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Self-Driving Car as a Legally Recognized Cyber Physical System on Public Roads – Safety and Security Aspects

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INTRODUCTION

In order to provide themselves with the basic necessities of life, people were always forced to travel shorter or longer distances. The main purpose was to find food to live. At first, people travelled on foot, but soon there was a need to travel longer distances and get to their destination quickly. This led to the need for the production of means of transportation. As technology developed in parallel with the development of people and civilization, the means of transportation were also developed. One of the most significant is certainly the car, that is, the vehicle for personal transportation from one place to another. It is believed that Banki Donat from Hungary was the first designer of the carburetor and Karl Benz from Germany of the first car that appeared on the public roads in 1886. Since that time, the engine and the body of the car have been significantly improved. Currently, the speed of the car is up to 450 km / h. The car is powered not only by conventional fuel, but also by electric current. The cars are very comfortable: even the noise and vibration are reduced to a low level. However, as the number of cars increases, road safety decreases. In addition, the time people spend driving cars is getting longer and tends to increase. Indeed, by 2030, as much as 70% of the world's population is expected to live in cities, and the global car population is expected to multiply from its current level to nearly one billion. This data prompted researchers to conduct new research on cars that are better suited for modern passengers. The tendency is to realize the futuristic idea of the car without a human driver, i.e. the self-driving car (SDC). SDCs are to be designed as autonomous vehicles (USDOT, 2018). SDCs are planned for comfortable and safe driving by humans without their active participation in the driving process. Automated vehicles are expected to provide additional benefits, such as reduced pollution, reduced fuel consumption and CO2 emissions, optimized traffic flow, and so on. These cars are expected to have benefits in improving road efficiency, reducing traffic accidents, minimizing the risk of accidents due to human error, reducing congestion, etc. SDC will relieve drivers from long trips, minimize the need for car parking, convert private cars into shared SDC, etc. The challenge is how to accomplish all these tasks.

The first trials of automated driving systems are recorded in the 1920s, but testing did not begin until thirty years later. The Tsukuba Mechanical Laboratory in Japan produced the first semi-automated car in 1977. This car had two cameras and an analog computer and required specially marked roads for its travel (Aro, 1977). The maximum speed of the car was 30 km/h. In the U.S., the Defence Advanced Research Projects Agency (DARPA) was the first to support SDC research in the U.S. Army and U.S. Navy, with the goal of developing self-driving vehicles that would protect U.S. soldiers from harm (Davies, 2021). DARPA and the U.S. National Automated Highway System supported the NavLab and ALV projects with Carnegie Mellon University, and the first self-driving car with a speed of 31 km/h was produced in 1984. There was another improvement in driving the car not only during the day, but also at night. The driving distance was increased to more than 4500 km and the driving speed to more than 100 km/h (Jochem, 1995). The cooperative networking between the vehicles and the highway infrastructure and also the embedding of the highway with automated technology in the vehicles showed the great progress. In 2016, the National Highway Traffic Safety Administration and the U.S. Department of Transportation prepared the Federal Automated Vehicle Policy (FAVP, 2016), which accelerated the SDC revolution. Since then, there have been some fully autonomous cab services in the US. In SDC, there is no safety driver; there is still an employee in the car.

The National Research Council of Canada established the cognitive vehicle strategy in 2011 (NRC, 2011). Since then, great successes have been achieved in automated vehicles.

Intensive research in SDC began in Germany with the establishment of the EUREKA Prometheus project at the University of the Armed Forces in Munich and Mercedes-Benz in Germany in 1987 (Dickmanns, 2002) and continues with the BMW SURF project in 2007. The research was focused on the cognitive vehicle (Hoch et al, 2007). With the results of the project, Audi produced a vehicle that drove more than 5,000 kilometers in self-driving mode on U.S. public roads, where it was allowed to test automated cars in 2015. Two years later, Audi added the "Audi AI" car model to its lineup. This is the version of the A8 in which the driver no longer has to perform safety checks as often and always keep his hands on the steering wheel. In 2016-2018, the European Commission supported the development of an innovation strategy for connected and automated driving through the coordination actions CARTRE and Smart Coding Robots SCOUT. As part of the Strategic Research and Innovation Agenda for Transport (STRIA), the Roadmap for Connected and

Automated Driving was published in 2019 (European Commission, 2019). These European smart roadmap systems allow automated vehicles to drive on public roads (Dokic et al., 2015). Under this European strategy, some cities in Belgium, France, Italy, and the United Kingdom have expanded their transportation systems with automated vehicles, while Germany, the Netherlands, and Spain have allowed public road testing. The company PSA Peugeot has tested the vehicles in real conditions in Paris, Bordeaux, Strasbourg, but also in Spain (Frangou, 2019). The new cooperation in testing vehicles between France has established cooperation in testing vehicles also with Germany.

Since 2015, ASEAN countries (Singapore, Malaysia, and Indonesia) have developed cars with advanced driver assistance systems (ADAS) (Hamid et al., 2019), which are being tested on public roads in Singapore (Ng, 20201). China is already producing 100 automated vehicles with 14 seats for commercial use. In 2020, the first fully autonomous vehicle (without a driver or remote control) was deployed on the public roads of Shenzhen city in China (Ng, 20202). Japan planned to conduct the world's largest experiment with self-driving cars to coincide with the Tokyo Olympics (Lyon, 2020), but it was postponed due to the pandemic situation. New Zealand also plans to use automated vehicles for public transport in Tauranga and Christchurch in the future (Fitt et al., 2018).

Nowadays, most countries in the world are actively working on development cooperation. However, for a long time SDC was only the dream of technological success (Thrun, 2010; Styton, 2013). Nowadays, we are aware that the realization of SDC is technically possible due to technological achievements. Recently, we are in the era of the new - fourth - technological revolution, which is promising As is known, the first industrial revolution took place in the period 1760-1870, when, thanks to new inventions in the field of steam and water power, the transition from manual labor to machine production was completed. This epoch is called the "early mechanization period". There were significant improvements in the textile and iron industries, mining, agriculture, etc. This period of introduction of new technologies lasted for a long time. After the discovery of electricity and its application came the second revolution, the "Technical Revolution", which lasted for almost a hundred years. Factories became larger and were used for mass production. This period also saw the improvement of communications and the expansion of railroads. The third so-called "Digital Revolution," associated with the development of automation and digitalization, took place in the period from 1962 to 2011. In this short period of time, computers and especially supercomputers have greatly improved the production process. However, the most important result of this period was the improvement of information, i.e. IT technologies and communication. Intensive networking led to strong communication, while the introduction of the Internet enabled global connectivity in the population. The fourth industrial revolution, with its high-tech strategies for computerizing production, known as "Industry 4.0," began only ten years ago. The main goal of this revolution is to achieve automatic production without human intervention, that is, to develop new methods and systems of communication between physical systems and computers, that is, the technology of cyber-physical systems (CPS). This system includes automation, which gives the system the possibility of self-optimization, self-configuration, self-diagnosis and detection. To accomplish the above tasks, it is necessary to improve knowledge in some areas of science. Let us mention some of them: Robotics, nanotechnology, quantum computing, biotechnology, artificial intelligence, the Internet of Things (IoT), the Industrial Internet of Things (IIoT), the fifth generation of wireless technology, etc. It is expected that the SDC project can be realized with the help of CPS and additional technologies. From SDC is expected to fulfil technical aspects but also all others: economic, legal, social, environmental protection, etc.

SDC as CPS must be able to identify environmental conditions and form a global path to the goal with waypoints that take into account environmental conditions. In addition, SDC must have a control system for navigation and safe travel. It seems that the necessary automation system and artificial intelligence of the vehicle could be technically solved in a short time. However, important problems related to the legal regulation of SDC would arise. Indeed, SDC legislation is introduced in only a few states in the U.S.; in most of the world, the provisions are mentioned only in passing. Writing coherent laws for SDC is very difficult and even impossible because there is no standardization in transportation and also in road traffic. Legislation must be guided by the main directions: regulating liability in SDC and also driving SDC on public roads, and protecting privacy and data protection. Indeed, SDC navigation requires a considerable amount of private data of the passenger. The question arises whether the data used for SDC can be used for legal evidentiary purposes. The data must be protected, and appropriate privacy and data protection laws must be enacted. Protocols must be established to protect the user's privacy, and the SDC manufacturer must be aware of this. On the other hand, legislation is needed to build the appropriate digital infrastructure to prevent SDC from hackers and increase the level of cyber-security. The U.S. has actively introduced legislation to address privacy and cyber-security issues, while the UK and Germany have enacted legislation on liability issues (Taeihagh & Lim, 2019). The most important legislative question to answer is: is the SDC liability, how could the laws be applied, and what would be the effect in the event of an accident? Does the responsibility lie with the vehicle manufacturer or owner, or with the installed software or hardware? Despite the results already obtained in the study of vehicles with a certain degree of automation, not all technical and legal aspects of SDC have been solved. The subject of this thesis is to give directions and rules for the development of SDC as CPS, which must be technically and legally available to be integrated into everyday life.

The first step in the consideration, however, is to define SDC as an autonomous, as opposed to an automatic, vehicle. This chapter establishes the classification for automated vehicles and the level of automation for SDC.

Definition of SDC

The term 'self-driving car' is used in a very broad concept, and the definition in the technical sense needs explanation (Techopedia, 2017). The terminology SDC is not uniform and is used differently in the self-driving car industry. Different organizations also give other names for such cars such as: 'autonomous vehicle' (AV), 'autonomous car', 'connected and autonomous vehicle' (CAV), 'driverless car' or 'robot car'. Moreover, the definition of such a vehicle also differs. For example, Stiller et al. (2007) gave a 'mild' definition for SDC as "a vehicle capable of moving safely with little human input," while Ezike et al. (2019) gave a 'strong' definition as "a vehicle with no human input, where the human driver never needs to take control to operate the vehicle safely." Dickson (2019) defines a self-driving car as "a computer-controlled car that drives itself." Hancock et al. (2019) explain that the "self-driving car is an autonomous vehicle (AV) that drives itself under most or all conditions." However, the most widely used definition of 'self-driving car' SDC is as follows: "It is an autonomous vehicle capable of sensing the environment and moving safely without a driver." It is obvious that all definitions imply that the vehicle uses various sensors (radar, lidar, sonar, cameras, GPS, odometry, and inertial measurement devices) and software to control, navigate, and steer the vehicle. Advanced control systems use information from sensors to detect obstacles, vehicles, pedestrians, etc. on the road, to signal the road, and to determine the appropriate navigation paths.

Autonomous vs. automated driving

The literature speaks of two types of cars: 'autonomous' and 'automated." The question arises whether there is a relationship between 'autonomous' and 'automated cars'. Autonomous' means that the system regulates itself, while 'automated' means that it works automatically. In the technical concept, 'autonomous' more or less means that the system works independently of human input while performing certain tasks. The legal definition of 'autonomous vehicle' is "a vehicle that is capable of navigating traffic and interpreting traffic control devices without a driver actively working on any of the vehicle's control systems" (Hilgendorf, 2015). Thus, an 'autonomous vehicle' drives without human commands.

In contrast to 'autonomous," the term 'automated' is used when operation and control by a machine is required. Automation in cars is introduced long before. Instead of manual work, some actions are performed automatically by using information obtained from sensors integrated into the system. Modern vehicles have partially automated functions such as lane keeping, lane keeping assistance, lane departure warning, speed control, emergency braking, accident avoidance, parking assistance, adaptive cruise control, congestion and queuing assistance, etc. Different Driver-Assistance Systems (DAS) are developed and incorporated into automated cars. Let us mention some of them:

Adaptive cruise control (ACC) - Maintain a chosen velocity and distance between a vehicle and the vehicle ahead.

Automatic parking - Control of parking functions, including steering, braking, and acceleration, to assist drivers in parking.

Automotive navigation system - Providing drivers with up-to-date traffic and navigation information

Night vision devices for motor vehicles - Allow the vehicle to detect obstacles, including pedestrians, at night or in bad weather when the driver has poor visibility.

Alcohol ignition interlocks - Do not allow the driver to start the vehicle if his or her breath alcohol level exceeds a certain level.

Driver fatigue detection - Aims to prevent collisions due to driver fatigue. Information: Facial patterns, steering movements, driving habits, etc. The vehicle emits a loud warning tone and vibrates the driver's seat.

Intelligent speed adaptation (*ISA*) – Regulates the speed according to the given limit.

Wrong-way driving warnings - Warns when it is detected that the vehicle is on the wrong side of the road.

Lane Keeping System - Auto steering that keeps the vehicle in the center of the lane.

Vibrating Seat Alerts - Emits a vibration pulse on the seat when the vehicle begins to drift out of the lane of a highway.

Hands-free autopilot - This is a control system that allows a vehicle to automatically steer and adjust its speed to stay in the center of the lane and a safe distance from the vehicle ahead.

Collision Avoidance System (P*re-crash system*) - The systems can respond to a potential collision situation with various measures, such as triggering an alarm, tightening the passengers' seat belts, closing the sunroof and raising the seat backs

Pedestrian protection system - Minimize the number of accidents or injuries that occur between a vehicle and a pedestrian. The bonnet of the vehicle raises to provide a buffer between the hard engine parts of the vehicle and the pedestrian.

Electric vehicle warning sounds – Sounds alerting pedestrians and cyclists that an electric vehicle is nearby.

A traction control system (*TCS*) - Prevents the loss of traction of vehicles and the overturning of the vehicle in sharp turns and when turning.

Anti-lock braking systems (*ABS*) – Regulates brake pressure when the vehicle skids or loses control due to black ice on the road.

Since 2017, attention has been focused on improving automated vehicles and DAS. Recently, engineers have developed the Advanced Driver-Assistance Systems (ADAS), which are the upgrades to DAS. The powerful Central Processing Unit (CPU) or Field-Programmable Gate Array (FPGA) built into ADAS work with the data from the various sensors and provide vehicle control corrections, such as collision warning and avoidance, to move a vehicle from pedestrian in front of them or the vehicle ahead, provide adaptive cruise control, help avoid collisions, automate lighting, incorporate navigation/traffic alerts, offer navigation assistance via smartphones, warn drivers of potential obstacles, and many other features:

GPS Blockage – When tall buildings, tunnels, bridges or dense trees block reception of the satellite signal, the car relies on its perception and sensor system to navigate.

Perception blindness - Whenever the on-board sensors are affected by environmental conditions such as precipitation, strong sunlight, or the accumulation of mud and dirt, the SDC's integrated navigation system is automatically activated.

Omni-view technology - Provides visibility through a 360-degree vision system.

Traffic sign recognition (*TSR*) systems - Recognizes common traffic signs based on their shape and color in all weather conditions and at night.

Emergency Stop - If the SDC detects a malfunction in its system and cannot safely continue operations, the embedded navigation system's rotation and acceleration data is automatically used to bring the vehicle to a safe and controlled stop.

Based on sufficient information equipment and appropriate vehicle control architecture, ADAS is expected to be the core of an autonomous vehicle that will enhance the safety characteristics of SDCs and reduce traffic fatalities by minimizing human error (Mahatapra, 2017). ADAS must be the step from automated to autonomous vehicle. Currently, ADAS provide better driving performance and higher safety due to the higher level of automation, but these systems very often require human-machine interaction. Thus, many processes and driving principles are tied to the presence of and commitment from a driver or operator. To address this shortcoming, autonomous control must be added to the system to operate satisfactorily in the face of significant uncertainty in the environment. The challenge for engineers is to design the system to compensate for failures without driver intervention. Wood et al. (2012) wrote that "the term 'autonomous' is currently more commonly used instead of 'automated' (and therefore more familiar to the general public) The latter term, however, is more in line with reality." Scientists in the United Kingdom believe that fully autonomous vehicles are still a long way off. Recently, it has become clear that technology alone is not yet capable of controlling the car.

Classification of cars

Ten years ago, the level of automation of cars was classified for the first time. In 2014, the International Society of Automotive Engineers (SAE) published the standard SAE J3016 (SAE, 2014), which contained the most accurate definition of AVs. Since then, the standard has been improved twice: in 2016 (SAE, 2016) and 2018 (SAE, 2018). The level of automation depends on the role of the human driver in performing the dynamic driving task (SAE, 2014), and AVs are said to have different levels of autonomy. SAE a classification is made according to the degree of autonomy of the vehicle. 6 levels of automation are introduced: 0 is the lowest level - without automation and 5 is the highest level - with full automation (Jones et al, 2019). This classification is widely accepted and used by manufacturers and regulators.

The classification is done based on the following factors:

1. Responsible for executing steering and accelerator pedal control: human driver or autonomous technology (AT)
2. Responsible for monitoring the external environment: human driver or AT
3. Responsible for acting as a 'back-up' when a malfunction results in a shutdown of the AT: human driver or AT
4. Autonomous operations are allowed: without restriction or only under special conditions. This means that all operation modes are unrestricted and only some operation modes (e.g. good visibility) are executed automatically.

Table 1. shows the classification made by SAE (Jones et al, 2019; Aria, 2019).

Level 0 (no automation): The automated system issues warnings and may intervene briefly, but has no permanent control over the vehicle.

Level 1 ("hands on" driver assistance): The driver and the automated system share control. For example, the driver controls the steering and the automated system controls engine power to maintain a certain speed, or engine and brake power to maintain or change speed. When parking, the steering is automated while the speed is manually controlled. In this vehicle, the driver must be ready to take back full control at any time.

Level 2 ("hands off"– Partial automation): Steering, braking, and accelerating the vehicle are under the full control of the automated system. However, the driver must monitor the driving and be ready to act immediately at any time if the automated system does not respond properly. Hand-steering wheel contact is often mandatory while driving and confirms that the driver is ready to act.

Level 3 ("eyes off"– Conditional automation): The driver can safely turn his attention away from driving tasks. The vehicle can handle situations that require an immediate response, such as emergency braking. The driver must still be ready to intervene within a certain time.

Level 4 ("mind off"– High automation): This level represents the improvement in safety over level 3. The driver does not have to pay attention to the driving process. Such vehicles are allowed to drive on roads in limited space areas or under special circumstances. Outside these areas, the driver must resume control.

Level 5 ("steering wheel optional"– Full automation): No human intervention is required at all. It is a CPS, which can travel to predominant destinations without human intervention by the driver.

It is important to mention that in the updated version of SAE classification J3016_201609 (SAE, 2016) all 6 levels of driving automation have their name. For example, the automation level, also called "driving mode", means "the characteristic dynamic driving task that requires a specific driving scenario (e.g., high cruising speed, low speed congestion, highway confluence, etc.)" (Aria, 2019). The formal analysis of the definitions in SAE suggests that as the levels shift, there is a gradual change in responsibility for the driving properties. In the transition from SAE 2 to SAE 3, there is a change in the monitoring of the human driver: monitoring of the environment is no longer required. This results in the change of driving style from human to automated system. However, on SAE 3, the human driver still needs to intervene if the automated system asks him to do so. The formal analysis of the definitions in SAE suggests that as the levels shift, there is a gradual change in responsibility for driving characteristics. When moving from SAE 2 to SAE 3, the change in supervision by the human driver occurs: monitoring of the environment is no longer required. This results in the change of driving style from human to automated system. However, on SAE 3, the human driver still needs to intervene when the automated system requires it. At SAE 4, the human driver is relieved of this responsibility, whereas at SAE 5, such intervention would never be required of the human driver. Between manually controlled vehicles (SAE level 0) and fully autonomous vehicles (SAE level 5), vehicles are only partially automated. These vehicles are referred to as partially automated vehicles. These partially automated vehicles (SAV) could take advantage of many of the benefits of fully automated vehicles, but the driver would still be responsible for driving the vehicle.

SAE Level	Name	Execution of Steering and Acceleration/ Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment					
0	No Automation	Human Driver	Human Driver	Human Driver	
1	Driver Assistance	Human Driver and system	Human Driver	Human Driver	Some driving modes
2	Partial Automation	System	Human Driver	Human Driver	Some driving modes
Automated Driving system					
3	Conditional Automation	System	System	Human Driver	Some driving modes
4	High Automation	System	System	System	Some driving modes
5	Full Automation	System	System	System	All driving modes

Table 1. Levels of automation in AVs. (From AS-IS SAE-International J3016TM, 2014)

- The realization of the full automation of the 5th stage for SDC requires further research. It is necessary to deal with the current problems and to make a predictive analysis for the development in the future. The improvement of two general systems to replace the activity of the human brain would be necessary: electronic devices and computers (Vdovin & Khrenov, 2018) with the aim of achieving effective
- Perceptual systems

- Positioning system of vehicle
- Path planning and navigation systems for global and local rout planning
- Control and Decision making systems

Perception and location systems must perceive and sense the environment. Various sensor systems detect the position of the vehicle between other objects. Based on this information, the path of movement is planned and navigation paths are determined. Decision-making computer systems equipped with artificial intelligence (AI) and deep learning technologies would guide the driving process (Grigorescu et al, 2019). In order to create optimal AI, it is not enough to have appropriate technical devices; scholars must also have a high level of knowledge regarding social, ethical, moral, and other aspects of human decision making. It seems that the connection of these aspects is still missing at the moment.

Aims, Hypothesis and Methods

Since the problem of SDC is complex and multidisciplinary, the intention of this work is to increase the knowledge of SDC from different aspects (technical, ethical, social, legislative) and to give a new direction for SDC security, especially in the area of privacy and human rights protection.

Topic (**Subject of the dissertation) is** SDC, the modern and legalized CPS, which should be introduced as soon as possible in public transport as a replacement for the conventional car with a human driver.

The purpose of research should help to ensure that the SDC is a vehicle with advantages over the classic vehicle, especially in terms of safety, which would ensure it greater acceptance among the population.

Objectives of the research are as follow:

- search for the advantages and shortcomings of SDC, taking into account technical, economic, financial, social, ethical, security and environmental aspects,

- knowledge of the opinions and attitudes of the population towards SDC and possible acceptance of SDC by the population in public transport

- propose the necessary measures and documents to ensure the protection of personal data and privacy in SDC with legal support

- develop an approval method for personal data and define the procedure for deleting data in real time

- legal regulation of SDC as a legal regulation of SDC as a legal entity.

- elaboration of documents and measures for the legalization of the SDC

- establish legislation that should be amended, adopted, modified, or added to existing legislation.

Aims of the thesis can be understood in the following points:

1. to prove that SDC is a kind of cyber-physical system CPS,

2. to provide evidence that SDC would change not only the technical environment, but also the entire lifestyle and various aspects of human existence, and to draw conclusions in this area,

3. to prescribe the list of laws necessary for SDC legislation,

4. erate proposals for changes to existing privacy, human rights, and data protection regulations by SDC. In addition, advice on security in the form of strict and detailed rules applicable in the EU and other countries of the world will be developed.

Hypothesis

The hypothesis interfaced with the aforementioned aims, which has to be proved, are as follows:

Hypothesis 1: For the car to be self-driving without a human driver, it should have a high degree of automation, a sophisticated sensing system for perception, a suitable navigation system, and a specially developed control system with artificial intelligence. Then SDC in the technical sense is a CPS. Finally, proof must be provided that the SDC can operate as a fully autonomous vehicle without a human driver.

Remark: Although the hypothesis seems trivial, it is included in the dissertation to prove the technical aspect of SDC.

In addition, it is possible to improve the SDC by suppressing the vibration and harvesting the excess vibration energy and converting it into electrical energy.

Hypothesis 2: For SDC to be accepted by the population, it should have advantages over a conventional human-driven car in technical, financial, social, ethical, economic, environmental, and safety terms.

- The aim of the hypothesis is to scientifically determine the conditions for the acceptance or rejection of SDC by the population.
- The goal of the hypothesis is to determine the reasons for the concern and the opinion of the population against the use of SDCs.

Hypothesis 3: The protection of personal data and privacy of SDC users is possible through the creation of a new system of authentication of data and through the reorganization and amendment of the GDPR, privacy and human rights laws, especially those related to security aspects.

- The goal of the hypothesis is to contribute to the increase of privacy and personal protection of SDC users, with the aim of increasing the level of security in SDC by incorporating SDC in the already existing documents and regulations in the field of human rights.
- The new data authentication system and data erasure procedure must be developed.

Hypothesis 4: In order for SDC to be included in public transport, appropriate legal regulations in the area of civil, criminal, labour, and administrative law must be developed that identify SDC as a legal entity. New registration documents are necessary.

- The aim of the hypothesis is to contribute to the creation of new, up-to-date documents for the legalization of SDC as a legal entity.

The main methods proposed in the theses to prove the hypothesis are: the analytical method, the comparative method and the descriptive method. To prove the first hypothesis, it is necessary to analyze the characteristics of SDC and of CPS. Using the method of comparing CPS and SDC, the main characteristics of SDC that need to be developed to convert SDC into CPS are defined and determined for future development. In the dissertation, the new method for opinion research is developed. The method is adopted for use in SDC's Citizen Science project. The results will be presented in the dissertation. In order to allow SDC to be on public roads, legislation is necessary. With the help of the analysis method, the already existing laws in SDC traffic must be considered.

