emission standards for passenger cars (DieselNet. EU: Cars and Light Trucs)

A special cycle has been introduced to measure emissions. Vehicle is strapped to a rolling road and operator is simulated driving through town and on highway. The cycle is known by manufacturers and in September 2015 a fraud, performed by Volkswagen AG, involving up to 11 million diesel powered vehicles, also known as Dieselgate, was revealed. The aim of the fraud was to significantly lower nitrous oxides emissions of vehicles and improve performance. As the cycle and the process of measurement was known, vehicles were taught to identify the moment it was on an emissions test. After identification of the testing, ECU (Electronic Control Unit, a unit that controls the engine operations in all modern cars) selected another program, that was able to maintain emissions low. As a result, Volkswagen had to pay a fine of approximately 18 billon US dollars, fix all other 11 million vehicles and be ready to refund the cheated customers. (Дизельгейт: Автомобили Volkswagen даже после переоснащения провалили тесты по выбросам [Dieselgate: Volkswagen cars fail emission tests even after re-equipment] 2018.)

Dieselgate became the reason of quicker introduction of new emission standards for diesel engines. Also, the scandal has boosted interest of manufacturers in electric vehicles and hybrids. Volkswagen AG has closed their motorsport divisions, that used diesel engines and entered Formula E (electric open-wheel racing series).

Scania, which is a part of Volkswagen AG, is testing a hybrid of a diesel powered lorry and a trolleybus on an eHighway in Germany in cooperation with Siemens. A pantograph is used to gather electricity from wires that run above one of the lanes. While the truck is connected to the wires it runs only on electricity.

Figure 1. Scania lorry testing eHighway

Another technology tested by Scania is done in cooperation with Bombardier. The idea is to use electromagnetic induction to transfer energy from the road to the vehicle through air. A vehicle has an inductive panel on the underside, approximately 10 cm from the road surface. Company now tests the amount of power they can transfer, power losses during the transfer, possible maximum height of the inductive panel from the ground, how does vehicle movement inside the lane affect the quality of transferred energy. (Scania tests next-generation electric vehicles 2014.)

4.5 Autonomous vehicles

Self-driving vehicles are slowly appearing in our daily life. Tesla with its AutoPilot function is the most well-known, but what is an autonomous vehicle? SAE (Society of Automotive Engineers) can describe 6 levels of autonomy, numbered from 0 to 5. Level 0 means that the driver has no aid at all coming from the vehicle. Level 1 means some level of autonomy, but driver must be constantly ready to take action. Autonomous parking, adaptive cruise control and lane keeping assistance are the aids for the driver. Level 2 is described as mode, when the vehicle controls acceleration, braking and steering at the same time, but driver needs to be alert and ready to interfere in case the vehicle is not capable of driving itself safely anymore. Level 3 is a more advanced version of level 2, when a vehicle can control itself on roads with predictable traffic, like highways. Driver is required in more complicated traffic. Level 4 is actual autonomy, meaning the vehicle can go from A to B all by itself, driver is acting as a passenger all the time. At level 4 vehicle requires infrastructure, like tarmac roads and road marking. Level 5 is full autonomy, vehicle can go safely anywhere, including unpaved roads. (Автономные автомобили: дальнейшие перспективы [Autonomous cars: further perspectives] 2016.)

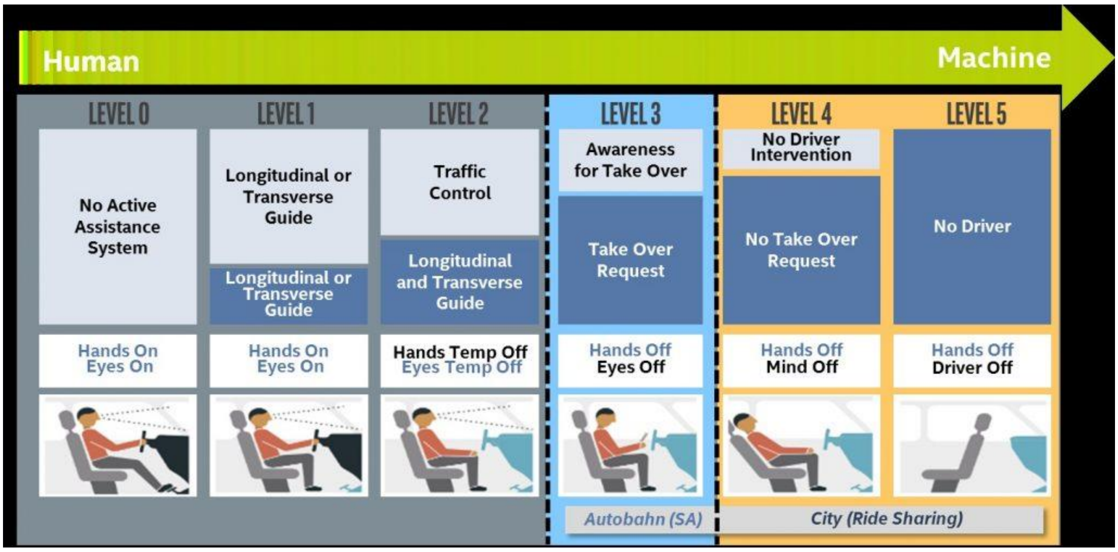

Figure 2. Levels of vehicle autonomy (Bolotov 2017).