Based on this, the method of prediction will be applied and new laws in different areas of life will be proposed. With the help of a questionnaire, the public opinion about the SDC will be determined. The main question would be whether people are aware of SDC and whether they want to use it in transportation and what benefits they expect from SDC. Using the comparison method of subjective opinions about SDC and objective statements from technical and legacy aspects, the prediction of the benefits of the system would be obtained.

The dissertation is divided into 5 chapters. The introduction gives the definition of SDC, the difference between autonomous and automated vehicles, and an overview of the history of SDC. The hypothesis and methods of the dissertation are discussed and the goal of the dissertation is also considered. Chapter 1 examines the technical aspects of SDC. Perception, navigation, and control of SDC are considered in light of CPS. The result of the study is to prove that SDC is a special kind of CPS. Chapter 2 examines the advantages and shortcomings of SDC by comparing the objective aspects and subjective opinions about the vehicle. The public opinion about SDC was collected by a questionnaire. Based on the subjective opinion of the future users of SDC and objective criteria about SDC, as a new type of CPS, the advantages and disadvantages for autonomous vehicles are discussed. The chapter gives a prediction about the future application of SDC and procedures and tasks to improve the public acceptance of SDF. Chapter 3 considers the system of privacy and data protection laws in terms of human rights. As a special aspect, the security of data is discussed. In Chapter 4, the legislation necessary for SDC to be included in public transportation and any additional protocols necessary for the system to work with SDC are considered. The list of laws for the legislation is compiled. The thesis ends with Chapter 5, which proposes conclusions and recommendations for future research.

1. SELF – DRIVING CAR AS A CYBER – PHYSICAL SYSTEM

There are a large number of definitions of what a cyber-physical system (CPS) is (Putnik et al, 2019). In general, CPS represents a combination of a physical and a sophisticated artificial computer system capable of making perceptions, collecting data, planning, implementing, and controlling processes. CPS consists of interacting digital, analog, physical, and human components that are made to work through integrated physics and logic. In a CPS, the process or realization in a real physical system is controlled or monitored by computer-based algorithms. In cyber-physical systems, physical and software components are tightly coupled, can operate on different spatial and temporal scales, exhibit multiple and different behaviors, and interact with each other in ways that change depending on the context. CPS includes multidisciplinary approaches that combine theories of cybernetics, mechatronics, design, and process science.

As mentioned earlier, CPS is an integration of computation and physical processes (Madden, 2013). The devices that make up CPS include sensors (to collect physical values) and computers, ranging from simple hardware to high-end devices for data management and control, to complex hardware for the overall system. The functioning of the system is possible thanks to a series of reliable, unreliable and compromised networks that transfer information and commands from one to another part of the functioning system. Thank you to the interconnection system, two types of CPS are developed: a completely closed one without external connection and a second one with internet connection.

The first type of CPS has its own independent system from data collection to self-decision. Then, CPS is an isolated system that focuses on effective, reliable, accurate, real-time, and secure data transmission and control. Examples of these systems include the smart bombs in flight to target, the Mars rover operating between massing from Earth, the original vehicle in the Defense Advanced Research Projects Agency (DARPA) first competition, etc.

The second type of CPS is usually associated with the Internet. Because the Internet is a global system of interconnected computer networks, i.e., the "network of networks" made up of all networks, it contains an enormous range of information resources and services useful for decision making in CPS. In conjunction with cloud servers accessed via the Internet, many software and databases are available CPS. Usually, the Internet of Things (IoT) is considered the Internet of CPS, which enables interaction between the cyber world and the physical world.

1.1 Definition of Cyber-Physical System (CPS) v.v. Internet of Things (IoT)

The usual question is: What is the Internet of Things (IoT) and how is it different from Cyber-Physical System (CPS)? The Internet of Things (IoT) describes the network of physical objects - "things" - equipped with sensors, software, and other technologies to connect and exchange data with other devices and systems over the Internet. It focuses on effective resource sharing and management, interfaces between different networks, bulk data and storage, data mining, data aggregation and information extraction, high network quality, etc. CPS is similar to the Internet of Things (IoT) in that it shares the same basic architecture. However, CPS has a stronger combination and coordination between physical and computational elements (Goswami et al., 2012). IoT emphasizes network sensors to provide data streams for applications. CPS completes the IoT by providing the means to design, implement, and ensure all aspects of composite systems whose components are sensors and data streams. Process control is often referred to as embedded systems. Embedded systems tend to focus more on the computational elements and less on an intensive connection between the computational and physical elements. An embedded system is a computer system that is a combination of a computer processor, computer memory, and peripheral input/output devices. It is suitable for controlling physical operations of machines, electrical and electronic devices because the computations are performed in real time. Such systems are a part of most CPS associated with the IoT. In the following text, we prove that the fifth-level autonomous vehicle, defined as SDC in SAE (SAE, 2018), is a type of CPS. Based on the definition of CPS and the requirement of SDC, it is shown that the system can be realized and produced by 2050 with the latest technologies proclaimed in Industry 4.0 during this industrial revolution.

1.2 Technical aspects of SDC as CPS

Conventional cars and their associated technologies are produced as finished products that can only be improved by redesign or replication. In contrast, SDCs are produced but are never finished due to their digital characteristics. Indeed, apart from the physical system (engine, chassis), the SDC also has a refined part that is digitised. This digitised part is a module of the SDC that can be modified over time. Following the definition of CPS, we assume that SDC is a modular system. The number of layers of the modular system for SDC is assumed to be three and SDC is considered as a three-layer modular system. The layers are:

(1) The first layer of the SDC architecture consists of the device layer. This layer consists of the following two parts: logical capability and physical machine. The physical machine refers to the vehicle itself (e.g., chassis and body). In digital technologies, the physical machine is accompanied by a logical capability layer in the form of operating systems that help control the vehicle itself and make it autonomous. The logical capability enables control of the vehicle and connects it to the other layers.

(2) The second layer is the network layer. This layer consists of the physical transport part and the logical transmission. The physical transport layer refers to the sensors and cables of the SDCs that enable the transmission of digital information. In addition, the network layer of SDCs also has logical transmission, which includes communication protocols and network standards to communicate the digital information with other networks and platforms or between layers. This increases the accessibility of the SDCs and enables the computing power of a network or platform.

(3) Above the device level comes the final level, which consists of two distinct parts: highly automated vehicles and artificial decision systems. Most driving is automated and there are a significant number of ADAS. The decisions are made by a machine-learning artificial intelligence (AI) system. This makes the car autonomous (Khan, 2011).

There is also the service layer, which contains the applications and functionalities used by the SDC owner to extract, create, store, and consume content, e.g., related to one's driving history, traffic congestion, roads, or parking. Finally, there may be a content layer. This layer would contain the sounds, images and videos. SDCs would store, extract, and use them to improve their driving experience and understanding of the environment. The content layer may also contain metadata and directory information about content origin, ownership, copyright, encoding methods, content tags, geo-timestamps, and so on (Yoo et al., 2010).

1.3 Classification of operating systems in SDC

SDC requires a very complex automated logistics system, which is the key technology for an autonomous vehicle (Zhao et al, 2018). Such logistics systems are necessary for machine vision in object and vehicle detection, automatic determination of vehicle position in the environment, automatic navigation and control, and management and decision making. The systems require a considerable number of sensors, connection to networks, but also algorithms for data processing. In general, the systems can be classified into the following groups (Zafarzadeh et al, 2021):

- System for perception of the environment
- Navigation system
- Complex positioning system of the vehicle
- Internal control systems of the vehicle
- Decision making system

The environmental perception system contains a sensor network that collects external and internal data (Corke et al, 2007). The multiple data from sensors and external networks (e.g., electronic maps) are used to determine the position of the vehicle as a moving body on the ground. The SDC navigation system uses its local and global networks to plan the movement route and operation execution. It also selects the optimal real-time path by using electronic map data and matching the maps (Durrant-Whyte & Bailey, 2006). Therefore, the software programs must be able to predict positional disturbances and change the kinematic characteristics (trajectory, velocity, acceleration) at short notice for safety reasons. Artificial intelligent systems (AI) are usually used for decision making in the SDC.

All these systems are partially developed, but further research in the matter is necessary. New automations need to be introduced and various software programs need to be developed and implemented in SDC to meet the requirements of SDC as an autonomous system CPS. The challenge for SDC developers is to develop control systems that are capable of analyzing sensory data to enable accurate detection of other vehicles and the road ahead. Algorithms must be developed to use data from multiple sensors and an offline map for location determination and map updates. Information from a variety of sensors in the vehicle must be integrated to provide a more consistent, accurate, and useful picture of the environment. Unfortunately, despite all the innovations in the system, bad weather conditions can also disrupt and even bring to a halt the normal work of the sensors and the vehicle as a whole.

This section describes sensors for perception and navigation systems. The link between positioning and navigation systems is discussed, and a direction for process modelling of short-term prediction of the motion of SDCs as autonomously driving objects is proposed (Madhavan & Schlenoff, 2005). The principles for further automation of SDC are layered. The principle of artificial intelligence for the control and decision making system is discussed.

Remark: A considerable number of sensors are installed in the SDC, controlling most of the motor functions and the physical state of the vehicle. However, in this paper, only the sensors of interest for the movement of the SDC in the environment are considered.

1.4 Perception sensor system

SDC combines a variety of sensors to perceive its environment (Cveticanin & Ninkov, 2021_3; Cveticanin & Ninkov, 2022_1). SDC's already deployed sensors for environment perception are: Radar, Lidar, Ultrasonic sensor and different types of cameras. The working principle and characteristics of each of the mentioned sensors will be discussed.

1.4.1 Radar - RAdio Detection and Ranging

Radar is one of the simplest sensors suitable for locating objects such as vehicles and pedestrians and determining their speed. It uses radio waves to detect objects. It consists of a receiver and a transmitter. The transmitter emits radio waves that strike an object and bounce back to the receiver. By controlling the direction in which the radio waves are sent and received, it is possible to determine the distance, speed and direction of objects This data is required for speed control, braking, and safety system control as the response to sudden changes in traffic changes. Long-range radars, medium-range radars, and short-range radars are used, depending on the application. Long-range radars (LRR) are used to measure the distance to other vehicles and to determine the speed of other vehicles. It is suitable for objects at distances up to 250 m. This data is required for speed control, braking, and safety system control as the response to sudden changes in traffic changes. Long-range radars, medium-range radars, and short-range radars are used, depending on the application. Long-range radars (LRR) are used to measure the distance to other vehicles and to determine the speed of other vehicles. It is suitable for objects at distances up to 250 m. Medium range radars (MRR) are used to detect objects in a wider field of view, such as for cross-traffic alert systems. The optimum range is therefore between 1 and 60 m. Short-range radars (SRR) are used for detection in the vicinity of the vehicle, e.g. for parking aids or obstacle detection. The distance is between 1 and 20 m. The radar is suitable for blind spot detection and lane change assistance. The radar does not provide accurate results when multiple objects are at the same distance and moving at different speeds. The radar resolves the speeds of the different objects, but it takes time. Also, radar does not give the exact size and shape of an object.

1.4.2 Lidar– LIght Detection and Ranging

Lidar scanning is the latest development in surveying technology (Chang et al., 2019). It is one of the most important and informative sensors used on SDCs, which are used for all-around vision, object detection, and detailed mapping, which SDCs need for locomotion. Lidar's function is similar to that of radar. It helps autonomous vehicles detect other objects such as cars, pedestrians and cyclists. Instead of using radio waves to scan the environment, lidar uses pulses of laser light. A lidar system consists of four main components: a transmitter that emits laser pulses, a receiver that captures the pulse echoes, an optical analysis system that processes the input data, and a powerful computer that displays a live three-dimensional or two-dimensional image of the system's surroundings. The transmitter sends laser pulses and receives reflections from objects. Hundreds of thousands of laser pulses are sent and received every second. An on-board computer records each laser reflection point and translates this rapidly updating "point cloud" into an animated 3D representation of the environment. Lidar thus literally captures the environment at the speed of light. Due to the propagation of light in all directions in air and vacuum, lidar works with a short-wavelength optical signal in the near-infrared range. This results in very fine scanning accuracy, much finer than longer waves such as microwaves. However, the disadvantage of lidar is that it cannot function normally in bad weather (rain, snow, dust). In addition, it is a projecting device.

1.4.3 Ultrasonic sensor

Ultrasonic sensors are used to detect objects in the vicinity. In addition, these sensors are helpful when parking the vehicle. The ultrasonic sensor emits short ultrasonic pulses. The ultrasonic waves are reflected by obstacles and the echo signals are received and processed. Unlike lidar, ultrasonic sensors can be used in poor weather conditions (including fog) and in low-light conditions at night.

Ultrasonic sensors are able to see through objects (this is not the case with lidar). Some newer versions have resolutions and object detection capabilities comparable to lidar. The ultrasonic sensor is relatively cheap, i.e., inexpensive. However, the ultrasonic sensor does not have the resolution to detect small objects or multiple objects moving at high speed. Compared to lidar, it has a smaller field of view and lower accuracy. The ultrasonic sensor cannot detect colors.

1.4.4 Video, thermal and far infra-red cameras

Video cameras are sensors that continuously record the view in front of the car. The cameras can automatically send images and videos to the screen. To get good video quality, the resolution of the camera must be high.

Thermal imaging cameras passively collect heat signatures from nearby objects and convert them into video signals. Computer vision algorithms detect and classify the objects.

Nowadays, far infrared cameras (FIR) are used (Thakur, 2018). These sensors provide reliable and accurate detection in real time and in all environmental conditions. While radar and lidar sensors transmit and receive signals, a FIR camera collects them by detecting the thermal energy emitted by objects. FIR Cameras achieve better detection than other sensors because the infrared wavelength is much longer than that of visible light. Unlike other detection options, thermal sensors do not require light to accurately detect, segment, and classify objects and pedestrians. They provide complete coverage of the road and its surroundings in all weather conditions. FIR can detect a car's surroundings without interfering with other vehicles' sensors, i.e., without interference. In contrast, lidar and radar devices installed on one vehicle can interfere and affect another passing vehicle

1.5 Navigation system

Vision systems for automated land vehicle navigation have been studied since 1988 (Turk et al., 1988) and need to be improved in the future. GPS odometry and inertial measurement devices are advanced control systems that interpret sensory information and detect appropriate navigation paths as well as obstacles and relevant signage (Balic et al., 2012).

1.5.1 Global Positioning System (GPS),

One of the global navigation satellite systems (GNSS) is called the Global Positioning System (GPS). This is a satellite-based radio navigation system that provides geo and time information to a receiver GPS at any location on or near the earth. The receiver GPS calculates its own position and time based on data received from several GPS satellites. Each satellite carries an accurate record of its position and time and transmits this data to the receiver. In this way, the time and three position coordinates of the receiver are calculated from the data of four or more GPS satellites whose locations are known with great accuracy. Since the speed of the radio waves is constant and independent of the satellite speed, the time delay between the transmission of the signals from the satellite and their reception by the receiver is proportional to the distance between the satellite and the receiver. Using this relation the obtained time and space data are accurately calculated. GPS gives the positioning information for all users at any time. The GPS operation is independent of any reception (internet, telephone, etc.) and need not a user to transmit any data. However, GPS fails if the line of sight is obstructed. Obstacles such as mountains, buildings, tunnels, etc. block the signals or give relatively weak GPS signals.

1.5.2 Inertial Measurement Unit – IMU

To overcome the environmental problem of navigation with GPS, the Inertial Measurement Unit (IMU) was developed for global positioning. IMU is a type of microelectromechanical system (MEMS). The unit determines the acceleration, heading angle, and relative position of the vehicle. The device is a combination of an accelerometer, a gyroscope, and a magnetometer. The accelerometer measures acceleration in three directions and provides the specific force information. The gyroscope gives the rate of rotation with three independent angles in space. The magnetometer is used as a direction reference and gives the orientation of the body. The website IMU relies on the principles of gravity and inertia instead of the external environment and provides a constant and complementary data source for the autonomous precision navigation system.

The IMU is used in algorithms that can compare position and location and then assign certainty to the overall location estimate.

Recently, GPS has been produced with IMU devices enabled. The GPS receiver allows IMU to function even when GPS signals are not available due to obstacles or when electronic interference is present

1.5.3 Complex positioning system

Data from navigation are not sufficient for complex positioning of SDC. Additional data from the so-called 'vehicle-to-everything connection' (other vehicles, pedestrians, infrastructure, etc.) is required.

1.5.3.1 Vehicle-to-everything connection (V2X)

As mentioned earlier, the SDC is equipped with an external and internal sensor network system for sensing the environment. The data is used to determine the positioning of the vehicle in space and time. For navigation, local and global route plans are created and there is a certain system in the SDC that performs navigation operations. The drive is usually controlled internally, but the system has the ability to calculate and apply control measures to obtain the local trajectory and target states of the vehicle. For control purposes, the vehicle communicates with other vehicles, traffic management infrastructure, etc. However, the SDC must also communicate with manufacturers, fleet operators, services, etc. This is possible by connecting the vehicle to other systems via the Internet or wireless networks to establish what is known as vehicle-to-anything (V2X) communication, i.e., connecting to other objects in the environment and road infrastructure (Gwak et al., 2019). In addition, it is noted that the IoT supports the integration of communication into vehicle systems. The data obtained enables navigation, accident avoidance and notification, traffic alerts, as well as monitoring the wear and tear of vehicle parts, etc. (Jones et al, 2019). with manufacturers, fleet operators, services, etc. This is possible by connecting the vehicle to other systems via the Internet or wireless networks to establish so-called vehicle-to-anything (V2X) communication, i.e., connection with other objects in the environment and road infrastructure (Gwak et al., 2019). In addition, it is noted that the IoT supports the integration of communication into vehicle systems. The data obtained enables navigation, accident avoidance and notification, traffic alerts, and monitoring of wear and tear of vehicle parts, etc. (Jones et al., 2019). Hardware and various 'connected vehicle' software programs implemented in SDC can also be used to predict the position, movement of the autonomous vehicle as a moving object on the ground, etc. The prediction is short term and requires network connectivity to various objects. Automatic connectivity involves the use of computer vision, localization, and intelligent communication techniques.

The following types of V2X are already installed in SDC:

vehicle to vehicle communication (V2V) – very often is the WiFi connection,

vehicle to infrastructure communication (V2I) – traffic infrastructure, road signs, lane marking, traffic lights,

vehicle to networks communication (V2N) - using mobiles, tablets, navigation systems

vehicle to grids communication (V2G) – uses and produces electrical energy stored in car batteries by communication with electricity grids

vehicle to pedestrian communications (V2P) – using wireless smart-phones

vehicle to device communication (V2D) – all other communications

The first two connections mentioned in the list are the connection of the vehicle with another vehicle (the so-called vehicle-to-vehicle V2V) and the connection with infrastructures (the so-called vehicle-to-Internet V2I communication). In such communication, the position, speed, and other information of the vehicles can be seen, and the vehicles receive information about road conditions, traffic lights, etc. All vehicles can act to avoid accidents and improve driving efficiency. Dynamic interaction between these components enables inter- and intra-vehicle communication, intelligent traffic control, smart parking, electronic toll collection, logistics and fleet management, vehicle control, safety, and roadside assistance. Individual vehicles can benefit from information received from other vehicles in the vicinity, especially information about traffic congestion and safety hazards. Vehicle communication systems use vehicles and roadside units as communication points in a peer-to-peer network that provide each other with information. As a cooperative approach, vehicle communication systems can help all cooperating vehicles become more efficient. According to a 2010 study by the U.S. National Highway Traffic Safety Administration, vehicle communication systems could prevent up to 79% of all traffic accidents.

Despite the fundamental importance of the connection, it is not easy to implement. This is because manufacturers have developed different hardware and software platforms, and at the moment cooperation between them is impossible. In addition, there is no full peer-to-peer networking for transportation, so each individual SDC would have to connect with potentially hundreds of different vehicles that could be traveling in and out of the area. Vehicle networking might also be desirable because it is difficult for computer vision to detect brake lights, turn signals, busses, and the like.

To solve this problem, it is proposed to design intelligent intersections for SDC. The intersections would not have traffic lights and stop signs, but would use computer programs that would communicate directly with every car on the road.

1.6 Internal control systems of the vehicle

Advanced control systems interpret sensory information to identify appropriate navigation paths and objects in traffic. The control system "learns" to navigate and monitor the situation, plan sensor sampling, and implement coupled cyber-physical control. Based on these values, the optimization of the trajectory and task planning are carried out. It includes physical trajectory optimization, computer system (cyber) optimization, and joint optimization (Bradley & Atkins, 2015).

1.7 Programming and decision making system

One of the most important parts of SDC to be autonomous is the decision-making system (Russell & Norving, 2010). Indeed, the SDC requires not only image recognition systems, but also machine learning algorithms and neural networks to develop systems that can autonomously control the SDC. To accomplish this task, SDC has a complex "machine learning" architecture that consists of many computational stages or layers that form a network (Zhu et al., 2014). The neurons of the network are simulated by environmental data extracted from real driving scenarios. The neural network in SDC "learns" how to perform the best action (Schmidhuber, 2015). Machine learning algorithms applied in SDC are a data-driven form of artificial intelligence (AI) and are considered a 'major catalyst for recent advances in driverless car performance and safety' (Madrigal, 2014). Roughly speaking, the performance and safety aspects of SDC depend directly on the decisions made by the AI programmer. The AI programmer indirectly instructs the SDC how to behave in the event of an unavoidable accident, such as whether the SDC should crash into a bus, potentially killing the occupants, or swerve, potentially killing its own passengers or nearby pedestrians. Cents on its own without precisely programming whether an action is ethical. However, this approach also has its limitations. For example, many human actions are performed out of self-preservation instinct, which is realistic but not ethical. Human drivers make various decisions when driving to avoid harm to themselves or to put themselves in danger to protect others. The routine decision is to keep traffic flowing, but it can lead to accidents and stress. Human thinking and reaction time are sometimes too slow to recognize the risk of an impending fatal accident, think through the ethical implications of the available options, or take an action to implement an ethical decision. It is extremely difficult to predict and judge whether the recognition of impending risk, the analysis of options, or the choice of a 'good' option among the bad options of an SDC, such as a particular automated vehicle, is as good or better than that of a particular human. This difficulty may be due in part to the fact that the automated vehicle system's understanding of the ethical issues involved in a given traffic scenario, perceived for a moment from a continuous stream of synthetic physical predictions of the near future and dependent on layers of pattern recognition and situational intelligence, may be opaque to human inspection because it is based on probabilistic machine learning rather than a simple logic of rules according to "human values." To include the human aspect in the control, navigation and tracking of SDC, the fuzzy logic programming system can be applied (Kumar et al, 2017). Petrovic et al (2013) suggested the application of Russian Theory of Inventive Problem Solving (TRIZ) and Multiagent System (MAS) for the preparation of the software to integrate process planning, scheduling and SDC navigation. These methods are beneficial but seem to be very complex. It is worth mentioning that for algorithmic decision making in SDCs, it is very important to understand the ethical and technical concerns for smart cities as well (Lim& Taeihagh, 2019).

1.7.1 Ethical and moral impacts in AI

Legal liability and moral responsibility aside, there is the question of how SDC should be programmed to behave in an emergency situation where either passengers or other road users such as pedestrians, cyclists, and other drivers are at risk (Goodall, 2016; Maxmen, 2018). Two main considerations come into play when programming software for safety: ethical and moral. To the challenge of determining machine ethics, it must be added that morality is not a universal category.

The well-known moral dilemma in SDC's operational system, known as the 'trolley problem," is: what is the 'right action' in situations where SDC can avoid hitting another car or pedestrian when doing so threatens serious injury to the occupants? Namely, should the individual prevent a driverless car from crashing into a group of people, causing the certain death of another person? In this context, the following question is: How should SDC's operating system be directed to perform actions that may protect one party at the expense of another (Greenmeier, 2016)?

1. A considerable number of studies address variation in this question. One study found that participants favor designs in which SDC occupants are sacrificed to save others, although they would prefer not to ride in such vehicles and therefore would be less willing to purchase one. However, Hars (2016) suggests that SDC should not be measured by the number of fatalities and accidents, but a new measure based on successful solutions to safety-critical situations. There is a moral dilemma that a software engineer or car manufacturer might face in programming the operating software (Awad *et al*, 2018):
2. On what moral basis would an automated vehicle make decisions?
3. How could those moral aspects be translated into software code?

In addition, they have to be aware of the following three priority sequences:

1. Do not hit pedestrians,
2. Do not hit other vehicles,
3. Do not hit objects.

The decision software is tested on some "thought experiments". They concern the case when an SDC accident cannot be avoided and several solutions of the problem exist. In practice, the researchers propose the application of one of the following two ethical theories for decision making in the behavior of automated vehicles in emergencies. These are:

1. Deontology and
2. Utilitarianism

Deontological ethics is the typical example of Asimov's 'Three Laws of Robotics' (Asimov, 1984). The theory states that an automated car must follow strict, written rules prescribed for each situation:

1. SDC ‘may not injure human being or through inaction allow a human being come to harm’;

2. SDC ‘must obey the orders given it by human beings except where such orders would conflict with the First Law’;

3. SDC ‘must protect its own existence as long as such protection does not conflict with the First or Second Law’ (Asimov, 1984).

The most impressive result of testing with this ethical principle is that an extremely high number of solutions exist and the automated vehicle must choose between several harmful courses of action (Himmelreich, 2018; Skulmowski et al, 2014). To overcome this weakness of the principle, utilitarianism is introduced. Utilitarianism suggests the idea that every decision must be made based on the goal of maximizing utility. This requires a definition of utility, which could be the maximization of the number of people surviving in an accident. However, the solution thus recommended is far from adequate for practical use. The result has serious shortcomings.

1. Critics suggest that automated vehicles should apply a mix of several ethical theories (Sparrow & Howard, 2017) in order to respond in a morally correct manner in the event of an accident. The ethics for AI of automated vehicles need to be articulated and controversies eliminated. The decision-making software with the two main ethical principles needs to be extended with some additional ones. These are for example,
2. Ethical egoism,
3. Virtue ethics
4. Principle of moral machine.

In this case, the basis for decision-making requires some additional data. Namely, the software needs a set of technical data and some additional parameters of human character (Mordue et al, 2020). Therefore, the AI should take more into account the variability, contextuality, complexity, and non-deterministic nature of human ethics, etc. To make an appropriate decision, the number of people in the car, the age of the passengers, the mortality per age, whether the passengers are parents, etc. need to be known. The proposed ethical principles are tested with the above additional data. It is concluded that all the principles lead to different results and none of them is recommended for application in practice due to its shortcomings.

It is important to emphasize that each situation SDC faces raises its own ethical issues. Moral choice is not universal. Awad (2017) from the Massachusetts Institute of Technology (MIT) developed a platform called Moral Machine and generated random scenarios in which SDCs malfunction and the user is forced to choose between two harmful courses of action. To determine people's moral preferences, the Moral Machine collected more than 40 million solutions from people in 233 countries. "The study MIT illuminates that ethical preferences vary across cultures and demographics and likely correlate with modern institutions and geographic characteristics" (Awad, et al, 2018). This conclusion imposes a serious constraint on the choice of ethical principles used for AI decision-making systems. Global trends from the MIT on Moral Machine study show that, overall, people prefer to save the lives of humans rather than other animals, prefer the lives of the many rather than the few, and prefer to spare the lives of the young rather than the old. Men are slightly more likely to spare the lives of women, and religious organizations are slightly more likely to prioritize human life.

AI decision programs need to solve some common driving problems in the shortest possible time. In addition to ethical decisions, risk calculations must be performed to determine the exact time in milliseconds that the car should swerve to overcome the problem (e.g., how to behave at a yellow light or how close to approach a bike lane). Such everyday ethical situations may be even more relevant to software development than rare fatal situations because they are very specific and far-reaching. Everyday situations involving motorists and pedestrians are so common that they add up to a large number of injuries and fatalities. Questions remain about the ethical dimension of SDC and the machine in general: "What does it mean to give the machine an ethical dimension? Is there a single correct ethical theory that we should try to implement? Should we expect to tell the machine how to behave in every ethical dilemma it might face? Is it necessary to determine the moral status of the machine itself if it is to follow ethical principles?" (Anderson, 2007). The questions still remains open.

The conclusion is that feeding ethical data into the computer cannot guarantee that the computer will capture the ideal behavior. Moreover, the data fed to an artificial intelligence must be carefully selected to avoid undesirable results. The depth of understanding, predictive power, and ethical sophistication required are difficult to implement and even more difficult to test or evaluate.

Nowadays, a Bayesian AI-based driver algorithm (Korb & Nicholson, 2011) is proposed for application. The algorithm is based on the definition of safety and ride quality requirements that a fully automated vehicle should meet when driving in a mixed traffic environment with vehicles of different automation levels. Khan (2013) describes advances in design that may overcome the safety and ride quality issues. Data from driving simulator studies are used as the basis for programming. After testing, it is concluded that the Bayesian AI-based driving algorithm provides safe driving and meets the driving quality criteria while operating in a driving environment characterized by uncertainty (Khan, 2019). However, the Bayesian AI-based driver can only be proposed to improve consumer and safety control and not as an autonomous driver.

However, the ethical question that already arises is: how would AV react if the situation that occurs is not programmed in the system? How can it be programmed to respond to certain impossible choices?

1.7.2 New programming challenges

The new step in AI programming must be for SDC to also understand verbal sounds, gestures, and nonverbal cues from police, other drivers, or pedestrians. This is an additional difficulty that needs to be integrated into the decision-making software as soon as possible.

The main problem with AI is that it can give SDC unexpected behavior. Since machine learning in SDC is based on repeated driving or learning experiences, the car is expected to behave in the same way. However, this is not the case. It is difficult to answer the question of why the car behaves in a certain way in a new situation (Hars, 2016). Here, the programmers are challenged to solve the problem. One of the explanations could be that the 'structure' of neural networks is nonlinear. Although the system is deterministic, i.e., if the input values are the same, the output is identical, small changes in the input can lead to large changes in the output due to the nonlinearity. This effect is known as the 'butterfly effect." In addition, the solutions obtained in the neural network branch, i.e., the number of solutions for the same values varies from 1 to n, depending on the characteristics of the system. Therefore, the initial values can be very different and unexpected. This property of neural networks and AI seems to be the most problematic and needs further investigation.

1.8 Principles of automation and digitalization in SDC

As mentioned above, it is necessary to increase and improve automation in the car. During the third industrial revolution, a high level of automation was achieved. However, it is expected to be improved in the future according to Strategy 4. For automation in SDC, the adaptation of the principles of Strategy 4 is proposed: the principle of reliability, guidance, robustness, accountability and competence, the principles of visibility, observation and comprehensibility, proactive control and degradation of capabilities. It is assumed that the application of these principles will improve the level of automation of vehicles. Automation principles are about finding efficient computerized ways to perform human tasks (Beck et al., 2007). It is expected that such automation, based on the aforementioned principles, would lead to increased trust in SDC. In addition, automation in autonomous vehicles must be extremely safe and controllable by a person or team of specialists in the field (Parasuraman et al., 2000).

1.8.1 Principles of automation in SDC

Many researchers are engaged in road vehicle automation and there are a large number of publications on this topic (see Meyer & Beker, 2014; 2015; 2016; 2018; 20191; 20192; 2020). DAS and ADAS systems are introduced and developed for SDC based on the principle of reliability to meet the consistency in the repetitive functions. To develop confidence in automation and SCD, automation must be competent and functionally correct with reduced weaknesses (Parasuraman & Riley, 1997). Depending on the input, the automation should perform tasks correctly. If the automation behaves as intended but the result is not desired, the automation should be classified as incompetent.

In machine automation, all information relevant to a particular situation must be visible to the operator and the owner of the SDC. Therefore, it is necessary to be informed about the status of the SDC. The state of the object must be visible on the computer at any moment of the real time. Visibility can be considered as supporting the first level of situational awareness. It is recommended that operators, i.e., specific individuals on the SDC team, must always have basic information about the system parameters being monitored, provided in a clear and easy-to-interpret format. In this way, operators remain involved and knowledgeable about the system. SDC should provide effective and immediate feedback to the operator that allows them to track the health of the system.

Visibility refers to providing information about the system being controlled, while observability refers to providing information about automation decisions and actions. Observability provides the ability to provide feedback. When observability is limited, the understanding of the automation is often incorrect and may limit the use of the automation (Norman, 1990).

The results obtained by machine automation must be understandable to the operators and the members of the teams. The principle is more efficient for the people whose knowledge of the automation process is higher. The principle of understanding is the basis for developing innate automation and predicting future actions of automation. It is expected that good understanding and high visibility will support better automation development

Fulfilling the principle of control enables efficient and simple control of SDC automation. Users direct the automation to achieve goals. Without the ability to influence and direct automation, the recommendations for observable and understandable automation are useless because the operator is essentially powerless.

The automation must be robust, i.e., stable under normal but also unusual operating conditions. That is, automation must be valid even in irregular and non-routine work systems. Thus, automation works for all levels of workload (Miller & Parasuraman, 2007).

Automation in SDC must be the result of responsible and accountable activity. The dilemma arises as to how to remove the human from control. Humans can be completely removed from the control loop, usually in areas that have very specific data and characteristics. However, computers cannot be expected to be responsible beings, and therefore the operator must be given the ability to control the system. The principle of proactive control in automation technology states that control is proactive, not reactive. This means that changing system parameters and understanding their effects enables proactive optimization of system performance, with the goal of avoiding future problems. By ensuring that automation is predictable, proactive control can be enabled in SDC systems. Automation should include a method to protect against operator skill degradation. Capability degradation is undesirable in automation. It occurs when automation reaches its limits and becomes inadequate (Hoc, 2000). It is expected that as automation increases, skill degradation will be eliminated. To meet this requirement, automated systems must have additional skills.

1.8.2 Principles of digitalization in SDC

An important area of digital technology that promises a number of benefits for individuals, society, and the economy in the transportation sector is connected and automated transportation (CAT). In 2017, a CAT Roadmap for Europe was developed for the different transport modes under the Strategic Research and Innovation Agenda for Transport (STRIA), including SDC transport. It was the result of a European Commission initiative (European Commission, 2019) to jointly develop a research and innovation roadmap for CAT involving EU Member State representatives and stakeholders from industry, academia, and government. The roadmap was revised in 2019 in line with SDC's new innovative strategy and technology as autonomous vehicles. This is because SDC digital technology has certain characteristics that distinguish it from other technologies and vehicles and must be integrated with existing technology. Because of the digital characteristics, SDCs are able to transform more and respond flexibly to potential changes. The digital characteristics of SDCs that need to be unified with other digital systems are based on the following themes: Homogenization and decoupling, connectivity, reprogrammable and intelligent, digital traces, and modularity.

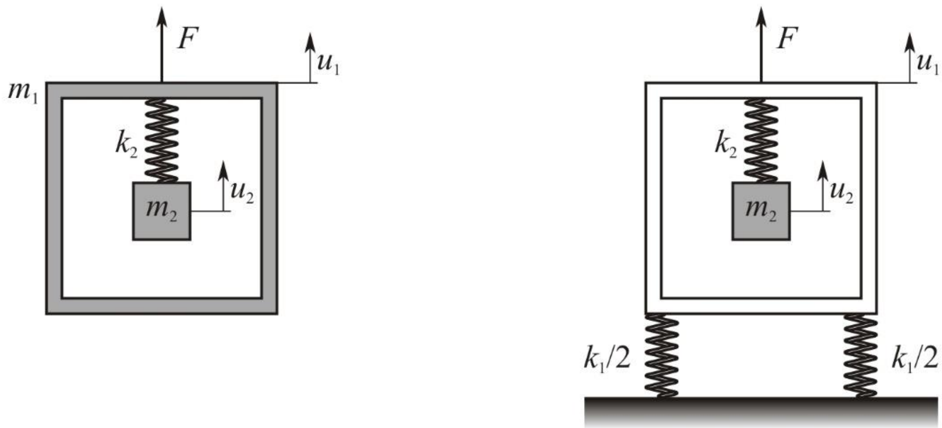
Homogenization results from the fact that all digital information has the same form (standards have been developed for how and in what format digital information is stored). In order for SDC to perceive its environment, it uses various techniques, each of which has its own digital information (e.g., radar, lidar, GPS, motion sensors, computer vision). Because of homogenization, the digital information from these different techniques must be in the same form, which means that their differences can be decoupled and the digital information can be transmitted, stored, and computed in a way that the vehicles and their operating system can better understand and respond to.

Because SDCs are equipped with various types of sensors, they can connect and interact with computers of other autonomous vehicles and/or roadside units. This means that autonomous vehicles leave digital traces when they connect or interact. The data that comes from these digital traces can be used to update the driving capabilities or safety of the SDC.

As mentioned earlier, it is important for SDCs to be connected to other equipment in order to operate effectively. SDCs are equipped with communication systems that allow them to communicate with other autonomous vehicles and roadside units to inform them of road work or traffic congestion, among other things. In addition, scientists anticipate that in the future there will be computer programs that link and control the individual autonomous vehicles as they navigate through an intersection. This type of networking would replace traffic lights and stop signs. The intent is that the SDC network would use the same network and the information available on that network. The advantage of the SDC is that it can be reprogrammed and the software can be updated to increase a particular benefit. The update may not be done only by the supplier. Machine learning allows intelligent autonomous vehicles to generate certain updates and install them accordingly (e.g., new navigation maps or new intersection computer systems). These reprogrammable features of digital technology and the possibility of intelligent machine learning give SDCs the ability to differentiate themselves in software. This also means that autonomous vehicles are never finished, as the product can be constantly improved. Digitization of infrastructure is also expected in the near future. There has been much discussion about whether to keep the existing infrastructure or implement a more digitized SDC-tailored infrastructure. Previously, SDCs had to be developed to understand human signs and use current road signs, lights, and markings to navigate the roads, but the transition from conventional to digital infrastructure must be prepared. The transition of infrastructure from conventional to digital will be one of the most complex and expensive processes.

1.9 Challenges in vibration suppression in SDC

Recently, intensive research has been conducted on SDC as a comfortable and safe vehicle for passenger travel. One of the factors that must be eliminated in SDC is vibration. A comfortable and safe ride requires a low vibration level. Vibrations in SDC are mainly caused by movement on uneven roads, but also by the rotation of mechanical parts of the vehicle (engine, wheels, etc.).



a) b)

Figure 1.1 Metastructure's unit: a) mass-in-mass (Cveticanin et al, 2022_2), b) mass-in-stiff (Cveticanin et al, 2022_5)

These sources cannot be eliminated, but the suppression of vibrations in the vehicle is necessary. Vibrations in SDC are a negative phenomenon, as they cause the loss of useful energy of the system and wear of machine parts, lead to inaccuracies in the operation of sensors, measuring devices, etc., and also affect passengers in the vehicle. Vibrations interfere with the working, reading, writing, sleeping, telephoning, resting, etc. of the people in the vehicle. In this dissertation, the problem of vibration suppression is studied. The new type of structure called mechanical metastructure is considered theoretically with the aim of absorbing or isolating vibration. Two types of metastructures are designed: one with mass-in-mass unity (Cveticanin et al, 2022_2) and the second with mass-in-stiff-structure unity (Cveticanin et al, 2022_5). Both metastructures have in common that they have periodic structures, but the first one is suitable to absorb vibrations in certain frequency ranges (including low ones), while the second one is a vibration isolator.

The metastructural layer for vibration damping is assumed to have a honeycomb base structure with additional masses in the cavities (Fig. 1.1a), while for vibration isolation the base structure is rigid with a small mass added (Fig. 1.1b).

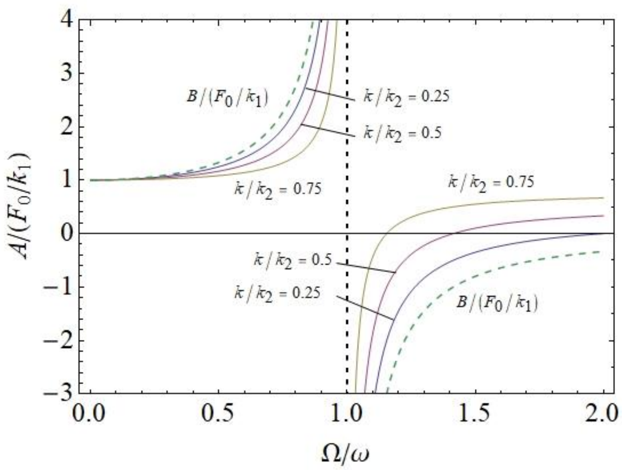


Figure 1.2 Amplitude A – frequency (Ω/ω) diagrams for various values of k/k_2 (full line) and boundary amplitude B (dotted line) (Cveticanin et al, 2022[5]).

In both units of the metastructures, the added mass m_2 with spring k_2 is connected to the basic structure with mass m1 or with stiffness k_1. The source of excitation is the force F, which is periodic (F_0 is the amplitude and Ω is the frequency). The force causes the unit to vibrate (deflection u_1), which is solid (e.g., a vehicle seat) or rigid (a micro-electro-mechanical system). The main component of the metastructure are the added mass-spring systems, which are oscillators with certain mechanical properties. Their task is to absorb the oscillation energy of the basic structure. The transferred vibrational energy causes the additional mass to vibrate (with displacement u_2), and the motion of the basic structure comes to a halt (u_1=0) or has a low level (u_1≈0). In Fig.1.2, the vibration amplitude A of the fundamental structure is plotted as a function of the frequency ratio Ω/ω (excitation frequency of the force). It can be seen that in the regions under resonance $\Omega/\omega < 1$ the amplitude of vibration is small after the action of the absorber. On the other hand, in a certain frequency range above resonance ($\Omega/\omega > 1$), the vibration amplitude is even zero. At a high excitation frequency, when $\Omega/\omega >> 1$, the vibration amplitude is small (see Fig.1.3).

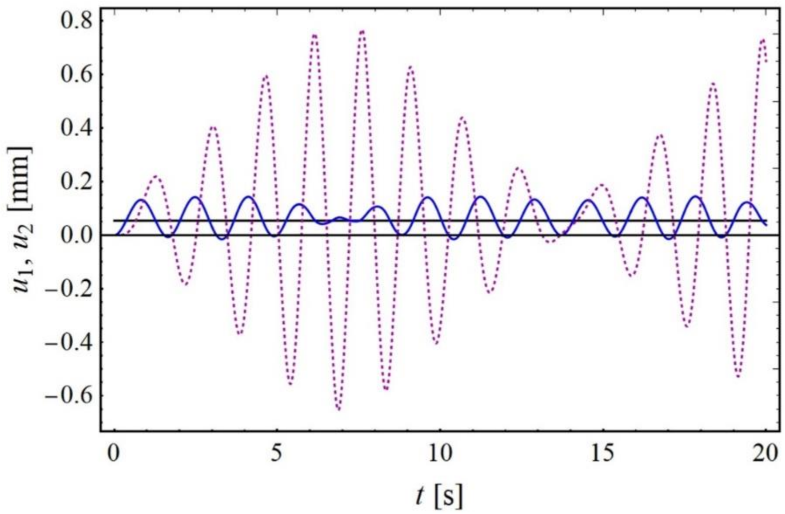


Figure 1.3. u_1-t diagram (full line) and u_2-t diagram (dot line) (Cveticanin et al, 2022_2).

The question was if the vibration energy is the waste one, or it can be transformed and applied. In the dissertation it is shown that by using the energy harvesting system (Fig.1.4), the absorbed energy of motion of metastructure can be transformed into electric one, which is appropriate for energy supply in sensors and other micro-electro-mechanical systems in the SDC.

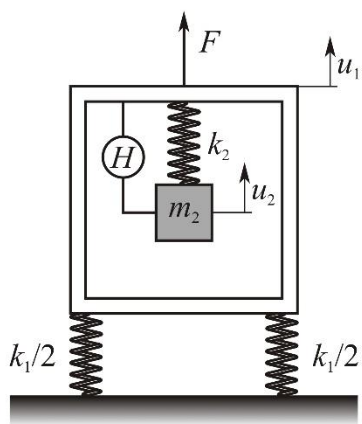


Figure 1.4 Mass-in-stiff unit with energy harvester H (Cveticanin et al, 2022_2).

The special case of powering of a LiDAR by energy harvester is tested. The efficiency of the system is proved (Cveticanin et al, 2022_2).

Remark: Mathematical consideration of metastructures are published in papers (Cveticanin et al, 2022_2) and (Cveticanin et al, 2022_5).

1.10 Conclusions

Based on the research given in this Chapter the following is concluded:

1. The hypothesis about SDC as a kind of CPS is proved as all of features of SDC correspond to those which are expected for the CPS. SDC is a digital technology coupled with real physical construction. SDC is an autonomous vehicle of modular type where all the activities: perception, navigation, controlling, decision making and driving are done automatically by the active coupled action of various networks and physical systems and processes within the systems.
2. The consequence of layered modular architecture of SDC is that it enables the emergence and development of platforms and ecosystems around the vehicle and certain modules. Conventional cars were developed, manufactured and maintained by traditional manufacturers as a final product without possibility to be modified. Nowadays application developers and content creators can help to develop more comprehensive product experience for the consumers which creates a platform around the product of autonomous vehicles and to modify the already existing SDC.
3. SDC technically achieved very high level due to new technologies and automation. However, some challenges remain. Further investigation in ADAS are necessary and enlarging of the interval of their activity. At the other side, it is expected that the ADAS would act on the human voice or according the human gesticulation and not only on inputs obtained from sensor outputs and computer information.
4. At the moment, in the most of SDC a huge number of sensors are installed physically on the vehicle. Most people recognize the SDC based on the whirling sensor perched on the roof. However, it is sure that some improvement has to be made, not only in sensors (to eliminating their fail), but also in the design of the car. Instead of the set of sensors it has to be made only one which would do the job.
5. New sensors in perception and navigation systems have to be designed which would minimize and even eliminate the sensitivity to different types of weather (such as heavy rain, fog, ice, snow) or deliberate interference, including spoofing and jamming on their operation.

6. Sensors need to improve their vision ability for better recognition and differentiation of objects and vehicles. It is the requirement for all robot systems at the moment.
7. To support the automation of car the AI has to be extended (Shekhar, 2019). Science and engineering have to make SDC to be more intelligent machine which would imitate human behavior and intelligence much better. The ideal scenario would be the automated machines to collect data and AI systems to understand, optimize and deliver the final decision to physical part or to process. Unfortunately, we are not AI ready yet. Nowadays the stage is cognitive automation which includes identifying of processes.
8. The AI of the SDCs have to be improved and developed to able the vehicle system to be the total CPS, which would drive on roads that they have never been on before, without using 3D maps. At the moment, the system combines the GPS and IMU position of the vehicle, a 'sparse topological map' such as digital road maps and a series of sensors that observe the road conditions. SDCs require very high-quality specialized maps to operate properly.
9. Current road infrastructure need changes for SDCs to function optimally. The digitalization between SDC and infrastructure has to be harmonized and unified.
10. Technical troubles in SDC motion can occur if the car's computer or the communication system between the cars and other objects (vehicle, infrastructure, etc.) is compromised. AI is still not able to function properly in chaotic inner-city environments, too.

2. PRO AND CONTRA FOR SDC

As it is shown in the previous Chapter, the SDC as a CPS is technically almost prepared for testing and application on public roads. However, inclusion of SDC in the everyday transportation seems to be very complex. Namely, the SDC has to be accepted by the users. The hypothesis of this Chapter is given in the form of a dilemma: Are people really ready for autonomous vehicles? To obtain the knowledge the population is worldwide questioned about the opinion on SDC. In the Chapter the results of scholars' investigation on benefits and barriers for SDC application are presented. The aim of this Chapter is to give a strong conclusion about pro and contra for SDC based on comparison of the subjective opinion of population and the objectives given by researchers and technicians.

Scholars say that SDCs have many advantages over conventional human-driven cars in terms of safety, comfort, convenience, energy efficiency, etc. (Litman, 2021). However, the implementation of these vehicles will not be successful if users do not accept them and do not use them for transportation people.

Introduction of SDC in the public transport is expected to be a very heavy task. Namely, although the automatizing and also decision and control system (artificial intelligence) of the vehicle seem to be technically solved, it is the fear that people will not be oriented toward application in the short time because they are afraid that SDC would change their future life style, as it is stated already by scholars (Myrick *et al*, 2019). The SDC would be a kind of taxi without driver. It remains unclear how to deal with the new challenges. Significant number of opportunities and barriers of various kinds for SDCs are expected which would occur and it requires policy recommendations and supports in all countries of the world (Anderson *et al*, 2016). It is certain that the preparation of the nation for autonomous vehicles is necessary (Fagnant & Kockelman, 2015).

The motivation for producing SDCs is significant. Due to Qu *et al* (2019) benefits of SDC would be: higher road safety, decrease of number of road accidents and traffic congestions, less traffic jams, improved mobility in overcrowded cities, shorter travel times, lower insurance rates, better time use (during riding to do other things), driving even if the person is under medicaments or impaired or drunk, transport for older and disabled people, less fuel consumption, lower vehicle emission, etc. The convenience of SDC is in economics, social, technics and environment.

However, disadvantage of SDC is also expected: the privacy would be disturbed, loss of pleasure of manual driving would be loosen, addition learning of the driver to operate on SDC would be necessary, but also and job loss of driver would occur.

Due to new types of cars it is expected that the traditional automobile industry would change due to new technology and novel market requirements. The changes and adaptation of the automotive industry would be done in a short time. Already some producers made some transmission from the traditional to new types of cars. However, at the moment the industry is confronted to the market uncertainty due to some unanswered questions. One of them is, whether the number of private owners of SDCs would decrease or not, and the second, whether the new transportation technology would be accepted by passengers.

In this Chapter the public result of opinion survey is published. The method of questionnaire is applied in some countries of Europa and USA but also in Serbia. The obtained results are classified as the subjective estimation about SDC. It is concluded that the part of population is against automation independently on its type, while other is supporting the ideal of automation in general (Pagallo & Durante, 2016). To improve the belief of population in the forthcoming era of CPS, all aspects of automation have to be highlighted and discussed in proper manner including the explanation of benefits of SDCs and also their lack.