Technology behind vehicle autonomy varies beginning from simple cruise control, using just a software feature, and ending with complex systems consisting of radars, LIDARs, HDR and night-vision cameras, GPS and Internet connection. Radars are required to detect objects, like other vehicles, pedestrians and animals. Cameras assist radars and, in addition, identify road marking and traffic signs. LIDARs work mostly like radars. With its help, onboard computer can make a 3D map of surroundings. In case of identifying pedestrians, LIDAR equipped vehicles does not require machine learning, unlike systems using only cameras. Internet is required to connect to infrastructure objects. (What is LIDAR, why do self-driving cars need it, and can it see nerf bullets? 2018.)

Adaptive cruise control (ACC) is currently available to choose from the options list of some budget city-cars, like 2018 Volkswagen Polo, 2018 Seat Ibiza and 2018 Kia Rio, meaning that level 1 autonomy becomes more affordable. Level 2 autonomy is available to more expensive vehicles, e.g. 2017 Volvo S90, 2018 Lexus LS, 2018 Audi A6. Price range and class of vehicles fitted with level 2 equipment varies by a margin, meaning, on one hand, that level 3 and higher vehicles are not entirely ready to be in mass production, and, on the other hand, budget city-cars may get the (level 2 autonomy) technology in the next generation, in 4-6 years. Level 3 autonomous vehicles are currently represented by Tesla and Audi. Most of manufacturers develop level 4 vehicles, skipping the previous one. Elon Musk has an opinion, that level 3 vehicles should not be mass produced as this type of vehicles are dangerous in case used unwise. The reason for that is quite simple: such advanced car can drive itself with driver not touching the wheel and it will only ask the driver to act in case of unpredictable traffic or faults in auto pilot system. Youtube videos show some Tesla drivers moving to the back row leaving the car without control. In case of a supernumerary situation, the vehicle itself will not be able to avoid collision and the driver will not have time to get back behind the steering wheel. Level 5 autonomy is still in process of development and is mentioned as a feature in some concept cars. (Автономные автомобили: дальнейшие перспективы [Autonomous cars: further perspectives] 2016.)

However, there are completely driverless military vehicles that are operating in battlefields. According to Army Technology website, vehicle requires precise positioning coordinates of the vehicle through military grade global satellite system (GNSS) and uses map registration software to operate safely. Machine also has a possibility to be operated remotely. Oshkosh TerraMax is the vehicle in question, equipped with a multimodal sensor suite consisting of a high definition LIDAR system, a wide dynamic range camera, a short wave infrared camera, four situational awareness cameras, 12 short range radar systems and three long range radar systems. (Oshkosh TerraMax Unmanned Ground Vehicle Technology.)

One of the applications to level 5 autonomy is vehicle convoys. The system is tested by Scania on closed roads and shows substantial progress. The idea is to have a chain of vehicles, 4, for example, going to the same destination and transporting goods. Leading vehicle has a driver behind the steering wheel, other vehicles are autonomous and follow the head. Autonomous vehicles track the route of the leading one and do not require visible road markings. Moreover, trucks keep a safe distance between one another and allow other vehicles to wedge in the convoy. (Scania takes lead with full-scale autonomous truck platoon 2017.)

5 Safety

Road transport has always been known as a source of danger. Horse carriages, automobiles, motorcycles; all of them may cause severe injury or even death to people around and those, who occupy them. To make matters better, technical and legislative solutions were introduced.

5.1 Technical solutions

Early motorized vehicles were mostly wooden carriages with considerably higher top speed. Also, steam and electric powered automobiles were quiet and stepping out on the road under the wheels of a vehicle was not such a rare accident.

Later, automobiles were made of steel and designed to move loads without breaking in half. An automobile had a frame, which looked like 2 parallel steel beams. Everything else: engine, transmission, wheels, interior and body were attached to that frame. A safety issue is such, that in case of a collision, the frame will stay in tact and will not deform at city speeds. That means that there is nothing in an automobile to reduce kinetic energy during an impact, meaning that occupants are going to suffer.

In the 3rd quarter of 20th century, deformation zones were introduced. From that time, the body of an automobile became the frame. It was also divided in several parts: engine and luggage bays, and passenger area. Engine and luggage bays are made of milder steels, so that in case of a collision these zones will deform and lower the force of the impact on occupants.

Nowadays most of the supercars have the passenger area made of carbon fibre composite material. It makes the vehicle weight less and have a more rigid structure to increase passenger safety. Also, manufacturers of mass produced vehicles begin to use composite materials in structure of their automobiles.

A seatbelt was invented in 1885, but it only became compulsory in 1957 in Sweden with other countries accepting the rule. First seatbelts were the same as passenger seatbelts in airplanes, with 2 points attached to the vehicle. Later, in early 1900's, a 5-poin seatbelt was introduced. An all-familiar 3-point seatbelt was invented by a Volvo engineer in 1959.

Another common safety feature of all modern vehicles is a headrest. It was invented in late 1960's and was not compulsory to be installed until 1972. NHTSA research shows effectiveness of a headrest in 27% of accidents.

Nowadays, many manufacturers spend their R&D money on autonomous driving. Autonomous vehicles have always been a dream of science fiction, but today the world is coming close to turn fiction into reality. Making road traffic safe from accidents and injuries is not the main idea of vehicle autonomy, but it has a very, if not the most significant role. (История автомобилестроения [Automotive history] 2010.)

5.2 Legislative solutions

Legislation, on the rise of motoring industry, was first concerned on safety of motorised vehicles and were and still are described as recommendations rather than actual laws. Nowadays, not following the recommendations on safety may be a reason for a vehicle to be banned from sales in those countries, which recommendations are not followed. Crash-tests, like EuroNCAP, have been developed to evaluate safety of occupants in cases of most common collisions. Automobiles get a star rating according to values received from dummies, possibility to escape vehicle freely and danger of fire. Today, pedestrian safety is also being considered.

Breaking distance is an important parameter for safety. Shorter distances mean that there is lower risk of hitting, for example, a pedestrian crossing a road in an incorrect place. That parameter is one of few, that is supposed to be taken into account strictly, as there is an upper limit for stopping distance, exceeding which will ban the vehicle from use on public roads. Assistive technologies, like autonomous emergency breaking, also give extra point in safety ratings. System uses a radar and, in some versions, a 3D camera to detect pedestrians, animals and other vehicles, distance to them and the speed of convergence. Then the system alerts the driver, in case no action is taken, or there is no time to alert the driver, the system will break the car to a complete stop.

Autonomous vehicles are currently not allowed on public roads. Vehicle testing shows that currently the technology needs a lot of work to be done, so that autonomous vehicles are safe. Statistics show that Uber’s level 4 autonomous vehicles require driver interference every 1,6 km and driver to avoid accidents every 320 km.

Obvious reason for not allowing autonomous vehicles on public roads is simple. A guilty party in case of an accident will be missing, if the autonomous vehicle causes an accident. That is not a very big deal in case of light collisions without human casualties, an insurance will cover the costs. But what about running over a pedestrian or a cyclist? In some cases, insurance won’t be an appropriate solution. (История автомобилестроения [Automotive history] 2010.)

6 Theory summary

Automotive industry played a significant role in history as it was a part of second industrial revolution. Invention of internal combustion engine and idea of personal transportation has opened a vast, economically significant market. Automobile has given job to millions of people in the world. Some are driving them, some are building them in factories, some are making a living by repairing or modifying them. Different challenges have been faced over the past years: poor efficiency, high ecological impact, issues with vehicle and traffic safety, choosing a good power source. Most of them are still being improved.

7 Research

7.1 Theory analysis

Automotive industry is aiming towards hybrids and electric vehicles nowadays. The aim is to reduce CO_2 emissions of vehicles and make city air less polluted. Currently, some cities have congestion charges or even bans for vehicles exceeding some limits of emissions to enter city centres. London is a good example here. To enter city centre area without congestion charges, vehicle should emit less than 95 grams of CO_2 per kilometre. Exceeding this limit means paying the charge of 11.50 GBP a day. That is quite a severe limit and only a few conventional cars fit in that limit. All hybrid and electric vehicles emit less and are free to enter city centre. That makes some of the drivers to switch to more eco-friendly cars.

2018 Geneva Motor Show has told us about automotive industry plans for the next few years. Volkswagen’s diesel emissions scandal or DieselGate became a reason for many manufacturers to abandon the idea of installing diesel engines in some models of their cars. These vehicles will go in 2 directions at the same time: one is downsizing, another is hybrid. Downsizing means that cylinder capacity of the engine will be decreased, but the power output will be kept at the same level due to the use of forced air induction. Theoretically and based on the same emissions tests, fuel economy will be improved, and emissions lowered. Practically, in everyday use, the end result is sometimes even worse, than it was with naturally aspirated engines.

Hybrid technology is a better solution to improve fuel economy and lower emissions, as hybrids can now travel longer on electric power only, they weigh less, and combustion engines are also better.

Vehicle autonomy is also one of the most important “must have” items in the upcoming models. Some production cars are getting level 2 and 3 autonomy on the launch, but all the concept cars shown this year are aiming to have level 4 autonomy when they will be officially revealed in a few years' time.

Nowadays, marketing is the locomotive for sales of any product. Hybrid and electric vehicles are advertised as low or zero-emission vehicles to turn peoples' attention to the environment. Marketing materials are true, no doubt about that, but nobody, except sceptics, think broader about each vehicle. These vehicles are still built in same factories as conventional vehicles. Their parts are built the same way. They are transported using fossil fuels. But the biggest difference is the battery pack. Lithium, that is used in modern batteries, is not mined in every country. Its deposits are mostly in South America, that means a lot of transportation needs to be done to factories where it's going to be purified and then sent to battery factories. According to researches, 7 tons of CO_2 is emitted during production of 1 conventional car and 14 tons during production of 1 electric car. Also, electricity should be generated somehow and nowadays, most of the electricity is generated using fossil fuels. Only 7.1% of all energy comes from renewable sources, 16% from hydro-plants and 10.6% from nuclear power plants.