The aim of this Chapter is to prove the population that it is necessary to accept SDC for future prosperity of civilization. The opinion of most of population has to be changed from contra to pro for SDC as it is expected that it will give some benefits in human lives. However, to predict future is uncertain, but uncertainty is a natural element of planning and forecasting.

2.1 Facilitators and barriers for SDC

As it can be seen, SDC is a complex system where is not enough to analyze its technical properties. The problem of SDCs has to be studied more widely including various aspects. Taiebat *et al*. (2018) added to technical also the energy consumption, environmental and sustainability implications to SDCs. Ryan (2020) found that the list of aspects is much wider and mentioned the following ones:

- 1.Ethics
- 2.Environmental aspect

- 3.Social aspect
- 4.Economics (including market, and also efficiency and productivity)
- 5. Safety and security aspects
- 6. Legal and political aspects

Ryan (2020) concluded that in almost all aspects there are advantages and also disadvantages. Which is the more important aspect has to be decided after considering all the relevant facts. The aim of this section is to investigate all the aforementioned aspects and to overcome the dilemma of importance offering some suggestion.

2.1.1 Ethical aspects and barriers

The ethical aspects in SDCs are already discussed in the view of making decision system using the benefits of AI. In that Chapter the most strictly attention was related to ethical solution in the case of SDC accident. It is found that the ethical impacts in relation with SDC are connected with autonomy and privacy of the passenger, responsibility and rights in driving and in the case of accident, safety and prevention of harm (Hevelke & Nida-Rumelen, 2015). From ethical aspect the following question are generated: Is the privacy of the person using SDC damaged? Who is the responsible in the accident with SDC? What are the rights of producer, owner and user? What is with insurance? What is with safety and prevention of harm in SDC?

Namely, as it is already said, the AI of SDCs is usually programmed with utilitarian principle as it is proved that it minimizes driving casualties and generate the least harm. Unfortunately, it does not mean that the maximal attention is oriented toward passengers in the SDC. People would like to prevent themselves inside the vehicle at all costs. This presents a paradox in which people prefer that others drive utilitarian vehicles but they want to ride car with priority in passenger safety and lives protection. In other words, there is the double moral of the people which cannot be incorporated into the machine.

Bonnefon *et al*. (2016) concluded that the prescription of any ethical principle by authorities may be counterproductive to societal safety. This is because, if the government mandates utilitarian ethics and people prefer to ride in safe protected cars, the large scale implementation of the SDCs would be prevented. However, the SDC technology is projected to save many lives and are adopted to vitiate the safety of society as a whole.

2.1.2 Environmental aspects and barriers

One of the biggest polluters of the environment are land vehicles that use diesel fuel and gasoline as fuel. The problem of air pollution caused by the combustion of fuel in the engine is being addressed by a large number of researchers. A number of measures have been proposed and introduced through laws regulating permitted pollution for vehicles. Modern tendency in the production of new SDC, as an autonomous vehicle, is believed to alleviate and contribute to air pollution problems. It is expected that SDC technology would decrease the energy use in engines and decrease the pollution or would use another type of power which is not the pollutant.

Liu *et al* (2019a) stated that the uncertainty about the environmental pollution caused with SDC depends on the following factors:

1. Type of the driving fuel
2. Consumption of fuel to specific weight of SDC
3. Driving style
4. Distance-fuel consumption

Due to improvement in automation of SDC with convention engines, progress in fuel consumption is expected. For minimizing the pollution and improving the fuel economy in SDC driven with convention fuel the drive cycle has to be optimized.

The car has to move at the constant speed controlled with the automatic ADAS system. SDC stops and slows down less and the velocity of motion is almost constant. For automated car acceleration and deceleration would be much smoother than that done by the human driver. SDCs would be able to accelerate and brake more efficiently, meaning higher fuel economy from reducing wasted energy typically associated with inefficient changes to speed. It would decrease the fuel consumption for 4-10 percent and the carbon emission, too.

For SDC it is expected that the number of crashes would be smaller than in the case of manually driven cars. It allows the weight of the vehicle to be decreased. The lighter is the vehicle, the fuel consumption is smaller. The emission of CO_2 is also decreased.

Light SDCs may be efficiently driven with electric current. The electrically powered SDC would not pollute the air directly, but it need recharging infrastructure, which is not developed at the moment. However, since SDCs are going to rely on electricity to operate, the demand for lithium batteries would increase.

Similarly, sensors and high-speed internet connectivity require higher auxiliary power from vehicles, which manifests as greater power draw from batteries. The larger battery requirement causes a necessary increase in supply of these type of batteries for the chemical industry. The production of lithium batteries is connected with serious environment pollution.

An aspect of environmental protection and pollution minimizing is by decrease of miles of travel with SDC. However, there is the dilemma and skepticism whether the travel distances would decrease. The improvement in vehicle energy efficiency does not necessarily translate to net reduction in energy consumption and positive environmental outcomes. Namely, it is expected that convenience of the SDC would encourages the consumers to travel more because of the comfort, ease of travel, ability to multitask, but also reduced stress in driving, and this would destroy the results of improvement done by automation. There is the fear that the kilometers of drive would be longer than at the moment, too, due to the fact that some persons with disabilities, old persons, non-drivers, etc., would use the SDCs and increase the travelling distanced. People will be able to commute longer distances because of the comfort of SDCs. It would increase the fuel consumption and environment pollution.

So, the consequences of application of SDC on global energy demand and emissions are highly uncertain, and heavily depend on the combined effect of changes in consumer behavior, policy intervention, technological progress and vehicle technology.

2.1.3 Social aspects

SDCs open the social dilemma of autonomous vehicles (Bonnefon *et al*, 2016) and the future impact of these vehicles in general (Marletto, 2019). The questions are oriented toward:

- Travel behavior and demands in SDC
- Inclusion old and disabled persons, non-drivers and also children
- Joy of drive
- Car - sharing
- Decrease urbanization

However, all of mentioned items have positive but also negative sides. In the following text positive and negative aspects of social features and arguments for pro and contra SDC would be discussed.

Social impacts include the travel behavior and demands in SDC. Riding in SDC may offer possibility to work and/or to relax. It gives the special benefit for the potential driver for better time use. The time spent in SDC would use for various business activities (work on computer, make telephone calls, etc.), leisure (watch TV, eat, read newspaper or book, etc.) or even sleep during long distance travels (Fagnant & Kockelman, 2015). For comfortable voyage the vehicle has to be redesigned and the quality of the car and roads improved (travel without vibration and noise in SDC). Vehicles need to be prepared for multipurpose usage (business and/or leisure) to be comfortable not only for transport but also relaxation, sleep, and even work. SDC could be redesigned for long-distance travel or as fully equipped bedroom, for example. It is believed that due to benefits of SDC most of passengers would chose the drive with this vehicle instead of short-distance flight. The arguments against short-haul flights are long waiting times at customs or the gate which implies the lost time.

SDCs will have a severe impact on the mobility options of persons that are not able to drive a vehicle themselves. Children and teens, who are not able to drive a vehicle themselves, are benefiting of the introduction of SDCs. Instead of parents the SDC would transport the children in daycares and schools. The fear for driving children by the human driver would vanish. SDC gives the condition of inclusion for senior citizens, non-drivers and for persons with disabilities in the driving process. Today elderly people have to walk, cycle, travel by bus or use the service of caretakers to get on the spot they need. It is expected that using SDC the transportation of elders but also disabled persons would be simplified and the dependence on caretakers would be decreased. For caretakers, who are mostly relatives, it would be relieved and give them the chance to work without interruption.

Incorporation of SDC in the traffic is expected to decrease the urbanization due to solved transport-net. Some people would rent far away from the city centers because commuting would be at reduced cost.

In the near future the driver interactions with the vehicle will be less common and in the more distant future the responsibility for drive will lie entirely with the vehicle. Passengers have to believe in reliability of SDC and pay less attention to the road. Due to improved comfort, ease of travel, ability to multitask and also reduced stresses in driving it is expected that the people would accept to ride SDC.

Nevertheless, there are some social barriers to SDC. Some persons would not like SDC because their personal joy to be the driver would be stopped. Namely, some drivers are not ready to give up of the joy of driving. The other social barrier to SDC is the share-trip. For better efficiency of SDC it is expected that the passengers would share the trip in SDC. Not all persons are ready to share the car during driving especially with strangers (Lavien & Bhat, 2019). It is extremely evident in the era of global pandemic situation.

2.1.4 Economic aspects

SDC is believed that would have a significant influence on the economic transformation in the transportation. Economic impacts of SDC are connected with luxury vehicle business, fuel choice (electricity and power), economic status of professional drivers (job loss), with incomes from insurance and for infrastructure etc. Thus the main economic challenges in SDC are connected with:

1. Job loses
2. Law enforcement incomes
3. Electricity and power supply of SDCs
4. Road infrastructure adaptation

In 2016 the US Highway Association reported that only 5% of available road space was taken up by manually driven cars. The capacity of cars per hour per lane was about two thousand. It is predicted that the introduction of SDC would make a significant improvement. It is calculated that the capacity would increase up to eight thousand (due to vehicle increased speed), or even to 12 thousand for 100% connected vehicles using vehicle-to-vehicle communication, traveling safely at 120 km/h and following distance of about 6 m of each other. (Human drivers at highway speeds keep between 40 to 50 m away from the vehicle in front.). However, this optimization of road exploitation requires very sophistical software and nets connections between cars and infrastructure. New road infrastructure with corresponding signalization would be necessary to be built.

SDC is believed that it would improve efficiency and productivity in transportation by reducing traffic jams and identifying better routs to take more sustainable driving. The distance between vehicles can be reduced and the capacity of the roadway would be improved. The lane size would be reduced and quantified due to driving efficiency. In addition, if the transport with SDCs would act, the number of personal cars necessary for transport passengers would be reduced.

Due to reduction of the number of SDC in comparison to the manually-driven cars it is expected that there would be the decrease of the conventional energy (fuel, gas) use which would have a big economic consequence. At the other side, SDC powered by electricity require recharging infrastructure which has to be built. The same requirement is for refueling infrastructures for SDCs with fuel cells.

Recently, it is reported that manually driven cars are used only 4-5% of the time and the remaining 95–96% of the time are parked: higher percent of car use is in USA and in high developed countries in Europa and Asia, while in the most of countries in the world it is even lower. Introducing the SDCs into passenger transport the efficiency of vehicle use would be drastically improved, as the autonomous vehicle as a taxi can drive continuously. The parking time and also the number of parking places would be drastically decreased. For non-personal SDC the parking place can be removed from roadside and the city would be free up for other properties like parks, recreational areas, buildings etc. Location of the parking can be outside the city where land is cheaper.

However, there are some economic barriers for SDCs. Benedikt and Osborne (2017) found that SDCs would make many jobs redundant. A direct impact of widespread adoption of automated vehicles is the loss of driving-related jobs in the road transport industry. As SDC need not driver it is believed that certain number of taxi drivers, delivery drivers, bus and van drivers, and others depending on driving as profession would be eliminated from their jobs. Namely, there could be job losses in public transit services, too. SDCs is expected to have small number of accidents and the number of crash repair shops and employees in these shops would decrease. Due to implementation of SDCs to the mass market it is estimated that almost 5 million persons would lost the jobs in the USA, which is almost 3% of the workforce. Loss of the jobs would have a tremendous impact on those persons and also on the social protection system. The governments of the most populous countries of the world, China and India, placed bans on SDCs with the aim to protect the job lost.

As it is known, insurance represents an important part of economics. The decreased number of traffic accidents would decrease the risks for SDCs and also the need for insurance as it for conventional vehicles. Namely, the ADAS which are already incorporated in cars, allow autonomous vehicles to enable self-driving features with minimized associated risks. SDC companies and manufacturers are recommended to have insurance but adopted for the new type of vehicles.

Analyzing the economic aspects of transformation from conventional to SDC cars it can be concluded that it would not be easy due to a strong competition between conventional and SDCs on the world market.

2.1.5 Safety and security aspects

Safety and security aspects of SDC seems to be the most important to people to accept this vehicle. In order for people to buy SDCs and vote for the government to allow them on roads, the SDC must be trusted as highly safe. Because of that, safety has been one of the strongest motivation and represents the primary concern in the driving industry. The manufacturers declare that the SDCs are waited to be safer than human drivers. However, there is the fear in population to put their lives in the hands of an autonomous vehicle where technical or systematic failure or malfunctions may occur.

If some disconnection or error between the SDC and other vehicles and communication systems occur, it may cause terrible inconvenience and even problems. The functionality of SDC is questionably. To reduce and even to eliminate this obstacle it is suggested to make the additional software program which will act in this special case and give some certainty to passengers.

There are two main human-factor challenges which can disturb the safety. One of them is the change from the automated driving to manual driving, often called “hand off drive”. It is activated when the road conditions are unexpected and unusual, or if the capability of the vehicle has limitation. Very often the human driver is not prepared for this sudden activity. The future drivers would have less practice due to SDCs, and might have a lower skill level in manual driving. The second challenge is known as “compensation of risk”. People enjoy benefits of SDC and engage in riskier behavior perceived that SDC are enough safe. For example, people ignore the advice of the company about the road or use electronic devices and extremely interrupt the safety of the vehicle.

There is also the challenge about the riskier travel of pedestrians, bicyclists and motorcyclists in the streets, believing that the safety of SDCs is excellent.

The safe drive in autonomous vehicle requires not only the absolutely technically accurate vehicle, updated road maps, road infrastructure suitable for SDC (traffic signalization, road signs) as it is previous mentioned, but also action of the corresponding legal aspects for detecting fail data and protect the personal data.

There is the safety problem between SDC and other road users, and vice versa. SDCs have difficulties of determining the intentions of pedestrians, bicyclists, and animals and models of behavior must be programmed into driving algorithms. Human road users are not sure about the intentions of SDCs, as in the car without driver they cannot exchange hand signals or make eye contact. One of possibility to overcome the problem is to mount on the outside of the car some additional signalization which would announce the status, for example, "going now, don't cross" or "waiting for you to cross", etc.

The security facility seems to be one of the most important in addition to reliability and predictability in SDC. For security of SDC the following properties have to be satisfied (Madden, 2013):

- Confidence
- Integrity
- Availability

The confidence is related to data and information to be highly protected. Due to integrity, data have to be valid and correct. SDC has the property of availability, i.e. capability of using resources. All of properties have to be incorporated, otherwise the work of the CPS is not correct.

As the security is one of the most important aspects which would decide if SDC would be accepted or not, specific principles of security concerning SDC have to be developed in:

- Privacy,
- Data processing and analysis,

- Modeling and metrics,
- Real-time guarantees.

The security is closely connect with data protection. SDCs developers try to navigate between privacy and data protection on the one side and the need for vast amounts of proceeding data for SDCs function on the other.

For every country not only the individual but also the collective security is of fundamental importance. Collective security is defined by Roberts & Kingsbury (1983) as: 'an arrangement where each state in the system accepts that security of one of them is a concern of all, and agrees to join in a collective response to aggression'. Namely, the SDC face cyber security, skills and safety challenges (Moore - Colyer, 2015). Types of challenges are:

- Technical
- Hacking
- Data and vehicle security
- Human safety

Potential obstacle to safety of SDC is the poring of a risk to be hacked. The types of hackers attack are various. For safety reasons the SDC system has to recognize the illegal passenger due to his data which is necessary to be given before the voyage. In addition, there is also the risk the program of SDC to be hacked. The data can be obtained through V2V (Vehicle to Vehicle) and V2I (Vehicle to Infrastructure) systems. The legal protocols have to be prepared and the cyber-security of the system has to be maximized (Neumann, 2016). Namely, there is the risk of terrorist attack and potential cyber-attacks on automated vehicles (Petit & Shladover, 2015). Hackers can mobilize enormous large number of SDCs on public road causing chaos. This action can be qualified as cyber terrorism. The driving can be malicious with the aim to cause physical danger to passengers. If the SDC is not secure from cyber-attack, the hacker can attack, and ask the owner for a 'ransom' if he wants the SDC to operate.

The vehicle's prior hacking history is not a reliable measure of the threat of SDC and is not suitable for prescribing of the cyber security. Namely on the previous vulnerability of hackers, it is not possible to predict the future one. In spite of the fact that the manufacturer would protect the system against vulnerabilities that hackers have previously exploited, the hackers are able to exploit a different vulnerability. The activity of hackers may not be the same in the testing period of the car and after distribution SDC in the market. At that time it is expected that the number of hacker attacks may increase and at that time the manufacturer is out of the link.

2.1.6 Multilevel impacts

Widely acceptance of SDC on public roads gives multilevel impacts and opens a series of various questions.

Thus, whether SDCs would disrupt the standard model of car ownership. It is expected that SDC would reduce the number of cars that would be individually owned the so called ‘personal-owned cars’ and would be replaced by taxi/pooling and other car-sharing services. This would dramatically reduce the size of the automotive production industry. At the other side, the cities have to be rearranged and urban planning has to be changed. If SDCs would be used as a type of taxi, the number of cars in the roads would decrease. If people order a self-driving car only when they need, utilization rates would rise, but ownership costs would decline. An added benefit is that the people would ride in newer-model cars but the environmental footprint would be smaller.

As it is already mentioned, the greatest benefit in applying SDC is the reduction of traffic accidents and collision, especially, of traffic fatalities and death-accidents. Level of safety in the traffic would be increased. Namely, it is proposed that the number of accidents would tremendously decrease and specially the death-ones. It is expected that 50 years from now, in the world there will be no traffic accidents. The autonomous vehicle excluded many human errors of the driver like tired even sleeping, aggressive drive, inattention, impossibility reacting in time, etc. The statistics made by US government shows that 94% of the vehicle accidents are due to human failures. Connection of SDC with the big data basis enables the AI of vehicle to give the real time decision in the shortest time and to avoid the accident. An advantage could be the use of real-time traffic information and other generated data to determine and execute routes more efficiently than human drivers. The time savings can be invaluable in these situations.

Consequence of accident and damages elimination is that lives are saved, money for health-cost (healthcare) and even car repair and insurance are decreased. For the case of decreased accidents, the owners of SDC would pay smaller amounts to insurance and also the payment from insurance agencies would be smaller. However, the total financial effect of the insurance agencies would drop.

As collisions are less likely to occur, and the risk for human errors is reduced significantly, the repair industry will face an enormous reduction of work that has to be done on the reparation of cars. At the other side, as the autonomous vehicle must have proper maintenance and the technical data of the vehicle are visible, the prediction for replacing parts (mainly mechanical) can be predicted and scheduled by reparatory industry.

Inclusion of SDC would attack the health of population. Due to comfort in driving, people would not go on foot or ride bicycle, but would arrange many short-distance trips. They would not be pedestrians and would decrease the everyday walking. Elimination of motion and other human activities would have a negative effect on the health and well-being of people (Wickens & Dixon, 2007).

As an unexpected conclusion about traffic without fatal accidents is that there would be a reduction in organs available for transplant.

The SDC, as the electric vehicle, was considered from the viewpoint of environment protection. However, it is found that the use of electric vehicles are an attack on the safety of pedestrians and those riding bicycle or motorcycle (Pardo-Ferreira et al, 2020). The reason is that the noise of electric vehicle is of low level and does not attract the attention to other traffic contributors. To overcome the problem the additional noise have to be produced and incorporated.

An additional question is about effect of SDC on travel behavior. Some people believe that SDCs will increase car ownership and car use because it will become easier to use them and they will ultimately be more useful. This may, in turn, encourage urban sprawl and ultimately total private vehicle use. Others argue that it will be easier to share cars and that this will thus discourage outright ownership and decrease total usage, and make SDCs more efficient forms of transportation in relation to the present situation. It gives the implication to transportation policy.

2.2 Survey on public opinion

As is discussed in the previous Chapter the SDC, i.e. 'the fifth level autonomous vehicle without driver' defined according to SAE (2018), is almost technically solved and prepared to attend the public roads and to be included in the everyday transportation system. The analysts predict that completely autonomous cars will be prepared for sale by 2025-2030 (Ilkova & Ilka, 2017). It has to be mentioned that some delay in realization of the project is expected due to global pandemic situation in 2020. Nevertheless, the SDCs will be ready for the market in the short time. Because of that it is necessary to know whether the SDC will be accepted for use from population. The reply is found by research of the public opinion with questionnaire.

In 2011, the online survey on two thousand persons from USA and UK was done and it was found that 49% of them were ready to use SDC. Since that time, further investigation show that the confidence in the future of the SDC continued to grow, in spite of the fact that the global pandemic gripped the world (Reiss & Pitts, 2021).

In 2012 thousand German drivers were questioned about SDCs. It is obtained that 22% of the respondents had a positive attitude towards these cars, 10% were undecided, 44% were skeptical and 24% were hostile (Floridi, 2020). Similar results gives the survey made in the USA, the UK and Australia (Schoettle & Sirak, 2014).

In 2015, a questionnaire survey was done by Delft University of Technology in the Netherland. The survey explored the opinion of five thousand people from 109 countries on automated driving (Kyriakidis *et al*, 2015). Results showed that respondents, on average, found manual driving the most enjoyable mode of driving. 22% of the respondents did not want to spend any money for a fully automated driving system. Respondents were found to be most concerned about software hacking/misuse, and were also concerned about legal issues and safety. Finally, respondents from more developed countries (in terms of lower accident statistics, higher education, and higher income) were less comfortable with their vehicle transmitting data. The survey also gave results on potential consumer opinion on interest of purchasing an automated car, stating that 37% of surveyed current owners were either ‘definitely’ or ‘probably’ interested in purchasing an automated car.

In 2018, 57% of 1500 questioned persons in China stated that ‘they would be likely to ride in a car controlled entirely by technology that does not require a human driver’ (Qu *et al*, 2019). The most are willing to trust automated technology.

A Pew Research Center (Smith & Anderson, 2017) surveyed more than four thousand adults from USA and found that 94% of them have heard about SDC and even 44% are ready to ride it. The reasons against riding the SDC are: no trust into the control (42%), no trust in the safety (30%), enjoy of driving is eliminated (9%), feeling that the technology is not ready for everyday use (3%), fear to be hacked (2%) and other (8%). The reasons to accept the ride of SDC are: "cool" experience 37%, safer drive 17%, can do other things 15%, less stresses 13%, greater independence 4%, convenience 4% and other 11%.

In 2019 a new standardized questionnaire about the autonomous vehicle acceptance or decline is introduced. The questionnaire includes the additional description which helps respondents better to understand the implications of different automation levels (Montoro *et al*, 2019). Using this questions the public opinion on SDCs among various groups of respondents was analyzed (Kyriakidis *et al*, 2015). Results showed that partial automation (regardless of level) which requires higher driver engagement (usage of hands, feet and eyes) was more supported by population than SDC with full autonomy.

According to aforementioned it is evident that in some countries of the world support the application of SDCs in traffic. For these countries it is common that they have large areas or/and significant number of inhabitants living in big metropolises with heavy traffic. For manufacturers of SDC and policy makers of these countries it is very important to know the people opinion on SDC, because it will help the progress of these vehicles and preparation of their inclusion in everyday life. It is believed that acceptance of SDC on public roads will give the revolution in persons transportation, but also introduce new economic, social and technical aspects. However, the survey made on SDC accepting is not done in countries with smaller area, shorter driving distances, lower number of inhabitants, smaller cities and towns, middle or low industrial technology level, etc. These countries are also expected to introduce SDC in application and to be their large users. Because of that the opinion of population in these countries about acceptance or rejection of SDC is also necessary to be known.

2.2.1 Citizen Science Project on SDC: Material and Research Method

Serbia is a country which satisfies the aforementioned requirements: it is a middle industrially developed European country with small number of inhabitants and has small area, without metropolis and big cities. In this country at the Province Vojvodina (at the north of Serbia) the

Citizen Science project (Halday et al., 2021) is established to investigate the subjective opinion of population on SDC. The population in Vojvodina has the specificity that the population multi ethnical and multicultural. The survey was done in the period of March, 2022 to February 2023.

The questionnaire survey (Ninkov, 2020) was done and the level of familiarity of the population with SDC is researched. The questionnaire is written in Serbian language (Cveticanin & Ninkov, 2021[4]) and is the translated but modified version of already developed questionnaire (Halday et al., 2021). However, the traditional type of one - dimensional bipolar scaled questionnaire (Eagly & Chaiken, 1993; Marletto, 2019), which implies answers in to be positive or negative, and that which include the neutral i.e. uncertain (Hulse *et al*, 2018; (Nielsen & Haustein, 2018)) answer is modified and extended. Namely, the traditional approach is very simply and is not enough sophisticated to include ambivalent and indifferent opinions. To overcome the lack in our investigation the model for estimation is conceptualized as a multipartite (Rosenberg & Hovland, 1960) with cognitive, affective and behavior components. Cognitive components define the object by perceptions and beliefs and also thoughts. Affective components describe the feelings and emotions which are linked to the object. The behavioral components include the behavior intention and verbal statements. The introduced gradation on answer is, for example, significantly less – less – neutral – more – significantly more (Cveticanin & Ninkov, 2021[2]).