It all looks like electric vehicle is not a solution at all, but there is another way of thinking about this. Production plants are most commonly built on the cities' outskirts or even in the countryside. These plants will emit more greenhouse gases while producing vehicles, but there are natural resources around these plants, that absorb some of these emissions and produce oxygen. Trees are very limited in cities and are not able to cope with CO_2 emissions. Using electric vehicles will make city air less polluted. Overall, the map of CO_2 emission will have a more even pattern.

A next step in automotive industry is creating a level 5 autonomous vehicle, a vehicle that does not need a driver or operator and can drive itself to any destination relentless of the surface or road marks. In 2018 we can observe vehicles with up to level 3 autonomy, meaning that they can see the traffic around, but the driver is required to be alert in case a non-scripted occurrence appear. Development of autonomous vehicles has picked up a pace and almost all large manufacturers are researching and implementing the technology in their vehicle.

Tesla’s Auto Pilot system is a level 3 system, currently in a beta-test. It has proven itself reliable and possible to be used on public roads. Also, Tesla has announced a semi-truck with Auto Pilot. Currently, there is a major problem of human factor that undermines the safety of such vehicles. Drivers rely on the system so much, that some of them get in the back seat of their cars and do other things except being alert of the traffic around. That irresponsibility has caused several accidents with driver fatalities since the appearance of Auto Pilot in Tesla cars. Uber autonomous vehicle has run over a cyclist while being in an autonomous mode. Neither the car, nor the driver were able to react to avoid impact. Cyclist passed away. Current autonomous vehicle tests were suspended by manufacturers and moved to closed areas.

Level 4 and 5 autonomous vehicles might probably be assisted by the Internet of Things (IoT). This means that all the traffic lights, variable traffic signs, pedestrian crossing, other vehicles, etc. are connected in one network and are feeding information to a server. An autonomous vehicle may connect to that server and get the information about the traffic to adjust the route to destination, to be alert of upcoming pedestrian crossings to slow down a bit, etc. That will make the traffic less dense and more safe, ideally with 0 accidents. Unfortunately, not every vehicle will be autonomous. Bicycles are still going to be a part of traffic, meaning that human factor will still be present. Also, not every pedestrian is willing or, sometimes, able to obey common traffic rules. That idea has ignited a serious argument on the Internet of morality and choice. One day, an autonomous vehicle may appear at an event on the road, when collision with one or more objects is inevitable. Collision will cause a severe injury or death to one of the people involved. The vehicle will have to decide, like a human, what object to hit. The problem is, that nowadays, in such a situation, a guilty party, if it exists, will be stated, judged and sentenced. Everybody knows that accidents happen, and society will not be blown even by facing many of them. Let’s now think of the case with autonomous vehicles. If anybody gets injured, the society will tell that autonomous vehicles are not safe, they should not be produced anymore and must be banned. But looking at both of these scenarios, they are identical. A human might have chosen a different object to hit, the result would still be the same. Respectively goes for the autonomous vehicle.

Most of the in-land transportation is done on the road. Busses and taxis transport people; lorries, trucks and vans transport goods. All of these types of vehicles have one thing in common, a driver. Being a driver means earning money for life. Some of them work on their own, somebody works for a company. What will happen to these people with appearance of autonomous vehicles? Companies will find that as an opportunity to massively reduce labour costs, meaning that many people would loose their jobs.

Vehicles connected to the internet are vulnerable to being hacked. 2015 showed that a level 2 autonomous vehicle has been hacked. Intruder was able to control an entire vehicle, including steering, braking and acceleration. This threat is even more dangerous nowadays, as vehicles get not only fly-by-wire accelerator pedals, but also break pedals. Fly-by-wire technology means that there is no physical connection between the pedal and component it is operating. So, if somebody takes control of the vehicle, driver is not able even to stop the car.

Overall, the future of automotive industry and related with it road transportation looks the following way: autonomous vehicles will become common by 2025, most common engine will become an electric motor, internal combustion engines will be less popular. Internet of Things will assist autonomous vehicles and make road traffic much safe, with low accident rate. Also, autonomous vehicles will make personal transportation more widespread. People without driving licenses will de able to have a unit of personal transportation for their use.

Transportation business will change significantly with appearance of autonomous vehicles. Full vehicle autonomy will dislodge human labour from driving heavy-duty vehicles, meaning significant cost savings for transportation business. Millions of people around the world will lose their jobs to machines.

Looking at transportation business from other perspective, autonomous vehicles open a good opportunity for rental use of heavy-duty vehicles to transportation companies. A person may buy a truck or a vehicle combination and rent it to operating companies that organize logistics of goods. Similar opportunity opens for car sharing, meaning that vehicle owners will be able to rent their cars for other persons’ use.

Hypothesis: level 5 autonomous vehicles would be the most popular choice in the group of ordinary drivers as well as in the group of companies; professional drivers would choose level 4 and lower as their future vehicles.

7.2 Collecting data and analysis

Questionnaire was done using Google Forms tool. First question was aimed on focus groups: regular drivers, professional drivers and transportation companies. Selecting one of the answers of the first question lead to separate forms containing identical questions. This allowed to get answers to other questions divided to corresponding groups.