The text of the questionnaire is given in Appendix I. At the beginning of the questionnaire the short description of SDC is given for those who have never heard about SDCs. After that the question are divided into two parts: Personal questions and Questions according to SDC. The personal questions concern the gender, age and education. The second group of questions have to give the conclusion about level of knowledge about SDC and its acceptance or rejection.

To examine the relationship between gender, age group, and educational background in relation to the ten questions on SDC implementation, a survey was designed and administered to a sample of 450 people, i.e., with two groups of male and female participants. Each group included 225 members (N=450), and participants were additionally stratified by age group (up to 18, 19-30, 31-60, over 61) and educational background (technician and non-technician). The survey consisted of ten items – one item was a single select multiple choice question, two were multi select multiple choice items, two required a yes/no answer, while the remaining five were Likert-scaled items (see

Appendix). SAS JMP r14 Software was used to conduct the cross tabulation and correlation analysis of the questionnaire data. As indicator of independence the *Chi-square* test was utilized.

2.2.2 Results of statistical analysis

The results of the chi-square test indicated a significant relationship between gender and familiarity with SDC ($\chi^2(1, N = 450) = 52.014$, $p < .0001$). Larger proportion of males (79.1%) than females (46.2%) expressed familiarity with SDC (Fig.2.1a).

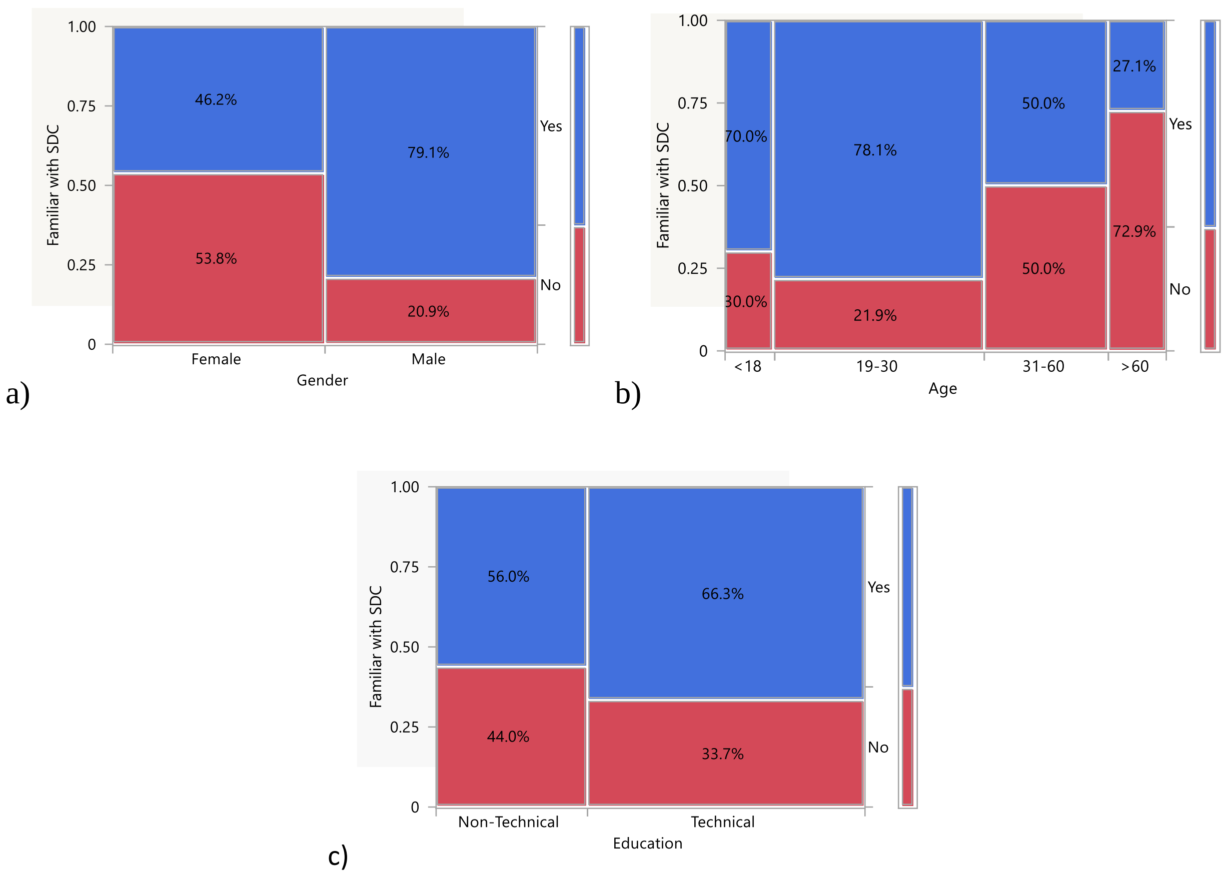


Figure 2.1 Mosaic plot showing proportions of Familiarity on SDC by: a) Gender, b) Age group, c) Education.

The results of the chi-square test indicated a significant relationship between Age group and familiarity with SDC ($\chi^2(1, N = 450) = 63.659$, $p < .0001$). Age group 19-30 was familiar with SDC in largest proportion (78.1%) compared to all other age groups (Fig.2.1b). The results of the chi-square test indicated a significant relationship between Education and familiarity with SDC

(χ^2(1, N = 450) = 4.706, p < .0301). Group with Technical education background was familiar with SDC in larger proportion (66.3%) compared to the Non-Technical group (56.0%) (Fig.2.1c).

The results of the chi-square test indicated a significant relationship between Gender and the Opinion on SDC (χ^2(1, N = 450) = 36.564, p < .0001), (Fig.2.2a).

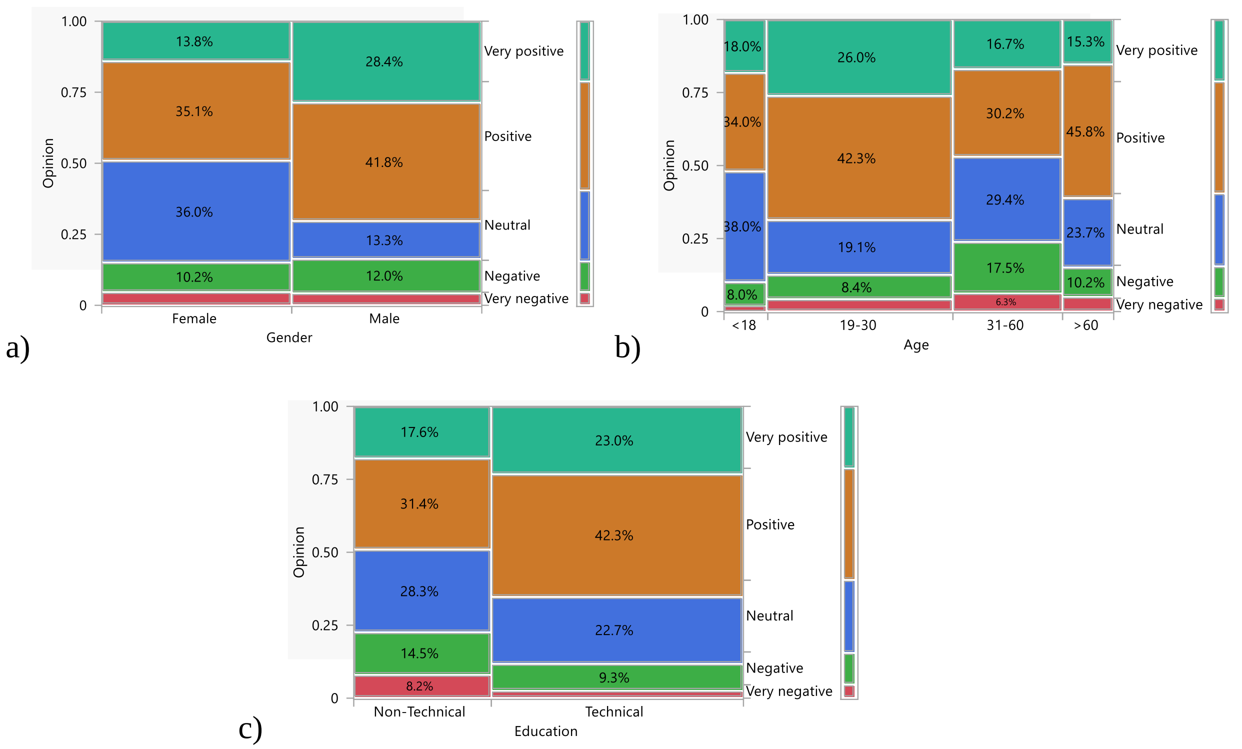
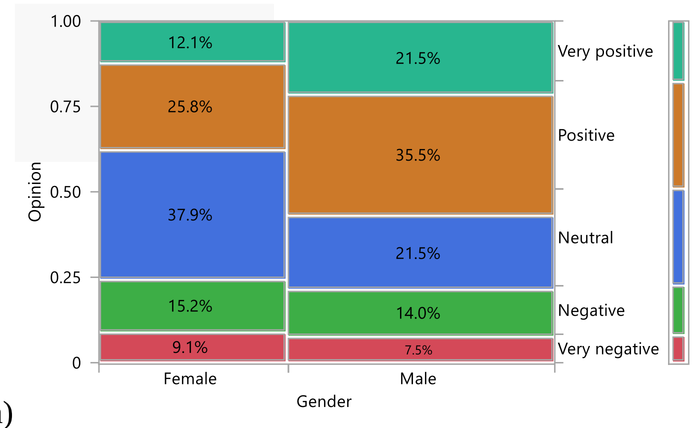


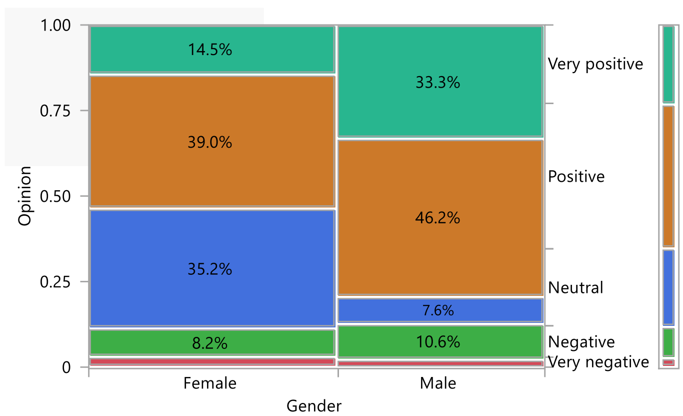
Figure 2.2 Mosaic plot showing proportions of Opinion on SDC by: a) Gender, b) Age group, c) Education.

The results of the chi-square test indicated a significant relationship between Age group and the Opinion on SDC (χ^2(1, N = 450) = 24.662, p = .0165), (Fig.2.2b). The results of the chi-square test indicated a significant relationship between Education background and the Opinion on SDC (χ^2(1, N = 450) = 14.856, p = .0050), (Fig.2.2c).

Considering the Opinion on SDC, the results of the chi-square test did not indicate a significant relationship between Gender and Opinion within the Non-Technical education background (χ^2(1, N = 450) =6.901, p = .1412), (Fig.2.3a).



a)



b)

Figure 2.3 Mosaic plot showing proportions of Opinion on SDC by Gender and: a) Non-Technical Education background, b) Technical Education background.

On the other hand, in the case of the Technical education background, Gender was significantly related to Opinion (χ^2(1, N = 450) = 37.001, p < .0001), (Fig.2.3b).

Results of the chi-square test indicated a significant relationship between Gender and estimation of period required for the introduction of SDC (χ^2(1, N = 450) = 11.090, *p* = .0039), (Fig.2.4.a), between Age group and estimated period required for the introduction of SDC (χ^2(1, N = 450) = 28.244, *p* < .0001), (Fig.2.4b) and between Gender and estimated period required for the introduction of SDC (χ^2(1, N = 450) = 17.500, *p* = .0002), (Fig.2.4c).

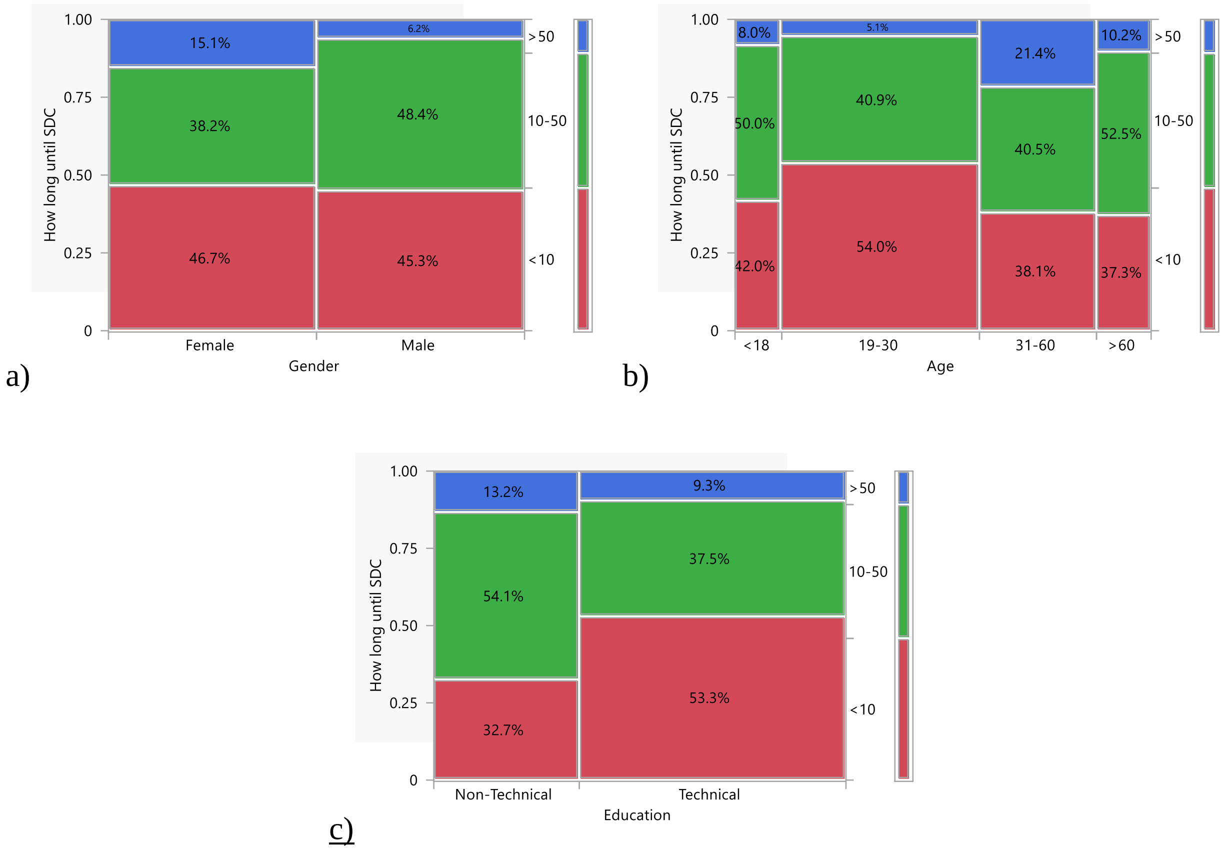


Figure 2.4 Mosaic plot showing proportions of Estimation of period required for the introduction of SDC by: a) Gender, b) Age group, c) Education.

The results of the chi-square test did not indicate a significant relationship between Gender and the Estimated SDC Accidents ($\chi^2(1, N = 450) = 7.263$, $p = .1226$), (Fig.2.5a) and between Age group and the Estimated SDC Accidents ($\chi^2(1, N = 450) = 7.747$, $p = .8046$), (Fig.2.5b) but indicated a significant relationship between Education background and the estimated SDC Accidents ($\chi^2(1, N = 450) = 13.425$, $p = .0094$), (Fig.2.5c).

A significant relationship between Gender and the estimated Fatal SDC Accidents ($\chi^2(1, N = 450) = 32.816$, $p < .0001$), (Fig.2.6a) is indicated with chi-square test. In contrary, the chi-square test did not indicate a significant relationship between Age group and the Estimated Fatal SDC Accidents ($\chi^2(1, N = 450) = 14.688$, $p = .2589$), (Fig.2.6b) and between Education background and Estimated Fatal SDC Accidents ($\chi^2(1, N = 450) = 8.327$, $p = .0803$), (Fig.2.6c).

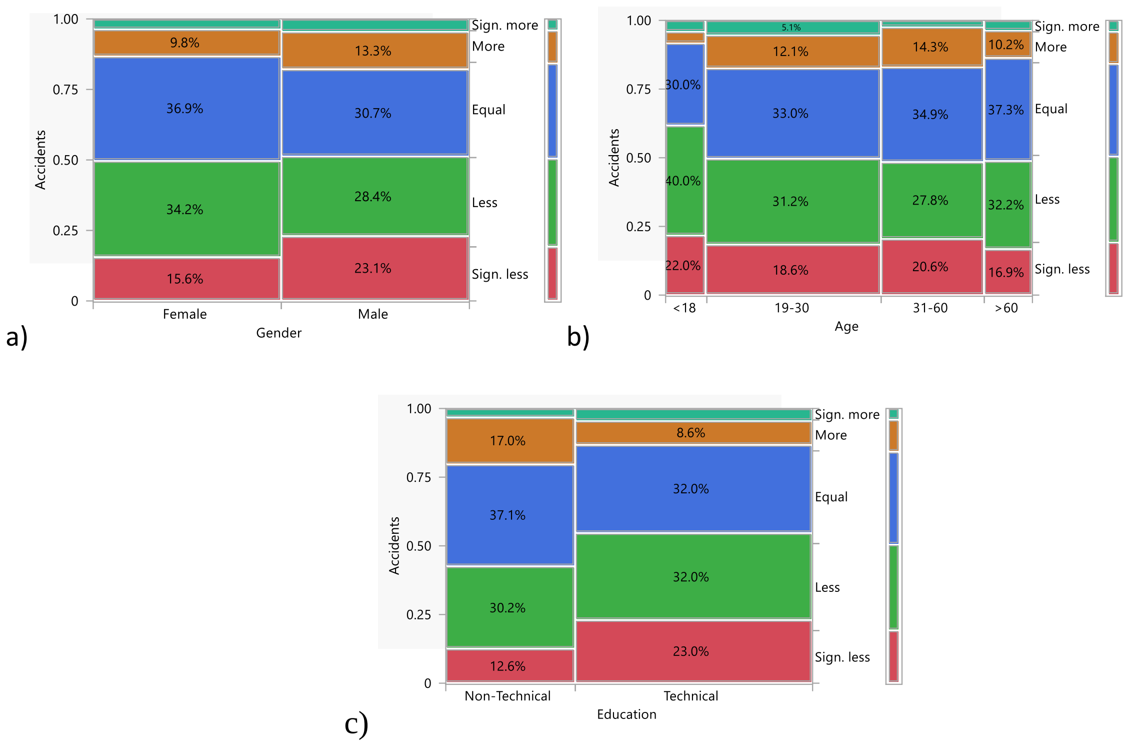


Figure 2.5 Mosaic plot showing proportions of Estimated SDC Accidents by: a) Gender, b) Age group, c) Education

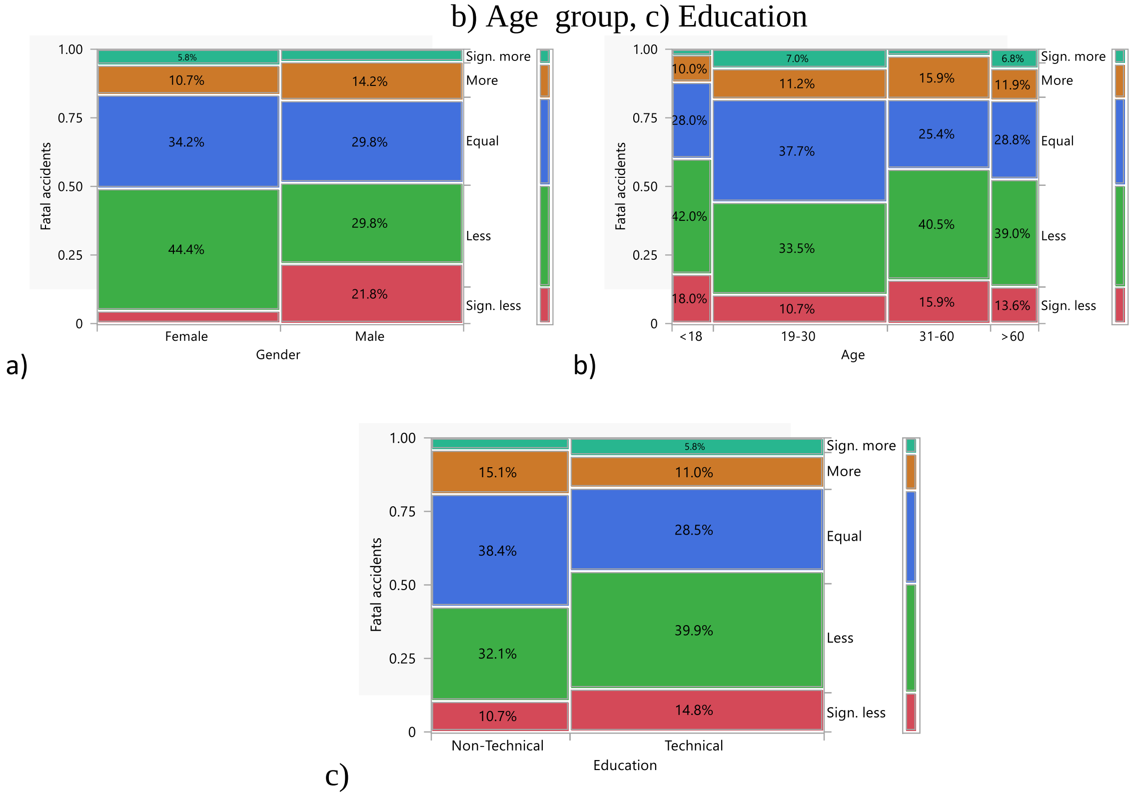
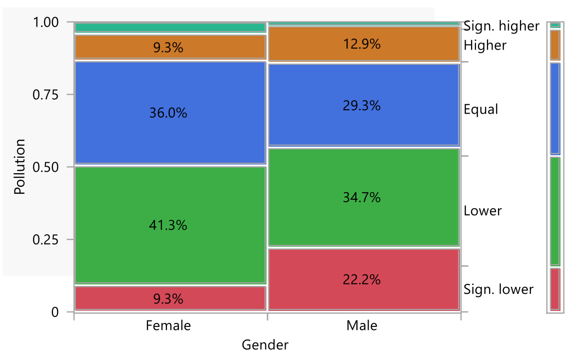
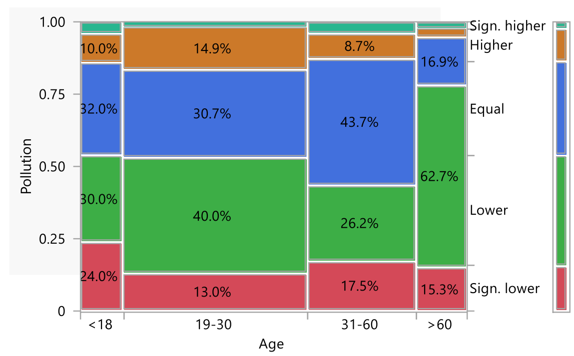


Figure 2.6. Mosaic plot showing proportions of Estimated Fatal SDC Accidents by: a) Gender, b) Age group, c) Education.

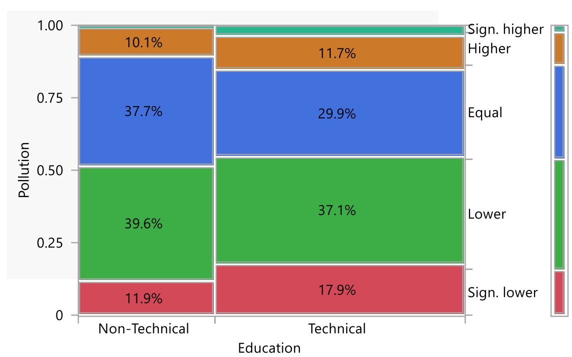
A significant relationship between Gender and the estimated Pollution ($\chi^2(1, N = 450) = 20.426$, $p = .0004$), (Fig.2.7a) and between Age group and the estimated Pollution ($\chi^2(1, N = 450) = 37.378$, $p = .0002$), (Fig.2.7b) according the results of the chi-test, while the relationship between Education background and the estimated Pollution ($\chi^2(1, N = 450) = 7.947$, $p = .0935$), (Fig.2.7c) is not indicated as a significant one.



a)



b)



c)

Figure 2.7 Mosaic plot showing proportions of Estimated Pollution by: a) Gender, b) Age group, c) Education

The results of the chi-square test indicated a significant relationship between Age group and the estimated Pollution ($\chi^2(1, N = 450) = 33.946$, $p < .0001$), (Fig.2.8a). The results of the chi-square test did not indicate a significant relationship between Age group and the estimated Fuel Consumption ($\chi^2(1, N = 450) = 14.979$, $p = .2426$), (Fig.2.8b) and a significant relationship between Education background and the estimated Pollution ($\chi^2(1, N = 450) = 13.227$, $p = .0102$), (Fig.2.8c).

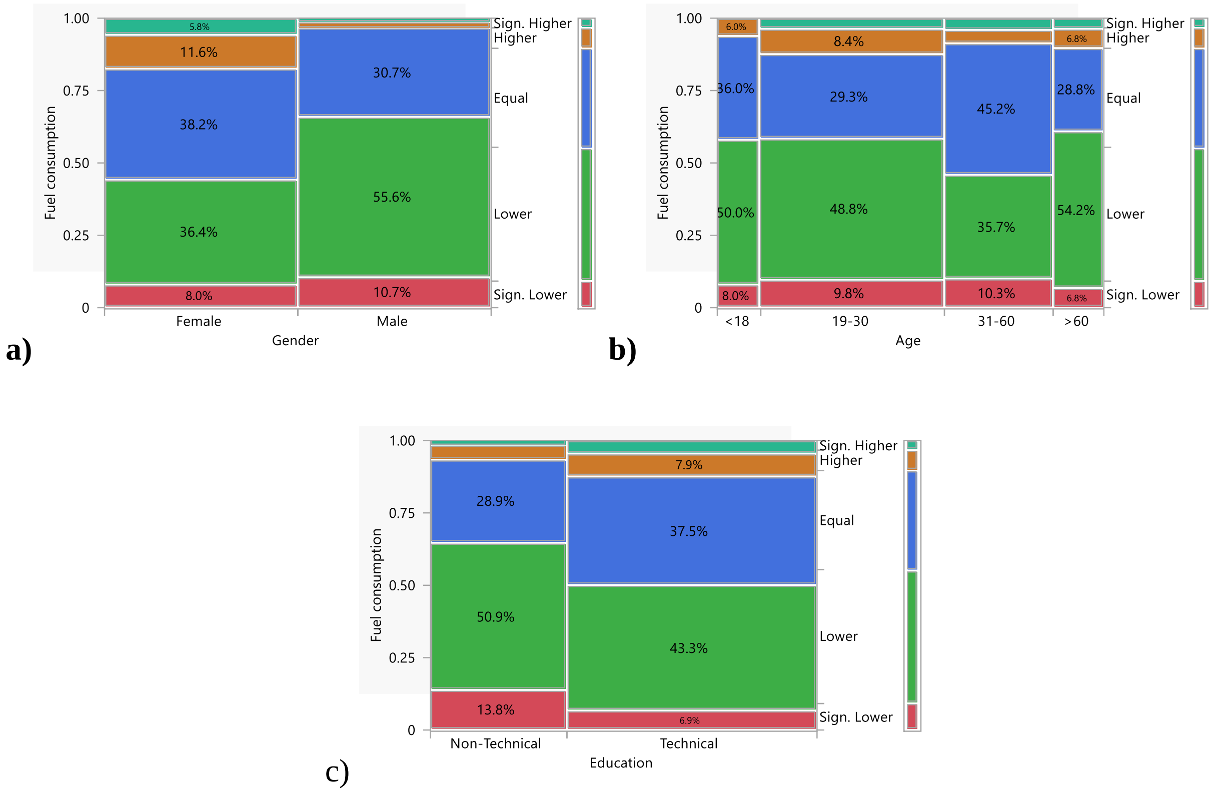
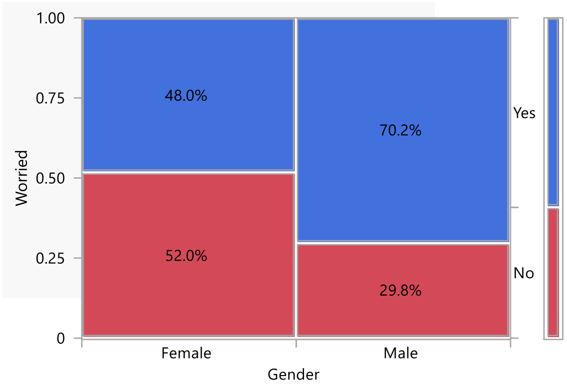


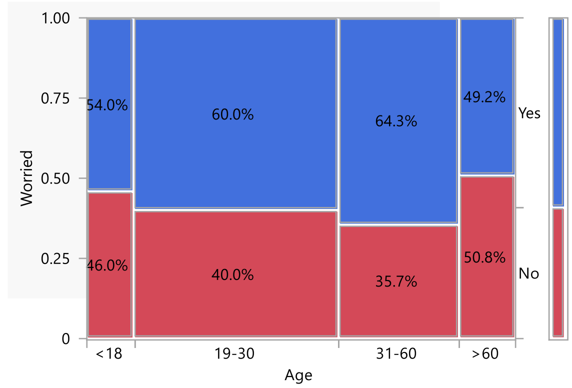
Figure 2.8 Mosaic plot showing proportions of Estimated Fuel consumption by: a) Gender, b) Age group, c) Education

The results of the chi-square test indicated a significant relationship between Gender and the concern (worry) about the introduction of SDC ($\chi^2(1, N = 450) = 22.985$, $p < .0001$). Larger proportion of males expressed concern about SDC introduction (70.2%) compared to females (48.0%) (Fig.2.9a).

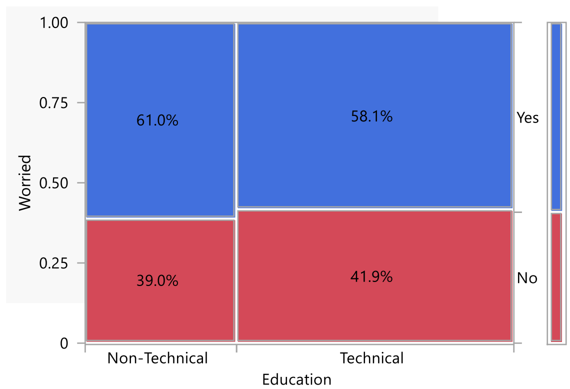
The results of the chi-square test did not indicate a significant relationship between Age group and the Concern (worry) about SDC ($\chi^2(1, N = 450) = 4.427$, $p = .2189$), (Fig.2.9b) and also between Education background and the Concern (worry) about SDC ($\chi^2(1, N = 450) = 0.365$, $p = .5455$), (Fig.2.9c).



a)



b)



c)

Figure 2.9 Mosaic plot showing proportions of Concern (worry) by: a) Gender, b) Age group, c) Education.

In the case of concern (worry) about SDC, the results of the chi-square test did not indicate a significant relationship between Gender and the Concern (worry) about SDC within the Non-Technical education background ($\chi^2(1, N = 450) = 1.980$, $p = .1594$), (Fig.2.10a).

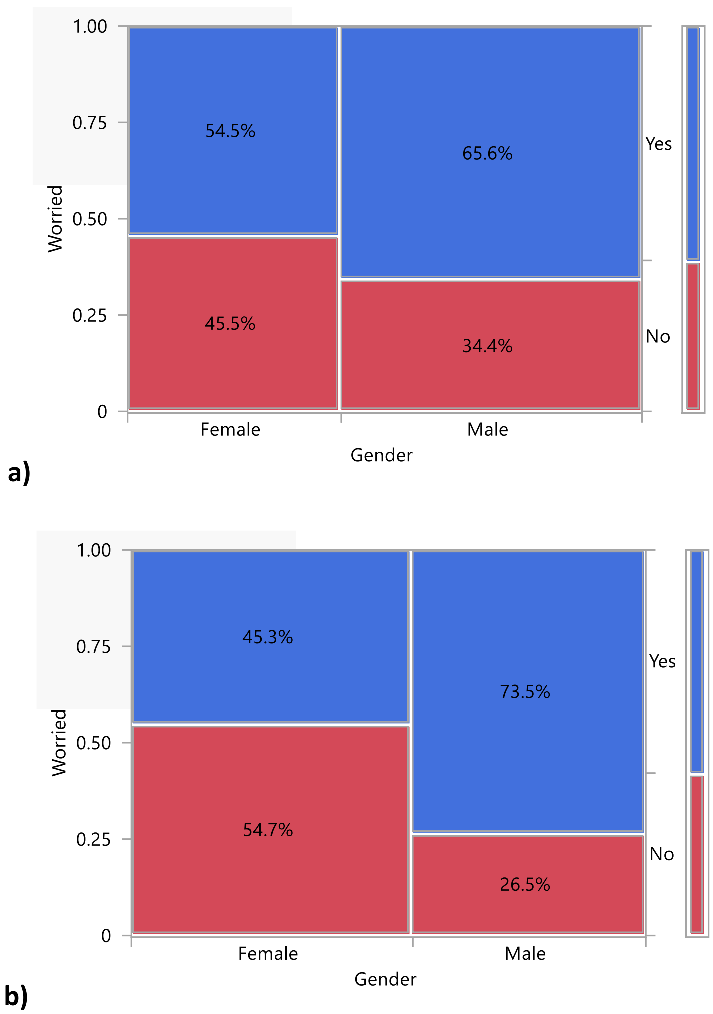


Figure 2.10 Mosaic plot showing proportions of Concern (worry) by Gender and: a) Non-Technical Education background, b) Technical Education background

Contrastingly, in the case of the Technical education background, there was a significant difference across Gender (χ^2(1, N = 450) = 23.560, p < .0001), (Fig.2.10b).

The final two sets of multiple questions were related to choices of activities which could be performed during SDC drive, and the Reasons against the introduction of SDC.

In terms of the possible activities which could be preferred by the subjects during SDC drive, Gender was significantly related to the following choices: Phone/Email (χ^2(1, N = 450) = 12.578, p = .0004), Reading (χ^2(1, N = 450) = 9.458, p = .0021), Resting/Sleeping (χ^2(1, N = 450) = 17.983, p < .0001), Games (χ^2(1, N = 450) = 13.770, p = .0002), Eating (χ^2(1, N = 450) = 10.360, p = .0009), Road Watching (χ^2(1, N = 450) = 16.872, < = .0001). On the other hand, there were no differences between males and females with respect to Movies/TV (χ^2(1, N = 450) = 3.125, p =

.0771), Working (χ^2(1, N = 450) = 0.062, p = .0803), and Sightseeing (χ^2(1, N = 450) = 4.147, p = .0417). Age group was significantly related to use of Phone/Email (χ^2(1, N = 450) = 39.172, p < .0001), Resting/Sleeping (χ^2(1, N = 450) = 39,323, p < .0001), Movies/TV (χ^2(1, N = 450) = 19.179, p =.0003), Games (χ^2(1, N = 450) = 34.501, p < .0001), Working (χ^2(1, N = 450) = 20.073, p = .0002), Eating (χ^2(1, N = 450) = 21.254, p < .0001), Road Watching (χ^2(1, N = 450) = 48.420, p < .0001) and Sightseeing (χ^2(1, N = 450) = 22.616, p < .0001). The only choice which was not related to Age group was Reading (χ^2(1, N = 450) = 4.313, p = .2296). The least difference between subjects was observed in terms of their Education, where a significant difference was observed in just two choices – Working (χ^2(1, N = 450) = 6.203, p =.0133), and Sightseeing (χ^2(1, N = 450) = 4.971, p = .0258).

In terms of the Reasons against the introduction of SDC, gender was significantly related to issues of Experience (χ^2(1, N = 450) = 98.498, p < .0001), Safety (χ^2(1, N = 450) = 4.712, p = .0300), Long Trip (χ^2(1, N = 450) = 8.559, p = .0034), Enjoyment (χ^2(1, N = 450) = 23.931, p < .0001), and Technical Problems (χ^2(1, N = 450) = 7.673, p = .0056). Significant relationship was found between Age Group and Long Trip (χ^2(1, N = 450) = 35.897, p < .0001), Distrust (χ^2(1, N = 450) = 25.281, p < .0001), Technical Problems (χ^2(1, N = 450) = 8.726, p = .0322), Safety (χ^2(1, N = 450) = 18.750, p = .0003), and Privacy Protection (χ^2(1, N = 450) = 75.128, p < .0001). Finally, Education Background was unrelated to most of the issues, while significance was found in the case of Long Trip (χ^2(1, N = 450) = 3.872, p = .0491), and Privacy Protection (χ^2(1, N = 450) = 10.870, p = .001).

2.2.3 Discussion

In general, based on results of survey, the following is concluded:

1. Analysing the answers to questionnaire it is concluded that the population in Serbia gives the support to SDC acceptance. This support is in the ratio 55% to 45% pro and contra SDC, respectively. An aspect which forms the opinion of population pro and contra to SDC are the SDC accidents. The research shows that the public's responses mainly depend on expectation of reduction of crashes done by SDC. The support of application of SDC is based on the assumption that the number of crashes will decrease. The special influence on the decision is the expecting that the mortality in accidents will be smaller. The result agrees with that published in Liu *et al* (2019a). However, some doubts in acceptance of

SDC exist and they are mainly of psychological character (Liu *et al*, 2019c). Namely, people have no trust in SDCs and the negative publicity around SDCs is the supports this statement. The 'fake news' about SDC act in negative direction (Ninkov, 2019$_2$).

2. Benefits of SDC in opinion of respondents is connected with comfortable long-time trip, faster trip in cities, cheaper transportation costs, possibility of ride for older and disabled, application of the time in car for another activities like work, rest, etc. The SDC are expected to give 'healthy life' in the environment with decreased pollution and available life outside areas with polluted air. The SDC is expected to decrease the environmental pollution and conventional fuel consumption, too. Respondents believe that SDC would increase the efficiency in reducing carbon emissions more than conventional vehicles. Population expects the manufacturer to place a greater emphasis on emission reduction and conventional fuel consumption (Liu *et al*, 2019b).
3. When SDCs can be used throughout the day the traffic will be optimally organized and many parking spaces in cities and towns may be eliminated in the future.
4. Population in Serbia is fearful about cyber-security and privacy in SDC. All the population is worried that SDCs will be easily hacked because of the abundance of digital infrastructure required for them to work. The population agree that the cyber-security in SDC has to be increased before inclusion of vehicle into the traffic. The population is afraid that criminals will use the data that they retrieve, hacking the vehicle and getting it to perform actions the user is unaware of, unable to undo, and maliciously causing harm to persons in the car. The similar consequences of cyber-attack are mention by Stevens (2018). In the survey of Kyriakidis *et al* (2015) made on 5000 respondents across 109 countries, it was found that 'people were most concerned about software hacking and misuse of vehicles with all levels of automation'. The population is aware if cyber-criminals take over a vehicle, they can cause minor nuisances (closing or opening windows), or they can create greater threats (disable the functionality of car to read stop signs, causing crash of vehicles, harm passengers), or they can use SDCs for terrorist purposes (transporting and detonating bombs).

These positive, neutral or negative opinions on inclusion of SDC on roads in Serbia are independent on personal differences like: gender, aging or education. There is the group of questions where answers differ if they are given by males or females, younger or older persons, technically or non-technically educated persons or those living in urban or rural ambient.

1. The persons from urban give higher support to SDC than those from rural environment. Namely, the last are mainly indifferent and not interested in SDC. The reason for urban inhabitants to accept SDC is based on the problem of traffic jams, not enough parking space, sparing driving time, better use of the time during driving and at last there is also an economic aspect. Living in the suburbs or in rural area and working in cities gives the benefits not to pay expensive flats in the downtown and living in more ecological environment. Individuals would be able to rent further away from the centres of towns and cities because of the ease of commuting with SDC and, in addition, reduced costs. It would be the new stream in living way: reduction in urbanisation and spread out of population throughout the region (Lim & Taeihagh, 2018). People would be less of a need to live in cities. The importance of this item is seen in this pandemic situation, when the human activity was possible only in fields and inside the houses. It is worth to say, that in Serbia the urban population lives mainly in flats. It is worth to say that the living location (rural or urban) has no statistical significance.
2. The answers in questionnaires highlighted that there is a difference in perceptions about SDCs between male and female. Namely, results showed that male and female differ in their willingness to use SDCs. Male felt less anxiety and more joy towards automated cars, whereas female showed the exact opposite. The gender difference towards anxiety is especially pronounced between young persons but decrease with participants' age. Male are ready to accept SDC on public roads, but female have serious worry (Hohenberger *et al*, 2016). Males thrust in SDC and consider SDC to be safer than conventional cars. Thus, male are ready to ride SDC because experience and have less stress and fear in comparison to females. Females are less enthusiastic and more fearful about their safety in SDC. As the advantage of SDC the females mentioned the long-time trip and the possibility to have other activities during riding.
3. Females and males opinion about the joy of driving differs, too. As it is known, the joy of driving is one of the primary pleasure of the vehicle (Kemp, 2018). The replies show that the most of men are not ready to waive the joy of driving. In contrary, it is not the case for women. For significant number of female driving is a necessary activity for fulfilling the

everyday duties, but for most of men it is a form of pleasure: a connection with surroundings, a sense of adventure and control, a relaxation form etc. Males think that SDCs would threat this joy.

4. Female have higher affinity to doing other things than driving in comparison to males. Female are primary ready to phone, read, to sleep or watch the road. Male spend time in phoning, playing games, working and watching films.
5. The survey shows that there is the fear during riding SDC. The stress and fear in driving is significantly higher in female than in male population. In addition, the fear is stronger than in driving conventional car. It is interesting to note, that females are afraid to ride in the SDC independently on ages. Similar result is reported by Johnsen *et al*. (2017) and Naughton (2019).
6. The age of the respondents proved to be a significant factor in decision making. This conclusion is already presented in some publication (see for example, Liu *et al*, 2019d). The younger population is ready to use SDC, while the older one perceives SDCs (Rahman *et al*, 2019). There is also a group of older persons, non-drivers and disabled who see the benefits of SDC in their inclusion into the normal life. They consider SDC to potentially reduce the inequality in population and have the positive opinion in accepting SDC (Abraham *et al*, 2017; Lee *et al*, 2017) It is worth to be said that school children where included into the survey. Namely, they would be most likely the users of this technical innovation in the future.
7. According to investigation done by Population Division of United Nations (UN, 2017) in 2017 the global world population over 60 is 962 million and has the tendency to be doubled in 2050. It is predicted that in 2050 there will be more old persons over 60 than young ones at ages 10 to 24. Because of that this group of people has to be strongly considered according to the problem of SDCs. It is expected that the old persons would not drive cars and their inclusion into traffic with SDC is important. However, the research shows the repulsive attitude to the autonomous vehicle: the person is alder, the level of negative attitude is higher. Currently, the transportation problem is solved by using of public traffic or they need help of the family or friends. It is expected that SDC would provide them the convenience of safe ride without need of other persons to help them. It is quite natural that, in general, older adults are more skeptic with new technologies than the younger ones. The older persons show smaller level of believe that the SDCs will give more benefits than lacks (Payre *et al*, 2014) and are not ready to adopt to new unproved technology. By studying the

attitude of older adults toward SDCs the opportunities and challenges related to the adoption of autonomous vehicles is necessary.

8. The persons with technical education have much more information about SDC than others. However, their knowledge is insufficient. Both, males and females, are ready to be included into the projects considering this autonomous vehicle. The population need education in this segment of life. Popular and informative lectures on the topic are necessary on all levels and for various aging (from those for children up to old persons). Scholars have to disseminate the knowledge in SDC while manufacturers and sellers have to invest in SDC advertising.
9. Finally, based on the research a new, quite unexpected aspect of SDC appears. There is an additional lack in using SDC due to pandemic situation with Covid-19. Namely, car-sharing which is a fundamental property of SDC ride, is prohibited for persons who are not from one family. This argument is mentioned in the research against SDC. At the moment, the solution of the problem is not evident.
10. Due to the obtained results it is obvious that the people's knowledge on SDC is not enough, and has to be increased to a high level which enables the acceptance of these vehicles, first, in testing on public roads, and then in everyday use. Liu *et al* (2019d) showed some effective and cognitive factors which drive people's intention to use SDC. In addition, the respondent believe that the trust in automation would change before and after the experience of take-over scenarios in a highly automated SDC vehicle (Gold *et al*, 2015). Overall, direct experience made participants to be more positive. However, the very often some sensationalizing stories, published in newspapers and appeared on site, against SDC focused on fatality rates in accidents (Jenkins, 2013) can destroy the endeavor to increase the people believe in autonomous vehicles. Thus, Naughton & Fisk (2015) are wondering if "a robot car with no one behind the wheel hits another driverless car, who's at fault? The answer: No one knows." Due to tendency of incorporating new technologies in our lives, it is expected the text of these types will be eliminated or refute in future.
11. In conclusion, this study provides insights into the relationship between demographic factors and attitudes towards self-driving cars (SDC). The results indicate that gender, age group, and education background are important predictors of the issues addressed in this study. However, this analysis also shows that the examined relationships are complex and

nuanced, and depend on the specific demographic groups. Overall, the findings of this study underscore the importance of considering demographic differences in attitudes towards SDC, suggesting that future interventions to promote the adoption of this novel technology may need to be tailored to specific subgroups of the population.

2.3 Conclusions and recommendations

Based on comparison of the subjective opinion, obtained by answers on questionnaire, and results of investigation done by scholars it is concluded:

1. There will be a great difficulty in transition of privately owned cars to shared SDCs. The primary reason is that the most of population do not believe in SDC and is not ready to change the life style and accept to be without own vehicle. To improve the conscience of population, the popularization and dissemination of knowledge about SDC is urgently necessary. It would be the chance for the success of the project.
2. People and also scholars are expected that the number of crashes with SDC and attacks with mortality would be decreased. It is the most important benefit of SDC. The SDCs would eliminate many car accidents and save tens of thousands of lives per year and prevent hundreds of thousands of injuries and their associated economic toll. Nowadays, human errors are recognized as a major factor to traffic crashes. More than 90% of traffic crashes can be tied to a human error or human choice (NHTSA, 2016).
3. Adoption of SDCs in traffic will: reduce traffic congestion, reduce traffic jams and give better traffic organization, increase human mobility special of those who currently are unable to drive (elders, non-drivers, disabled, children), ride in modern vehicle, ride would be more comfortable, long-distance trips would be more appropriate due to adoption of interior of cars, better time spend, etc. The public opinion agrees with the opinion of researchers (Liu & Xu, 2020).
4. One of the most important task for SDC is to be the vehicle which would reduce the emission and environment pollution. However, there is the doubt about air pollution and consumption of conventional fuel due to uncertainty of kilometers of drive. If the short-distance drive would be included (people will not to be pedestrians or ride bicycle), as it is obtained as the result of responds to the questionnaire, riding kilometers would increase

and the pollution and fuel consumption would increase. Scholars and people have opposite opinion in the matter.

5. Problem of lithium batteries as environment pollution is not solved, yet. Researcher give a great effort to solve the problem, but the people are not aware of its elimination and are not ready to accept the new pollutant.
6. People are not satisfied with the level of safety and security in SDCs. Manufacture declare that they do their best to protect data and privacy by introducing corresponding algorithms. However, to overcome the problem it is suggested to introduce the valid legalization in this topic which will decrease the risks and challenges related to safety, legal liability, security and especially cyber security (Penmetsa *et al*, 2019; Anderson *et al*, 2016; Fagnant & Kockelman, 2015; NHTSA, 2016).
7. Significant infrastructure changes have to be done in signalization, in vehicle – infrastructure (V2I) connections and in power stations for electric cars and fuel batteries.
8. Both, subjective and objective, opinions are that introduction of SDC would increase the urban quality by changing of urban structure with much smaller number of parking places and giving benefits for pedestrians and cyclic mobility.
9. The general opinion is that the transportation possibility of the SDC is much better than of the conventional car according to the driving time. At the same time, there will be much lower traffic in towns due to better traffic organization monitored and operated from a center.
10. The need for car-drivers would be stopped, but new professions like operators of SDC and IT technicians for modulating the vehicle, operating with infrastructures, etc. would be introduced.
11. SDC is based on share-drive. However, the people does not agree with this property of SDC. May be that the reason is the problem with pandemic situation at the moment.
12. Questionnaire survey shows that gender, age and education background were all significantly correlated with three issues: familiarity with SDC, opinion on SDC, and estimated time to introduction of SDC. However, a more detailed analysis of Opinion on SDC by gender and education, revealed significant relationship between gender and Opinion just in the group with technical education background, while in the non-technical group this relationship was insignificant. In addition, results of questionnaire research show

that the population independently on demography (gender, age and education) concern (worry) about SDC. The main reason for Concern is connected with worry for life of the individuals: the problem of personal safety in SDC is not finally solved, there is the absence or there exist only weak measures for privacy and personal protection and, finally, the SDC is not recognized as a legal entity in the legal system and society.

Based on the analysis of results obtained by questionnaire survey and objective aspects of SDC the research has to be oriented toward solving problem of AI in decision-making (which primarily includes ethical and moral aspects) and toward considering legal aspects of SDC and the possibility of recognizing SDC as a legal entity in contemporary legal system. The latter problem is investigated in this dissertation. The aim is to adopt and modify the existing regulations to SDC and develop and recommend the newly developed set of rules for SDC.