476 people submitted answers to the questionnaire. Most of the respondents are from the group of ordinary drivers, 382 people, which is 80.25%. 76 professional drivers (15.96%) and 18 company representatives (3.78%) attended in the survey. All participants came from north-west part of Russia. Also, such a small sample is not a trustful source of data and it is hard to make forecasts based on it. Collected data may differ in other regions in countries.

7.2.1 Ordinary drivers

The first question described levels of vehicle autonomy and driver involvement in the process of driving. Respondents were offered to choose the level of autonomy they would like to use in their vehicles. Chart 1 describes the results visually.

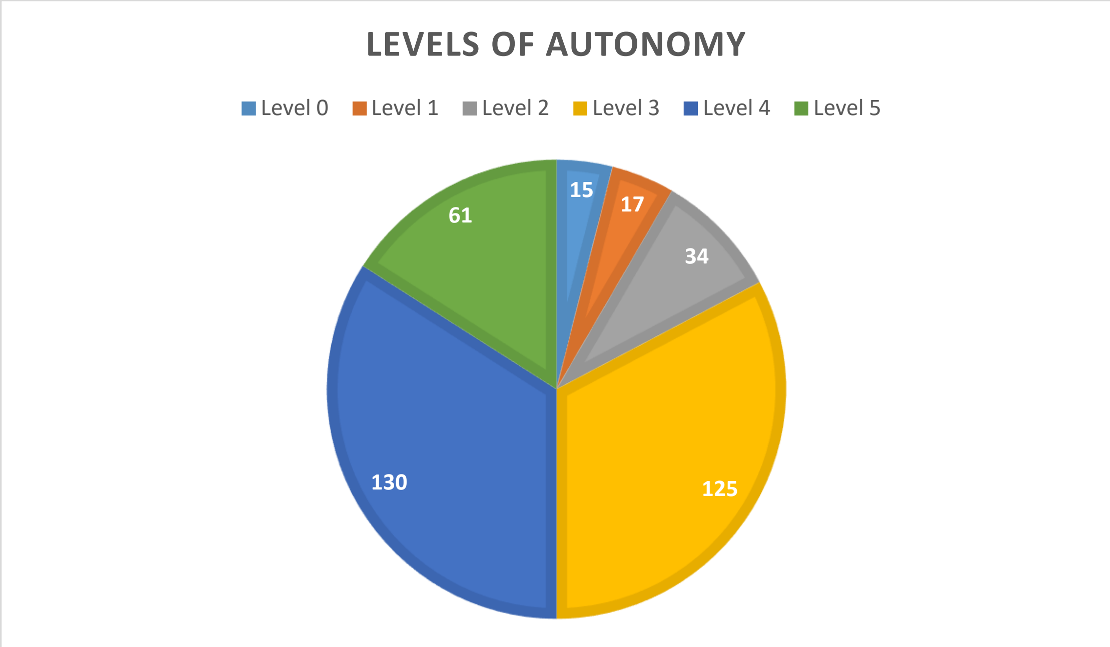

Chart 1 Levels of autonomy. Ordinary drivers

The following questions' aim was to understand the level of trust to the technology in own vehicle and in surrounding vehicles. Answers to these two questions helped to understand the reason to choices made in the first questions. Results are as follows in the Chart 2.

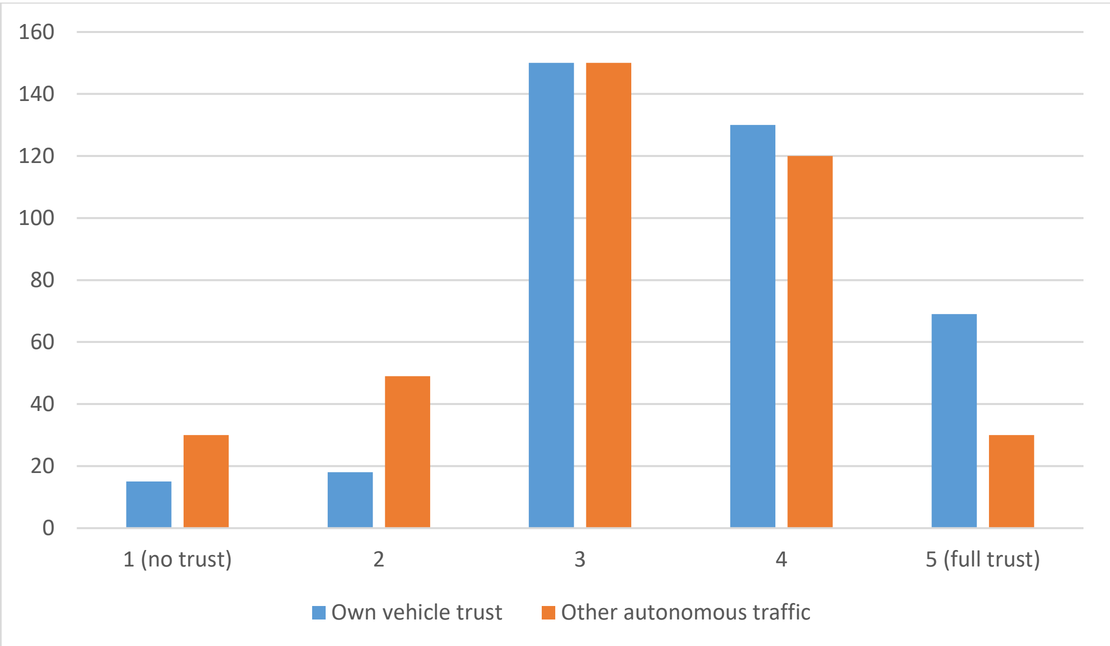

Chart 2 Trust to autonomous technology. Ordinary drivers

The last question was meant to define the trust to cyber security of vehicles as more of them are now connected to the internet. Information to the question described vulnerability of connected vehicles. Results are following:

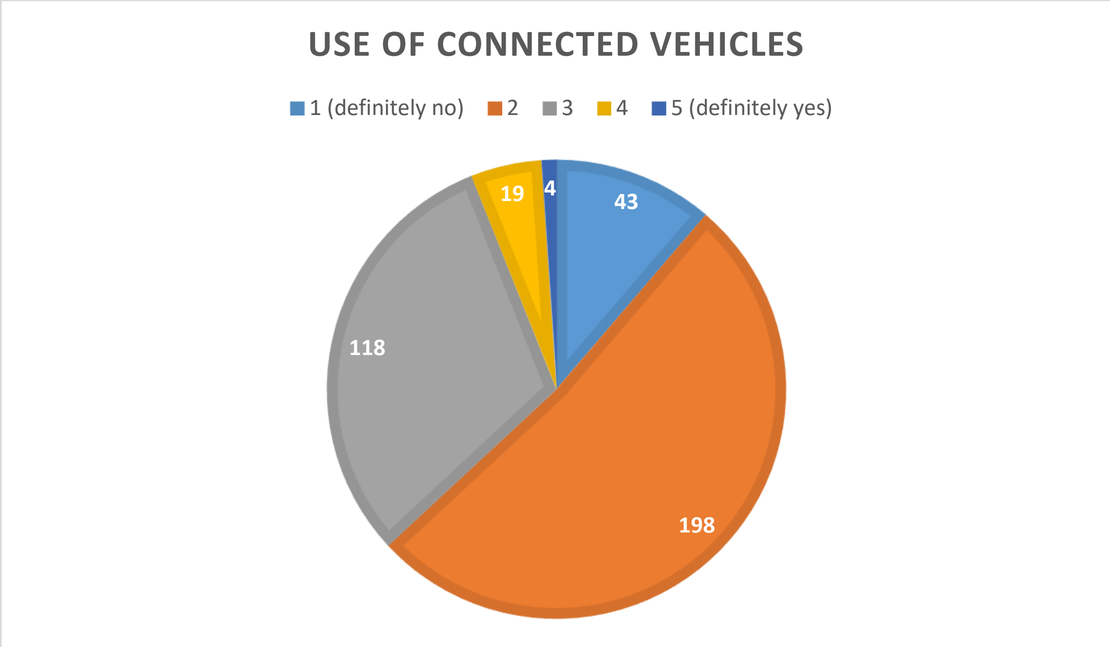

Chart 3 Use of connected vehicles. Ordinary drivers

From the data gathered from the group of ordinary drivers I could define, that the majority would have level 3 and 4 vehicles and are mostly fine with facing autonomous traffic. Information on the matter of autonomous vehicles' cyber vulnerability made most of the respondents to select answers closer to "no" section.

First group's vehicle range was defined as suitable for category B and C1 driving licenses or vehicles with total weight of up to 7,5 tons. This is a very large sector of automobile market. Currently, most vehicles have level 1 autonomy, but up to level 3 vehicles are available for sale. In a matter of years, more models will get up to level 4 autonomy. Cyber security plays a very important role in the future of autonomous vehicles and is now highly researched and improved.

Overall, autonomous vehicles for ordinary users do not affect their lives in a negative way. In case of use of these vehicles by most of the drivers, it would be possible to decrease accident rates, allow non-drivers to have a personal means of transport other than a bicycle and, in some cases, even earn money from car sharing.

7.2.2 Profesional drivers

76 professional drivers had quite similar answers for the questions as the group of ordinary drivers. Results described in Chart 4, 5 and 6.