3 PRIVACY AND DATA PROTECTION

As it is already mentioned in the previous Chapters, SDCs need an enormous number of data for their operation. SDC's database includes: official public databases (concerning the street facilities of towns), meteorological databases, data which give the pictures of the outside artificial world and human environment, but also personal data (information about the exact location of a person, social security numbers, credit card information, etc). The recorded data of passengers of SDC are also: how, when, and where individuals drive. These data give the position of the person travelling by SDC at every moment. The question is, whether the privacy of the person and even the human rights may be disturbed by giving this data in air. To protect the privacy of the passengers of SDC measures for privacy and data protection have to be established (Ninkov, 2019_1). The legal impact is concerning the problem of private and data protection of the passenger in SDC. For individual privacy (if individuals are identifiable) the question is who has access to this data and what can be done with data. Whether data acquired from SDCs can be used as legal evidence. To achieve the goal, legalization in privacy and data protection is necessary. Protocols for protection of user's privacy have to be established and the owner and operator of SDC has to be aware of them. The already existing GDPR need an Annex to give privacy barriers and data protection.

Misuse of data in SDC can lead to compromise passenger safety and security. The question is how to protect data and form the cyber-security. This question is connected with security problems. It is necessary to form the legal regulation in digital infrastructure to prevent the actions and attacks of hackers and to increase the level of cyber security.

To prevent data from hacking cyber security systems have to be introduced. In spite of the fact that some private data are widely evident, the regulation which include security and cyber security elements according to SDC will protect the abuse of private data.

Legal aspects governing data protection and privacy are:

1. Data protection and privacy rules
2. Legal definition of individual privacy issues
3. Definition on conditions under which data obtained from the SDC can be used as legal evidence
4. Cyber security

Some additional limitation have to be introduced. Private data required from passengers may be only those which are strongly connected with SDC riding. The explanation and requirement has to be prescribed.

As SDCs is believed to be easy hacked because of the abudance of digital infrastructure, the problem has to be legal treated. Special laws and regulation have to be prepared in cyber security of SDCs.

The data flow has to be free from misunderstanding, misinformation and hacking, as it may causes interoperability or the system to fail. To found the faulty data a certain software have to be built in the SDC system, but also in the road traffic checking system. Their duty is to take of care of actors on public roads. If there is a misinformation sent, the system has to stop it immediately. Then the sender of the information is identified. If the sender knows that the information is false, he is liable for negligence or fraudulent misrepresentation. Unfortunately, some misinformation cannot be 'catch' by software. For such cases to prevent SDC from hackers and to increase the level of cyber security, legal regulation for forming corresponding digital infrastructure is necessary (Cveticanin & Ninkov 2022_1).

Hacking remains an evergreen issue the software is often not able to manage. Software in Cyberspace are extremely intertwined. SDCs are often facilitated by/on the internet, but are also designed to be active in the real space and real time. Thereby, it is possible much easier and more to cause physical harms on SDC and widely.

Cyber security seems to be one of the heaviest aspect in SDC which has to be solved. The cybersecurity rules have to be connected with existing principle of data protection and has to eliminate the possibility of privacy interruption even if the information are stolen or improperly handled. Cyber security protocols for special verifications of messages and other protection are required to be developed.

The aim of this Chapter is to give legal instruction for processing data of SDC.

3.1 'Personal data' in SDC

The definition is that the 'personal data' are all those which are or can be assigned to a person in any kind of way. The personal data are referenced as direct or indirect identifiers like: identification number, location data, an online identifier or one of several special characteristics, which expresses the physical, physiological, genetic, mental, commercial, cultural or social identity of ‘natural persons’ and is not references to information about legal entities such as corporations, foundations and institutions. The subject identification also includes, for example, the telephone, credit card or personnel number of a person, account data, number plate, appearance, customer number or address are all personal data. Since the definition includes “any information,” one must assume that the term “personal data” should be as broadly interpreted as possible. The same also applies to IP addresses. If the controller has the legal option to oblige the provider to hand over additional information which enable him to identify the user behind the IP address, this is also personal data (European Parliament, 2016). The law states that the information for a personnel reference must refer to a natural person. For natural persons protection begins and is extinguished with legal capacity. Basically, a person obtains this capacity with his birth, and loses it upon his death. Data must therefore be assignable to identified or identifiable living persons to be considered personal.

Sometimes, in addition to general personal data, which are previously mentioned, one must consider above all the special categories of personal data (also known as sensitive personal data) in SDC which are highly relevant because they are subject to a higher level of protection. Some of so called sensitive personal data include genetic, biometric, sexual information and health data.

3.2 Privacy in SDC

The biggest issue dominating ethical and legal discussions about SDCs is the concern about privacy (van Asbroeck *et al*, 2014). People are entitled to freedom from government interference in the quiet use and enjoyment of their property, but only to a certain extent (Onsrud *et al*, 1994). The level of that extent is still developing in the sense of the law. Such guarantees and protections are today embodied in most countries laws as well as in various international rights legislation. Of especial note, the International Covenant on Civil and Political Rights (ICCPR) was first adopted by the UN General Assembly on the 16th December 1966 and took force from the 23rd March 1976 committing parties to respect civil and political rights of individuals, including the right to life, freedom of religion, freedom of speech, of movement or assembly as well as the right to due process and a fair trial (UN General Assembly, 1966). Also, the right to privacy is recognized worldwide and needs to be protected as a fundamental one, especially nowadays. Article 12 of the Universal Declaration of Human Rights (UDHR) recites: “No one shall be subjected to arbitrary interference with his privacy, family, home or correspondence, nor to attacks upon his honor and reputation. Everyone has the right to the protection of the law against such interference or attacks" (UN General Assembly, 1948).

Aside from the presence of a powerful tool such as the UDHR, the right to privacy was further taken into great consideration in relation to the digital age by the OHCHR. The Human Rights Council, in fact, adopted in 2013 Resolution 68/167 which deals specifically with the protection of the right to privacy in the digital age. The Council fully recognized the particular need to consider the human rights implication in a context of "interception of digital communications and collection of personal data, including on a mass scale, with a view to identifying challenges and best practices" (UN General Assembly, 2013).

The big data from SDC can be used useful to help to determine liability in accidents, insurance pricing, motivate better driving practices and improve safety, but with potentially minimal impact on privacy (Dhar, 2016).

The privacy and freedom in SDC regulation has to be reconciled with tort liability widely explained in the previous Chapter (Boeglin, 2015).

3.3 Personal data protection system

There is a great need to strengthen the realization of the right to data protection for SDC as a fundamental human right owed to all individuals. Big data are collected with SDC and the question is "what rights users have over the use of these data" (Rodriguez, 2019). What is the duty of the data user concerning protection of privacy of data owners in spite of the fact it is claimed that such data can be announced or generalized. In addition, the conceptualizing of the right to data protection in an era of big data has to be considered (McDermott, 2017).

SDCs have raised understandable concerns for lawmakers in data protection. Legal acts concerning the use of SDC data are primarily directed towards the safety of people whose life could be at risk from the use of these vehicles. While some countries have clear, established laws in personal protection, many others have not, or the existing regulations do not take into account the influence produced by the SDC. It appears that with acts of personal data protection every owner, operator or user of SDC should be familiar. It is also necessary to think about legal acts which could regulate the which personal data would be usable for certain purposes. Laws and regulations on SDC have to be very similar in all the countries where they exist and have to include security aspects of personal data. The authorities have to be aware of what can be achieved by using data of SDC.

Due to their importance the private data have to be treated in specific manner and the legislation is necessary. In SDC the following problems with private data are evident:

- first, how to store safely these data and protect them of the abuse and
- second, whether the human right for privacy, as the fundamental right, is disturbed due to using of personal data.

In addition, it is the question how the public notation of the data affects the personal safety. For sure, the legal advice is necessary. Namely, development has given rise to a plethora of legal problems, particularly in data protection law (European Union, 2018).

Since 2013 a negotiations on legal regulation of personal data protection began. The Data Protection Working Party of EU, which is the independent advisory body on data protection and privacy, published its views to raise awareness about developments in the IoT and its associated security issues (Pillath, 2016). Based on the result of investigation, the European Union (EU) adopted in 2016 a new legal framework called 'General Data Protection Regulation**'** (GDPR). The European Union General Data Protection Regulation GDPR is one of the strongest and most comprehensive attempts globally to regulate the collection and use of personal data by both governments and the private sector. It was enacted in 2016 and went into effect in 2018, across the EU's 28 (i.e. 27) Member States. GDPR is the most comprehensive piece of data protection legislation in the world given in 11 Chapters divided into Sections and 99 Articles. In this text the intention is to specify the GDPR to private personal data necessary in the ride by SDC. As GDPR is a regulation (not a directive), which is under the EU law, directly applicable and there is no need for national implementation it is expected that its specification and annex for SDC would be also applicable for all EU members and also widely. GDPR provides consistent data protection rules throughout EU. It is truly important because it establishes an environment of legal certainty.

The GDPR, introduced in EU, give information how to protect personal data in all spheres of human life. Some specification is necessary to be done due to SDC. To reach the goal, the specific privacy policy according to data for SDC given by passengers has to be formed. The collection, use, sharing and storing of data has to be in secure way directed with rules. Writing a clear and understandable privacy policy requires the right approach. For all of them it is common that the document should be written in simple language and presented in an accessible and easily understandable form and, even more, to cover all aspects of personal data processing activities (European Union, 2017). Persons who read the personal policy have to understand it without any struggle. Of course, such policies will vary across different organizations. In the guidelines the particular needs and requirements of the organization have to be considered. Let us mention some of them.

Firstly, it is important to establish who will collect and process the data i.e. according to Article 13(1) (a) of GDPR “the identity and the contact details of the controller and, where applicable, of the controller’s representative”. Usually, the name of the company or organization, its location, address and contact information has to be mentioned.

Article 13(1) (c) of GDPR requires the information on: “the purposes of the processing for which the personal data are intended as well as the legal basis for the processing” to be provided. In the privacy policy the chosen ground(s) for processing personal data should be clearly stated and the reasoning behind each ground should be explained. Also, the users should be informed about their rights to object to a certain type of processing and provide them with a way to do so.

Another requirement resulting is to present the purposes for which personal data is processed. Information about every aspect of processing should be comprehensive, detailed and easy to understand. The exact types of personal data have to be collected and processed.

Due to the requirement of Article12(2)(a), it is obliged to inform about “the period for which the personal data will be stored, or if that is not possible, the criteria used to determine that period”.

Article 13 (1)(f) of the GDPR requires the information about: “[…] the fact that the controller intends to transfer personal data to a third country or international organization and the existence or absence of an adequacy decision by the Commission, or in the case of transfers referred to in Article 46 or 47, or the second subparagraph of Article 49(1), reference to the appropriate or suitable safeguards and the means by which to obtain a copy of them or where they have been made available.”

Article 12(2)(f) of GDPR says: “the existence of automated decision-making, including profiling, referred to in Article 22(1) and (4) and, at least in those cases, meaningful information about the logic involved, as well as the significance and the envisaged consequences of such processing for the data subject." Based on this article the automated decision-making is suitable for fulfilling the requirement.

Article 13(1) (e) requires provides information about: "the recipients or categories of recipients of the personal data, if any". However, in our opinion, simply listing all the names of third parties involved in processing personal data is not enough. The presentation must have a description of each third-party, data retention, location and storage policies, and also purposes of data processing and legal basis under which the process data is realized using a given tool.

In Article 13(2) (b) it can be read that the privacy policy should also include information about "the existence of the right to request from the controller access to and rectification or erasure of personal data or restriction of processing concerning the data subject or to object to processing as well as the right to data portability." For the record, GDPR requires to tell users about their eight rights, which are: the right to be informed, the right of access, the right to rectification, the right to erasure, the right to restrict processing, the right to data portability, the right to object. Along with the list of the rights, a way how to exercise them has to be provided. It also requires the inclusion of information about visitors' right to lodge a complaint with a supervisory authority if they are not satisfied with the content of the privacy policy or the way of processing the data.

The last thing to include is a description of the process for notifying users and visitors of changes or updates to the privacy policy. After all, users need to know if the document has changed since the last time they read it.

Where is the GDPR applied?

GDPR is applied in all countries of EU. Data protections apply to all corporate entities that process the personal data of EU citizens, even if the processing of relevant data does not take place within the EU. The regulation contains restrictions on transferring personal data outside of the EU.

Even though, GDPR is directly applicable, the Member States should update their existing national data protection laws. The Data Protection Act (DPA, 2018) supplements the GDPR by filling in the sections of the Regulation that were left to individual member states to interpret and implement. All the rights in the GDPR together are at the heart of the regulation's purpose—to give citizens back control over their personal data. Under the GDPR, consent has to be unambiguous. Lubowicka (2021) gives the 7 elements every GDPR-compliant DPA should have.

Thanks to GDPR, more than 100 countries around the world have data protections law, now. The principles of GDPR have to be incorporated in SDC legislation.

Analyzing the GDPR two question are generated:

1) What are the benefits of the regulation?

2) How right of privacy correlate to the data protection declaration in the sense of the GDPR?

Data protection system must be considered at the design stage of SDC. In addition to laws, appropriate safeguards have to be integrated into the processing. Implementation of the data processing principles will be effective if suitable technical and organization measures by data controllers and processors in SDC will be also incorporated.

3.4 Correlation between Right of personal data protection and of Right of privacy

An additional question appears: What is the correlation between right of personal data protection and of right of privacy?

Even though the rights to privacy and data protection are commonly recognized all over the world, they represent two separate rights. They are both crucial components for a democratically oriented society. The data protection originates from the right to privacy and together they have the instrumental role in promoting fundamental values. It is very important to make it clear that the protection of personal data is of fundamental importance of the enjoyment of the right to privacy so, the right to respect for private life and the right to personal data protection, although closely related, are distinct rights. This distinction raises the question of the correlation and differences between these two rights.

Both of them protect the similar value – the dignity of human beings. Also, both of them represent the prerequisites for the exercise of other fundamental freedoms (Lee & See, 2004). It is clear that privacy, itself a fundamental right, is a value that the right to data protection seeks to protect (Lubowicka, 2019). Data protection and the right of privacy have the instrumental role in promoting fundamental values.

There is a greater need than ever before to strengthen the realization of the right to data protection as a fundamental human right owed to all individuals. Examples of abused identification made a ground for adoption of international human rights treaties. The right to privacy is represented as fundamental human right.

Nowadays, almost every country in the world recognizes the right to privacy in various international human rights legal instruments. It is enriched in the article 12 of the Universal Declaration of the Human Rights, article 8 of the European Convention on Human Rights (Council of Europe, 1950), article 7 of the European Charter of Fundamental Rights (European Union, 2012), article 17 of the International Covenant on Civil and Political Rights (UN General Assembly, 1966), in Article 10 of the African Charter on the Rights and Welfare of the Child (Organization of African Unity, 1990), article 11 of the American Convention on Human Rights (Organization of American States, 1969), articles 7 and 8 of the Charter of the Fundamental Rights of the European Union and article 21 of the Arab Charter on Human Rights (League of Arab States, 1994). Not only that the right to privacy is one of the fundamental human rights it is also a tremendously important social value.

3.5 Human rights and security of privacy

The increasing sophistication of information technology with its capacity to collect, analyze and disseminate information on individuals has introduced a sense of urgency to the demand for legislation in the area of protection of human rights (Ninkov & Mester, 2020; Ninkov, 2020_3). The new developments SDCs and advanced transportation systems have dramatically increased the level of information generated by each individual in the 21st century. In SDCs many new types of information are gathered. Everything from GPS trackers and DNA profiles to IP addresses of passengers in vehicle are up for grabs. It is crucial that data protection laws are underpinned by a respect for fundamental human rights. That is because the storage and use of personal information should be at the service of people. To ensure this, data protection laws should take into account people's right to a privacy, which is protected by Article 8 of the Human Rights Convention. They also need to comply with more specific rules set out in the EU Charter of Fundamental Rights, which protects personal data.

Article 8 of European convention for the protection of human rights and fundamental freedom (Council of Europe, 1950) requires public bodies to respect the private life of an individual and any information held about them. They must be able to justify storing or processing of any personal data. To be justified, any interference must both follow the law and have a valid purpose. In addition, the Human Rights Convention provides that governments have a duty to ensure that national laws provide adequate protection for personal data more generally. Comprehensive data protection laws are essential for protecting human rights – most obviously, the right to privacy, but also many related freedoms that depend on ability to make choices about how and with whom to share personal information. The EU regulation expands the directive's privacy protections and introduces new safeguards in response to new technological developments. The GDPR provides new ways people can protect their personal data, and by extension their privacy and other human rights. "Personal data" is defined broadly under the GDPR as "any information relating to an identified or identifiable person" while "processing data" is defined as any activity that touches personal data, such as collecting, storing, using, or sharing it.

Even though the GDPR is an EU regulation, it will affect the data practices of many organizations outside the EU. It applies to any organization that offers ride by SDC or services to people in the EU, or that monitors the behavior of anyone in the EU, regardless of the organization's location. The EU regulation also provides many more privacy protections for people and the data they may be giving a company or government agency.

SDC owners, companies, governments, and other organizations must obtain consent before they can collect, use, or share a person's personal data. Every company must explain how a person's personal data is used, shared, and stored. The request for consent must be clearly distinguishable, in an intelligible and easily accessible form, and use clear and plain language and easy to understand. Sensitive information issues which include information revealing someone's racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, as well as data about genetics, health, and biometrics (for example, fingerprints, facial recognition and other body measurements). Anyone can ask the SDC company about his or her personal data they hold and then request to delete them. A person can download their personal data and move it to a competitor through a new right to data portability. SDC companies are encouraged to build privacy-protecting mechanisms into their systems – a concept known as privacy by design

Application of GDPR is mandatory in SDCs. The GDPR gives people enhanced protections against unnecessary data collection, use of data in unanticipated ways, and biased algorithmic decision-making. In the digital age, personal data is intrinsically linked to people's private life and other human rights. Everything a person does leaves digital traces that can reveal intimate details of their thoughts, beliefs, movements, associates, and activities. The GDPR seeks to limit abusive intrusions into people's private lives through their data, which in turn protects a range of other human rights.

The GDPR regulation also guarantees some protections from decisions based on profiling and from computer-generated decisions. Systems that incorporate algorithmic decision-making or other forms of profiling can lead to discrimination based on race, sex, religion, national origin, or other status. Even if individuals consent, they still have the right to human review of significant results from automated decision-making systems. The application of GDPR, like any new rule, will become clearer over time as people and companies challenge practices and interpretations of its requirements. There are already certain areas that are likely to be contentious and await further resolution.

Member States of the EU have a certain amount of flexibility in deciding how to apply the law and reflect it in their own national data protection regimes. One area in which some variation is expected is the age at which children can themselves consent to the processing of their data without a parent or guardian. Namely, it is the age of children at which they can be passengers in SDC without parent or guardian. The EU regulation allows member states to set the age of consent to anywhere between ages 13 and 16. This raises the risk of inconsistencies in approaches across the European Union.

Another area of uncertainty is when the regulation permits organizations to obtain and process a person's data without consent if the entity's "legitimate interest" outweigh a person's rights and freedoms. What is for certain that the EU member states will still need to apply and enforce the regulation in a way that ensures respect for people's human rights found in the Charter of Fundamental Rights of the European Union. The EU regulation is likely to become a de facto global standard, much as the previous European Data Protection Directive did, because it will apply to any organization that collects or processes the data of EU citizens, regardless of where the organization is based or where the EU data is processed. It is also possible that non-European countries will copy some or many of its protections as they modernize or establish data protection laws.

All countries should adopt comprehensive data protection laws that place individuals' human rights at their center. The GDPR is not perfect, but it is one of the strongest data protection regime in force anywhere in the world.

The GDPR will most likely lead to a flood of court cases and enforcement actions as data protection authorities and companies contest the contours of the rules and the meaning of ambiguous terms. Effective implementation, monitoring, and enforcement are now needed to ensure that the GDPR truly protects the personal information that people share with SDCs and others.

Finally, what is for certain, the GDPR is a vital step toward stronger privacy protections, but it will not be effective without interpretation, implementation, and enforcement.

National data protection authorities will need to rigorously respond to complaints, promptly investigate breaches, and actively pursue investigations to enforce the provisions. Many data protection authorities are poorly resourced, particularly in comparison to large companies, and lack the capacity to play a comprehensive enforcement role. Member states should allocate appropriate financial and human resources to data protection authorities.

Even with strong enforcement, there are still many structural challenges to achieving the GDPR's vision of data privacy and control.

Principles of data processing according to GDPR

There are established six general principles for data processing in the GDPR:

1. Processing has to be lawful, fair and transparent.
2. Collection of personal data is allowed only for specific legitimate purposes.
3. Apply adequately, relevantly and limited to what is necessary.
4. Dates have to be kept up accurately to date, where necessary.
5. Dates have to be stored only as long as is necessary.
6. Appropriate security conditions have to be satisfied during the data processing.

These principles correspond to data protection ones:

1. Processing has to be legal
2. The processing with data has to be in accordance with the law. It is required:

3. Subject to give his consent for data processing.
4. Contractual obligations has to be met.
5. Legal obligations have to be complied.
6. Vital interests of the data subject's has to be protected.
7. Data to be applied for tasks in the public interest.
8. Data to be used only for the legitimate interests of the organization.

Controllers of personal data must put in place appropriate technical and organizational measures to implement the data protection principles. Business processes that handle personal data must be designed and built with consideration of the principles and provide safeguards to protect data (for example, using pseudonymiation or full anonymisation where appropriate), and use the highest-possible privacy settings by default, so that the datasets are not publicly available without explicit, informed consent, and cannot be used to identify a subject without additional information (which must be stored separately). The anonymisation is the one of the recent methods for privacy data protection (van Asbroeck *et al*, 2014). Anonymisation is a process of hiding or concealing data (deleting or omitting data) which makes difficult to identify the subjects, while pseudonymisation is the process of replacing of the direct identification parameters with codes or numbers. For the second the encryption techniques is usually applied. The technique available the change of the plain text into un-intelligible code. The method requires the secure encryption key and algorithm.

No personal data may be processed unless this processing is done under a lawful basis specified by the regulation, or unless the data controller or processor has received an unambiguous and individualized affirmation of consent from the data subject. The data subject has the right to revoke this consent at any time.

The GDPR extends the data rights of individuals (data subjects), and places a range of new obligations on SDCs that process EU residents' personal data.

3.5.1 Subject valid consent

The GDPR introduces stricter rules for obtaining consent for data processing. Consent must be freely given, specific, informed and unambiguous. Silence, pre-ticked boxes and inactivity will no longer suffice as consent. Consent can be withdrawn at any time.

GDPR brings several improvements concerning data protection. Privacy policies have to be written in a clear, straightforward language instead of using complicated terms. The user needs to give an affirmative consent before his/her data can be used. Processing personal data is generally prohibited, unless it is expressly allowed by law, or the data subject has consented to the processing. While being one of the more well-known legal bases for processing personal data, consent is only one of six bases mentioned in the GDPR. The others are: contract, legal obligations, vital interests of the data subject, public interest and legitimate interest as stated in Article 6(1) GDPR.

The basic requirements for the effectiveness of a valid legal consent are defined in Article 7 (European Union, 2012) and specified further in recital 32 of the GDPR (European Union, 2016). Consent must be freely given, specific, informed and unambiguous. In order to obtain freely given consent, it must be given on a voluntary basis. The element "free" implies a real choice by the data subject. Any element of inappropriate pressure or influence which could affect the outcome of that choice renders the consent invalid. In doing so, the legal text takes a certain imbalance between the controller and the data subject into consideration.

For consent to be informed and specific, the data subject must at least be notified about the controller's identity, what kind of data will be processed, how it will be used and the purpose of the processing operations as a safeguard against 'function creep'. The data subject must also be informed about his or her right to withdraw consent anytime. The withdrawal must be as easy as giving consent. Where relevant, the controller also has to inform about the use of the data for automated decision-making, the possible risks of data transfers due to absence of an adequacy decision or other appropriate safeguards.

The consent must be bound to one or several specified purposes which must then be sufficiently explained. If the consent should legitimize the processing of special categories of personal data, the information for the data subject must expressly refer to this.

There must always be a clear distinction between the information needed for the informed consent and information about other contractual matters.

Thus, for example, consent of children and adolescents in relation to information society services is a special case. For those who are under the age of 16, there is an additional consent or authorization requirement from the holder of parental responsibility. The age limit is subject to a flexibility clause. Member States may provide for a lower age by national law, provided that such age is not below the age of 13 years. Consent for online service from a child under 13 is only valid with parental authorization. Organizations must be able to evidence consent. When a service offering is explicitly not addressed to children, it is freed of this rule. However, this does not apply to offers which are addressed to both children and adults.