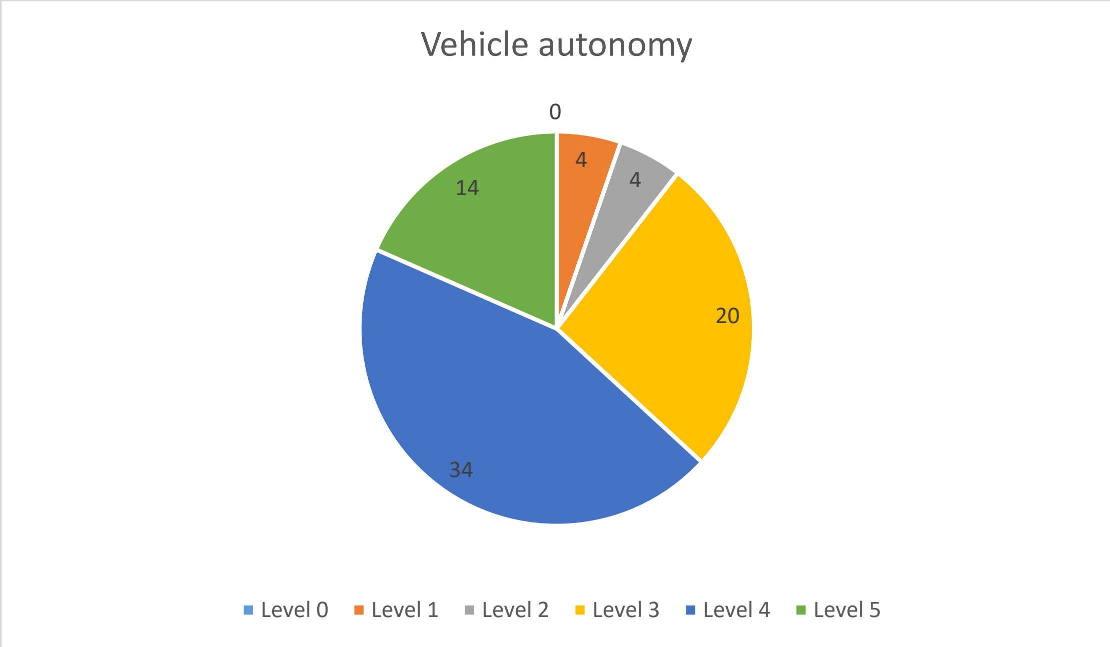

Chart 4 Levels of autonomy. Professional drivers

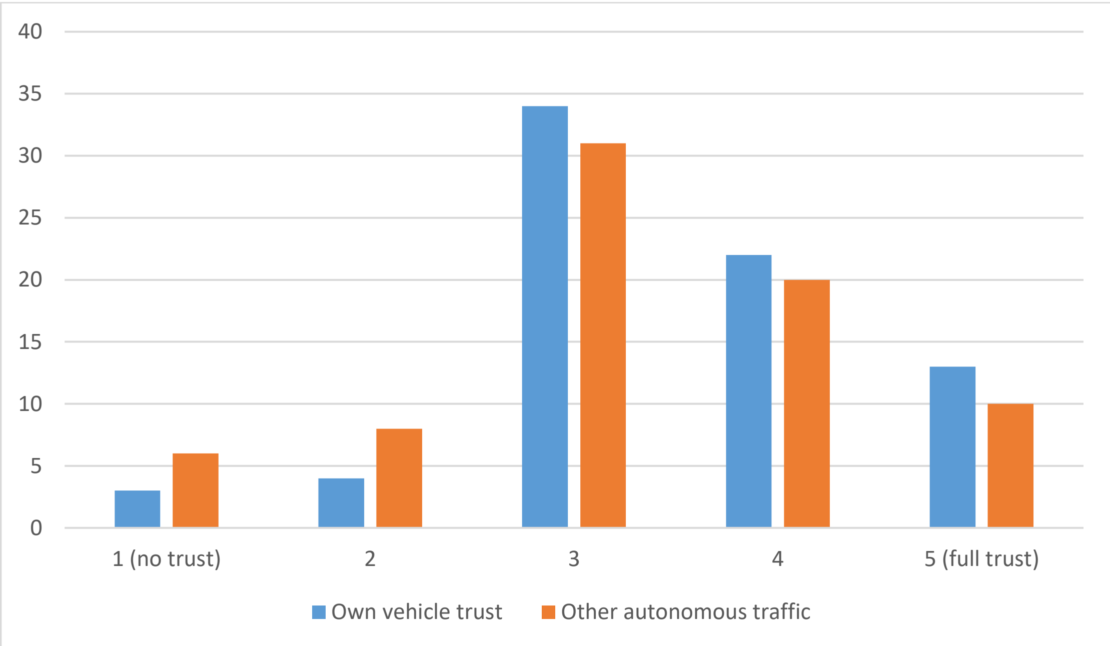

Chart 5 Trust to autonomous technology. Professional drivers

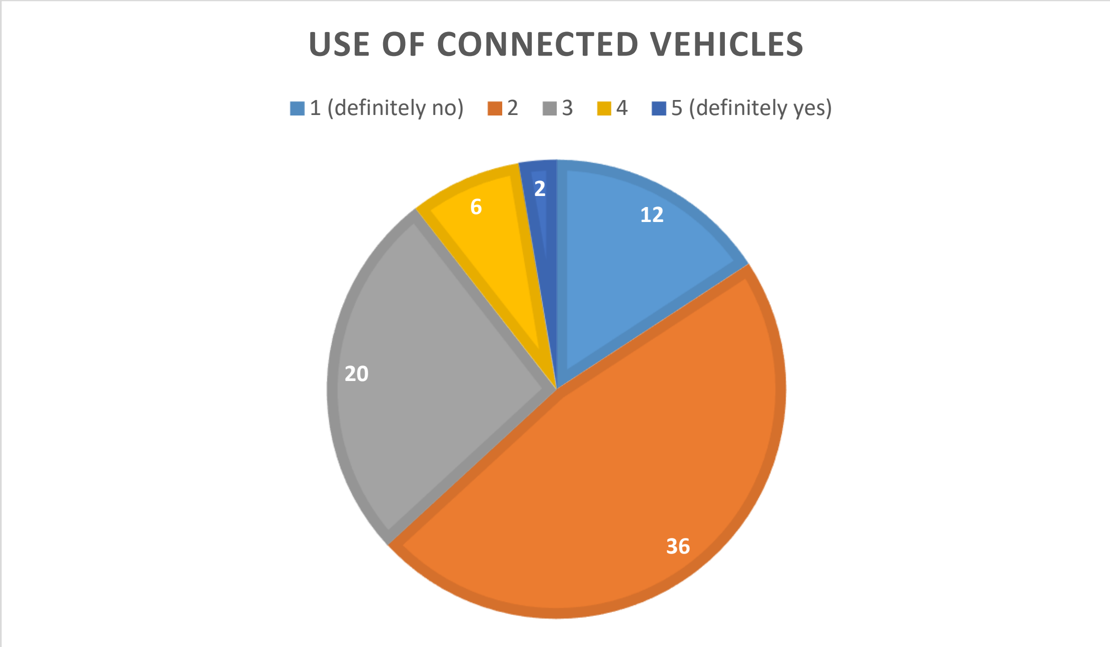

Chart 6 Use of connected vehicles. Professional drivers

The results were quite similar to the ones given by the group of ordinary people. Full autonomy was also a not popular choice, most likely because of lack of trust to the technology as well as vulnerability to hacking. Generally, a picture of the future for trucks, busses and lorries looks identical to personal and light cargo transport. Level 5 autonomous vehicles are also a threat to professional drivers as they might lose job to artificial drivers. At the same time, fully autonomous heavy-duty vehicles gives an opportunity to lend these vehicles to transportation companies, providing income for vehicle owners, cost savings for transportation companies and lower prices for company clients.

7.2.3 Companies

Companies was the smallest group, that participated in the questionnaire and results may vary significantly with larger number of respondents. Trend in companies was approximately the same as within other two groups: most interested in level 3 and 4 vehicles, were quite confident about the use of autonomous vehicles and facing them in traffic, and mostly think that cyber security is a matter to be improved. Companies would find autonomous vehicles helpful for the business, as level 3 and 4 vehicles will allow driver to be less stressed on highways, load be safer and accident rate be decreased. Level 5 autonomy vehicles will also allow to decrease labour costs, as drives will not be required.

7.3 Scenarios of future transportation

Information revolution, as other two industrial revolutions, will make a serious impact on the way we live today. Transport is now on the edge of becoming autonomous, meaning that drivers will no longer be required. Millions of people, who make their living from driving vehicles will lose their jobs. Having that in mind, forces to think, that it is not a bright future for quite many people, but, looking back to the first industrial revolution, it also means opening much more new jobs.

One of the scenarios requires significant marketing of workplaces in the field of information technology and in service. In case the world gets level 5 autonomous vehicles, these machines will require not only mechanical service, but also software support. Internet of Things with all the traffic infrastructure will need qualified IT-support to continuously run smoothly. Cyber security specialists will have significant increase in workload, to support car manufacturers and ministries of transport of different countries to operate safely.

In other scenario, use of autonomy vehicles should be restricted, meaning lawmakers should find a beneficial solution to users of technology, manufacturers and third parties, like the government and the citizens. First, vehicles with up to level 4 autonomy must require a driver in the vehicle ready to take action at any moment. This will increase safety of vehicle occupant, other vehicles and their occupants as well as cyclists and pedestrians in extraordinary road situations. Second, driver of the vehicle should still be responsible for any actions with his/her vehicle. In case of level 5 autonomous vehicle accident, where that vehicle causes that accident, manufacturer should be responsible for accident. Third, level 5 autonomy should be available only in passenger cars to protect workplaces of cargo vehicles and buses. In that case, we will get safer traffic, employed professional drivers and manufacturers, who didn’t spend R&D money for nothing.

Due to the fact, that development of level 5 autonomous vehicle is significantly harder, than development of other level vehicles, appearance of such vehicles in the nearest future is hardly possible. These vehicles must be able to operate in any terrain and weather conditions. That means, that vehicle requires a very detailed map of the area it is going to operate in, as well as precise location coordinates, which are available to military only. Northern countries with heavy snow cover, as well as countries with poor road marking are bottlenecks of development of the technology. Also, psychological factor will play its role to many potential users of technology, as it is quite hard to gain trust to a machine. Moreover, if people do not feel safe and they cannot trust an autonomous car, it is irrelevant how well the vehicle behaves and how safe it is. That is why fully autonomous vehicles are still decades away from mass use. (Автономные автомобили: дальнейшие перспективы [Autonomous cars: further perspectives] 2016.)

7.4 Conclusion

The research has shown that the hypothesis did not find confirmation due to lack of trust to full autonomy technology, its cyber security issues and general complexity of development. As in the past, new technologies take a significant amount of time from being developed to being implemented and used in the field. Transportation business is not going to change significantly in the nearest future, if level 5 autonomous vehicles will appear and prove being safer in traffic than piloted vehicles.

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