Last but not least, consent must be unambiguous, which means it requires either a statement or a clear affirmative act. Consent cannot be implied and must always be given through an opt-in, a declaration or an active motion, so that there is no misunderstanding that the data subject has consented to the particular processing. That being said, there is no form requirement for consent, even if written consent is recommended due to the accountability of the controller. It can therefore also be given in electronic form.

3.5.2 Notices of transparency and privacy

SDC owner or operator can collect and process data only for a well-defined transportation purpose and not for different purposes than for the reason initially announced without informing the user about it. It has to be prescribes how personal data is going to be processed, by whom and why. SDCs owners must be clear and transparent about the following: When personal data is collected directly from data subjects (it is the most usual case) or personal data is not obtained direct from data subjects (it is for children and mentally disabled persons) data controllers in SDC must provide a privacy notice at the time of collection. The privacy notice have to be done without delay. For all processing activities, data controllers must decide how the data subjects will be informed and design privacy notices accordingly. Notices can be issued in stages. Privacy notices must be provided to data subjects in a concise, transparent and easily accessible form, using clear and plain language.

Considering the statement of the European data protection authorities which made clear “that if a controller chooses to rely on consent for any part of the processing, they must be prepared to respect that choice and stop that part of the processing if an individual withdraws consent”, by strictly interpretation it means that the controller is not allowed to switch from the legal basis consent to legitimate interest once the data subject withdraws his consent. This applies even if a valid legitimate interest existed initially. Therefore, consent should always be chosen as a last option for processing personal data.

3.6 GDPR in SDC

Application of GDPR in SDC has strictly be defined. Dasko (2018) reported about GDPR modified for SDC and revolution coming to European data protection laws. SDC can collect and process data only for a purpose to fulfill the transportation process and not for different purposes. Reason for data collection has to be initially announced to passenger. Passengers have to be informed about the use of their data.

To date, Germany is the only jurisdiction, where guidelines to development of SDCs with the aspect of protection of human life and rights are placed. The guidelines were done by the Federal Ministry of Transport and Digital Infrastructure (Germany, 2017). In the guidelines any distinctions based on personal features (age, gender, physical or mental constitution) are included as in the Human Rights Codes (described in the text above). In 2016, the German federal government established also an ethical commission to consider the legal and ethical questions within the context of SDC. The commission adopted a final report with 20 ethical rules where the priority fact was the protection of human rights including the human right on life. In the rules three clear principles were highlighted: transparency, self-determination and data security. The ethics commission gave strict requirements in terms of data protection which are in correspondence with GDPR. In the rules it is stated that it is unethical to apply data of individuals (such as their age or gender) for algorithms in the SDC, special as criteria for decision-making during accident (FMTDI, 2017). There is an open discussion regarding the responsibility of persons designing such algorithms.

At the moment it is required that other jurisdictions introduce their own guidelines in develop of SDC. The guidelines have to be accommodated to technical development of SDCs and capability of AI to process complex dilemmas, including for example, multi- stage, chain reaction situations, circumstances where divergent levels of risks and probabilities arise and to include the basic principle of data and privacy protection.

3.6.1 Privacy rights of individuals

In GDPR privacy rights of individuals are defined in 8 items:

- The right to be informed;
- The right of access;
- The right to rectification;
- The right to erasure;
- The right to restrict processing;
- The right to data portability;
- The right to object; and
- Rights in relation to automated decision-making and profiling.

3.6.2 Right to erasure and forgotten

The right to be forgotten was codified and is added to the right to erasure in GDPR (see CJEU, 2014). It grants data subjects a possibility to have their personal data deleted if they do not want them processed anymore and when there is no legitimate reason for a data controller to keep it. The rule regulates erasure obligations. According to this, personal data must be erased immediately where the data are no longer needed for their original processing purpose, or the data subject has withdrawn his consent and there is no other legal ground for processing, the data subject has objected and there are no overriding legitimate grounds for the processing, or erasure is required to fulfil a statutory obligation under the EU law or the right of the Member States. In addition, data must naturally be erased if the processing itself was against the law in the first place. The controller is therefore on the one hand automatically subject to statutory erasure obligations, and must, on the other hand, comply with the data subject's right to erasure. The law does not describe how the data must be erased in individual cases and such an explanation is necessary to be added. The decisive element is that as a result it is no longer possible to discern personal data without disproportionate effort. It is sufficient if the data media has been physically destroyed, or if the data is permanently over-written using special software.

In addition, the right to be forgotten is found in Art. 17(2) of the GDPR. If the controller has made the personal data public, and if one of the above reasons for erasure exists, he must take reasonable measures, considering the circumstances, to inform all other controllers in data processing that all links to this personal data, as well as copies or replicates of the personal data, must be erased.

An erasure request is not subject to any particular form, and the controller may not require any specific form. However, the identity of the data subject must be proven in a suitable way. If the identity has not been proven, the controller can request additional information or refuse to erase the data. If there is a request or a statutory obligation to erase, this must be executed quickly. This means that the controller has to check the conditions for erasure without undue delay. In the case of an erasure request, the data subject must be informed within one month about the measures taken or the reasons for refusal. The right to be forgotten is reflected a second time in the notification obligation. In addition to erasure, according to Art. 19 of the GDPR the controller must inform all recipients of the data about any rectification or erasure and thereby must use all means available and exhaust all appropriate measures.

As in general the right to be forgotten is not unreservedly guaranteed, it has to be prescribed for data in SDC. Passengers may ask the right to transfer their personal data from one service provider to another or not to erase them if their voyage is a routine one and is repeated in certain time intervals. The right to data portability can be exercised also when the legal basis for lawful processing is either - consent, explicit consent or actual necessity. For these cases the transparency about how these data are used (with easy-to-understand information), information about data breach without delay (within 72 hours, for example), clear and affirmative consent when it is required and easy access of the owners to their data is necessary.

3.7 New human authentication system tendency in forming personal data

To improve the cyber security new human authentication system is necessary to be developed (Horizon, 2021). The problem with data for authentication and data to prove authorization is that they are fixed and easy to be hacked. Nowadays, new method for authentication and to prove the authorization is suggested based on the tendency to have the form of the one-time passcode. The idea is not a new one, but the realization is not far to be done. The correct authentication would help for user to know whether the SDC is just that he need. At the other side, the authorization of action is without name or personal details. New technology has to give the cyber-secure system which need not the additional hardware. For example, it is suggested that the new technology use the screen with the grid of repeatable numbers (Horizon, 2021). Users can simply extract random sets of numbers from a randomly numbered on screen grid to create new passcode. All the user requires is a pre-set pattern or shape which tells them which numbers to read off. Because each digit is repeated several times on grid it is extremely difficult for attacker to reverse engineer the user’s secret. Users could set up authentication accounts which they could use whenever they are required to strongly prove their identities. Such an alliance with existing databases would enable persons to go about daily lives, secure in the knowledge that they will be able to prove who they are in a way which cannot be used against them. It is believed that such strong authentication for humans as well as for SDC would decrease the crime.

3.8 Conclusion

The following is concluded:

1. At the moment GDPR is the most comprehensive piece of data protection legislation for SDC in the world. For privacy advocates in SDC the GDPR has to be applied in spite of the fact that it has many loopholes. The GDPR in SDC has to be a big step to the bright future of the modern personal data market. The regulation should be an opportunity to build on SDCs customers loyalty and trust, and to improve their data management systems.
2. Even though, GDPR is directly applicable, the Member States should update their existing national data protection laws and incorporate their specificities considering the SDCs.
3. Both the Data protection and the right of privacy in SDC protect the similar value i.e., the dignity of human beings. Both of them represent the prerequisites for the exercise of other fundamental freedoms in SDC. As the right to privacy represents the fundamental human right, the personal data protection is the part of the human right legality. Protection of personal data is of fundamental importance of the enjoyment of the right to privacy. However, privacy and protection of personal data in SDC should not be considered to be identical but only closely linked, as it is already stated in the jurisprudence of European Court of Human Rights and Court of Justice of the European Union.
4. SDCs developers navigate between privacy and data protection using GDPR (2018) on the one side and the need for vast amounts of proceeding data for SDCs function on the other. In addition, the data protection has to be connected with security and cyber security requirements of SDC. Security and cyber security of the SDC has to be included into legal consideration of privacy and personal data protection. New complex regulation is necessary. Security aspects of the persons have to be arranged in spite of the fact that some private data are widely evident. The cyber security system has to eliminate the possibility of privacy disturbance in spite of some information are stolen or improperly handled.

5. To protect the privacy, it is suggested the new type of person authentication in SDC has to be introduced which will eliminate the possibility for identification personal data and their collection and misuse.
6. In addition, instead of memorizing of pictures during driving, as it is done at the moment, it is suggested the pictures to be transcribed in the shortest time (in a few milliseconds) into a version which is suitable for permanent storage in the form which is inaccessible and not understandable to hackers.

4. LEGAL REGULATION IN SDC AND LEGAL IMPACTS

Technological progress in SDC requires the development of legal regulations (Cveticanin & Ninkov, 2021[1]). In some ways, it is obvious that SDC will be technically ready much sooner than legislation (Greenblatt, 2018), and legislation needs to be addressed as soon as possible. Indeed, there are significant gaps between the technology that enables autonomous vehicles and the legal regimes that govern them, which is a barrier to the diffusion of this technology. In this chapter, the author will present several situations and issues that will need to be carefully regulated in the future. Therefore, each research question related to the legal regulation of SDCs is increasingly necessary and required (Ninkov, 2000[1]). One of the most important and significant questions is certainly how to transform the already existing laws into the new real world of SDCs (Geistfeld, 2017). In addition, SDC liability is also an open question. This chapter provides current information on the legal regulation of SDCs and aims to provide a list of laws needed to regulate SDCs in practice. Brodsky (2016) notes that "the uncertain legal situation can slow down SDCs." Rather than waiting for the law to keep up with technology, or enacting laws that may be too restrictive Rodriguez (2019) suggests legal norms that need to be developed in the context of this transportation innovation, which raises important legal and policy issues. Key legal challenges related to SDCs address legislators and others (insurance companies, consumers, automakers) as well as policymakers, with the goal of creating consistent national frameworks for SDC testing and use (Ilkova & Ilka, 2018).

Some legislation has already been enacted in European countries in 2021 and in the United States (Slone, 2016), but this appears to be only the beginning of this complex problem. There are many shortcomings in the existing legislation and laws and regulations need to be improved (Aarhang & Olsen, 2018).

The state of the law is such that for Level 1, 2, and 3 vehicles (Favaro et al., 2018), key features such as lane keeping, priority at intersections, parking, queuing, merging, overtaking, and passing can be studied on public roads. In such an automated vehicle, the human driver performs the driving tasks on the roads, but the vehicle has systems that automate certain functions, such as parking, adaptive cruise control, lane departure detection, automatic braking, i.e., emergency braking that is not controlled by the human driver. With parking assistance, for example, the car steers itself into the parking space, and adaptive cruise control maintains a certain distance from the vehicle in front. In this vehicle, the driver can work with the software, the 'brain' of the vehicle, especially when a malfunction occurs. However, at Level 3 automation, a problem arises that has not yet been solved: no way has yet been found to return control of the vehicle to the human driver in a fraction of a second, as is required in emergencies. In this vehicle, the driver can work with the software, the 'brain' of the vehicle, especially when a malfunction occurs. Some manufacturers solved the problem by limiting the Stage 3 limit only to lower-speed, low-power vehicles. Some companies have already produced so-called 'fully autonomous' Level 4 and 5 vehicles. Technically, SDCs can move autonomously on existing roads and can handle many types of roads and environmental conditions with almost no direct human intervention. Their testing on public roads is strongly recommended. Testing of SDCs has already been done in a virtual environment, i.e., using computer simulations, but now testing needs to be moved from the laboratory to a physically enclosed environment or on public roads. However, this action requires the authorization of the legal regulation. Nowadays, driving SDC on public roads is possible, but always with test drivers, but also with permitted owners who are always ready to take control. Thus, the vehicles are legal on the road. However, it is expected that starting in 2023, some SDCs will be on city streets without drivers. This requires guidelines for transportation by SDCs on public roads. Traffic regulations will need to be changed to include SDCs. Unfortunately, in most countries around the world, the conditions for introducing the vehicle into public transport are not in place. Recently, it has been forbidden for these SDCs to be sold on the market and to be freely put on public transport. In a few countries, Level 4 and 5 vehicles may be tested on public roads only if the vehicle has a manual override function that allows the driver to take control of the autonomous vehicle at any time and if there is a human driver in the driver's seat of the vehicle during operation who is prepared to take control of the autonomous vehicle at any time. The human driver must undergo special training required by the authorities to be involved in the driving process. So test drivers must always be ready to take control of prototype self-driving cars. Some confusion in the legislation, however, is documented in the Society of Automative Engineers' standard SAE J3016, which states, "Some colloquial uses associate autonomous specifically with full driving automation (Level 5), while other uses apply the term to all levels of driving automation, and some state legislatures have defined it to roughly correspond to any automated driving system at or above Level 3 (or any vehicle equipped with such an automated driving system)."

It is proposed that legalization in SDC be based on existing laws that are established and applied to conventional vehicles and transportation. However, the question is whether there is a legal paradigm shift regarding the legal environment and autonomous vehicles (Petervari & Pazmandi, 2018). Authors Petervaradi and Pazmandi state that the "paradigm, rudimentarily summarized, would mean a complex world where scientific development is achieved by putting together the tiny verified puzzles of the big picture." In this section, the problem of paradigm shift in legal thought is developed through the technique of legal analogies. The review of the fragmentary data obtained by SDC and the analysis of various shortcomings of the current regulations show the tendencies of retreat (Favaro et al, 2018). The findings provide an important starting point for improvements to the current draft testing and development regulations for SDC. However, based on the already accepted legal environment for driverless vehicles (Glancy, 2016), the legislation needs to be improved in the shortest possible time, as it is a serious question how SDCs would function in an unlawful environment (Dolianitis et al., 2019). Laws must incorporate technological, algorithmic, social, economic, and ethical issues (Lim, 2018). Today's laws leave a lot of room for uncertainty. For this reason, automotive companies will not invest in a new fleet of SDCs if they could be forced to take all vehicles off the road after the first accident. Manufacturers are waiting for regulation.

Currently, regulations on SDC vary across countries (Pargendler, 2019). For example, different countries have different legal instruments related to road safety and SDC: declarations (MALTA, 2017), resolutions (European Parliament, 2015), guidelines, but also directives (Kiilumen, 2018) and regulations on type approval of motor vehicles (EU Regulation, 2017). The field of road transport is treated differently in most countries of the world. The EU has introduced the principle of shared competence in transport policy (TFEU Article 4.2.(g), 2008) to the level where it is indispensable for the common commercial policy or competition within the internal market. EU legislators adhere to the classic notion of subsidiarity and proportionality. The concept gives the competent authorities of the Member States the possibility to act and regulate, as it is not yet preempted by the EU. Countries have the option to set their own legal regulations in some segments of transportation, especially in the development of new technologies and sustainable development. In addition, the standards for SDC are not the same in Europe, Japan and South Korea, which meet the United Nations requirements, and China, the U.S., India and Canada, which have their own guidelines. Despite the fact that there is some displacement, the vehicle from one country may not be able to drive on the lane of the other country. For this reason, the regulation must be unified and changed to common principles. The differences are related to demographic, regional and national aspects, individual values, issues related to moral ambiguity, etc. However, these differences must be overcome. To accomplish this task and improve workflows for resolving legal, risk, and compliance challenges, such as data privacy, data breach notification, regulatory reporting, and freedom of information requests, an interface between countries that leverages new types of information technologies such as platforms is needed (Kirk, 2021).

An important part of the future investigation is the prescription of product liability, tampering and accident of SDC depending on the manufacturer (producer, IT), supervisor of the operator and also owner of the SDC. The most important part of liability relates to accidents between an SDC and a conventional vehicle, an SDC and a pedestrian, or two SDCs. Regardless of how laws and infrastructure evolve and how smart cars become, bad things can still happen. The question is what laws will apply in the event of a dispute. Right now, no one knows. Today, the law is trying to keep up with modern technology, which is developing very quickly, and only marginal attention is paid to what is left behind in traffic. Finally, based on the advantages and disadvantages of SDC in all areas (technical, ethical, social), this chapter proposes areas of legal regulation. The responsibility, liability, and security aspects for SDCs must be defined in future legal regulations.

Legal documents must also make changes to infrastructure regulations that are already known. In a sense, the city plan must be changed because the number of parking spaces can be reduced. Namely, the number of individual vehicles will decrease, and parking in front of houses or in front of the workplace will no longer be necessary.

As Westbrook (Martinesco et al., 2019) concluded, SDCs "appear to be able to break the law without the intervention of the human operator,' while other technologies cannot. Thus, when it comes to an accident involving SDCs, the existing contracts and their updates have no potential to address the problem because they all basically exclude the human driver's responsibility in the event of a traffic accident. With SDCs, the driver is outside the vehicle, and the concept of legal regulation must be redesigned to reflect this fact.

4.1 Legislation in testing and road driving of SDC

Thousands of test kilometers will have to be completed in the future to determine the actual characteristics of the vehicle. Over the past decade, SDCs built for Tesla, Waymo, BMW, Audi, Google, Apple, etc. (Bergen, 2015) have been tested on public roads. Unfortunately, the legal regime for SDC testing is very poor and there are significant problems with driving legislation. In most countries and states where SDC testing on public roads is allowed, SDCs must be overseen by a person who monitors proper operation and 'takes over' when necessary. The authorized person must be licensed and comply with a set of operating principles that are required. The licensed operator may correct the vehicle throughout the driving period. The authority responsible for issuing the license depends on the country.

The 1968 Vienna Convention on Road Traffic, signed by more than 70 countries worldwide, establishes principles for traffic law. One of the fundamental principles of the Convention is the concept that a driver always has full control and responsibility for the behavior of a vehicle in traffic. Advances in technology that assist drivers and take over their tasks are undermining this principle, so the convention needs to be adapted and rewritten. New laws and legal regulations are needed for SDC autonomous driving (Smith, 2012). Amendments to the 1968 Vienna Convention on Road Traffic introduced in 2016 provide the opportunity to legalize the use of autonomous vehicles on public roads. The amendment allows SDC to be tested on roads, but the driver must be prepared to take control of the vehicle at any time. The European Parliamentary Research Service (EPRS) stated that this requirement is incompatible with SDCs that do not require a driver. Therefore, further improvement of the amendment to the Convention is needed (Pillath, 2016).

4.1.1 Legal status in the United States and Canada

Expanding on the Vienna Convention, in 2011 the Nevada Legislature became the first to pass a law authorizing the use of automated vehicles. As a result, Nevada became the first state in the world to legally allow SDCs to operate on public roads. According to the law, the Nevada Department of Motor Vehicles was responsible for setting safety and performance standards and designated areas where automated vehicles could be tested. The law defined SDC as 'a motor vehicle that uses artificial intelligence, sensors, and global positioning system coordinates to steer itself without the active intervention of a human driver." The law also recognized that the driver does not need to pay attention while the car is driving autonomously. In addition, Nevada regulations required that one person be behind the wheel and one in the passenger seat during testing.

By 2016, seven U.S. states (Nevada, California, Florida, Michigan, Hawaii, Washington, and Tennessee, as well as the District of Columbia) had enacted autonomous vehicle laws. California and Nevada laws allow SDCs on public roads as long as a human driver is behind the wheel and on alert, and other states allow testing on certain roads. In 2016, California added an appendix to the law that allows automated vehicles to operate on public roads, including those without a driver, steering wheel, accelerator or brake pedal." California is one of the trailing states regulating SDC testing on public roads by adopting rules CA DMV. Under these rules, owners (not just test drivers) are allowed to engage autopilot mode in SDC. In these cars, the human (professional driver or car owner) must sit in the driver's seat and keep their hands on the steering wheel and eyes on the road.

In 2017, the U.S. National Highway Transportation Safety Administration issued 12 new guidelines for SDC. The guidelines propose to remove all barriers to SDC technological development and also encourage the development of legal measures to promote safety. The U.S. National Economic Council and the U.S. Department of Transportation have issued federal standards describing how automated vehicles should respond when their technology fails, how passengers in SDC should be protected in the event of an accident, and how passenger privacy should be protected. These federal guidelines avoid the patchwork of state laws.

In 2019, the U.S. Department of Transportation law stated that the automated system may perform all driving tasks. Under the current law, manufacturers bear all responsibility for self-certifying vehicles for use on public roads. This means that there are currently no specific legal barriers to selling a highly automated vehicle in the U.S., as long as the vehicle meets the legal requirements. It is worth noting that SDC policy at the U.S. level is developed based on federal regulatory law and state principles of federalism (Salatiello & Felver, 2018).

However, incidents such as the first fatal accident involving Tesla's Autopilot system have led to a discussion about revising laws and standards for automated cars.

As outlined above, most jurisdictions in the United States have rules for reviewing SDCs. In addition, some states have more progressive legislation than others or the federal government.

In Canada, Level 3 cars with drivers have been allowed to move on certain public roads since 2019. Transportation is regulated by federal law, but also by some provincial and territorial laws. In 2021, the new guidelines for the testing of SDCs will be introduced, which will clarify the roles and explain the organization for obtaining permits for the testing of SDCs of the various federal, provincial, territorial and municipal governments.

4.1.2 Legal status in Europe

Most countries in Europe have established special agencies for SDCs and have enacted legislation for vehicle testing. While some countries have adopted some sort of roadmap for the next steps in introducing autonomous vehicles on public roads, the current regulatory framework is likely to evolve in the coming years as the technology continues to move toward higher levels of autonomy and ADS .European regulators have allowed limited tests of SDCs. The main barrier for giving the permanent regulation are the safety and security aspects of SDC. In 2016 the EU gives the Amsterdam Declaration (EU, 2016), which mandates guidelines for SDC review and includes a statement on the need for biannual meetings to share and monitor best practices and regulatory progress. European governments are still assessing the impact of SDCs before imposing strict regulations. The goal of the EU and contributing countries is to develop a single regulatory strategy for SDCs.

In 2013, the UK government allowed testing of automated cars on public roads. Previously, all testing of robotic vehicles in the UK had been conducted on private property. Since 2015, the UK has established the Centre for Connected and Autonomous Vehicles, which develops regulations for the public use of self-driving cars. In 2018, experts from this center prepared the Automated and Electric Vehicles Act 2018 (UK Public General Acts, 2018), which received royal assent in 2018. The Act clarifies the liability regime for autonomous vehicles in the United Kingdom. In 2021, hands-free driving for vehicles with automated lane-keeping systems will be legalized for the first time. Further legislative reforms for SDC are expected to be completed by the end of 2021.

In 2015, the French government allowed SDCs to be tested on public roads in Bordeaux, but full legislation was not implemented. In 2020, the French government introduced some regulations in the field of SDCs. The most developed legal regulation focuses on criminal liability. Mandatory safety measures, safety tests, and specific approvals for SDCs used in sectors such as transport and construction are prescribed. In 2021, an amendment to the Road Traffic Act and the Transport Act will be introduced in France, allowing the application of the already existing legal system to the use of SDCs. From 2022, SDCs will be allowed to drive on certain roads as a result of a decree. That same year, the Swiss Federal Department of Environment, Transport, Energy and Communications (DETEC) approved SDC's test on the streets of Zurich.

In 2016, the federal government made changes to the national law and conducted experiments with safety standards as part of the PEGASUS project (FMEAE, 2017). A law amending the Road Traffic Act and the Compulsory Insurance Act is in preparation for 2021, called the Autonomous Driving Act (BGBI, 2021), which will allow SDCs and other vehicles with autonomous driving capabilities to perform driving tasks without a driver on public roads under certain conditions. Certain requirements are prescribed in order to obtain an operating permit. Obligations for owners and manufacturers of SDCs and mechanisms for data protection are given. The special attention is given to accident prevention systems and liability conditions of the SDCs. The adopted legislation allows driverless vehicles on public roads by 2022 (Bellan, 2021). This would allow operations of SDCs without a human safety operator behind the wheel. “In the future, autonomous vehicles should be able to drive nationwide without a physically present driver in specified operating areas of public road traffic in regular operation,” said Bellan (2021). "In the view of the federal government, further steps must be taken to bring appropriate systems into regular operation so that the potential of these technologies can be exploited and society can participate." However, additional regulations are currently lacking, for example in the area of liability. Italy has no fully regulation respect to SDC. In Italy there is the restriction of the use of the SDCs at public roads. Nevertheless, the current regulations allow only the testing of autonomous vehicles of the Level 3 and Level 4 on certain roads and the vehicle must have the human driver who is ready to act at any time. In Spain the legal framework for driving is also introduced (Elizade &Pastor-Merchante, 2021).

Since 2017, it has also been possible to conduct public road tests for development DSCs in Hungary. The test track in the Zala zone (near the city of Zalaegerszeg) was built, which is suitable for testing highly automated functions of SDC. The Hungarian authorities have amended the already existing regulations and introduced a version that only refers to the testing of highly automated vehicles (NFM, 2017).

In Russian, permission was granted to test the prototype SDC cab on the streets of Moscow in 2018. The SDC completed a 780 km trip on a federal highway from Moscow to Kazan, staying in autonomous mode 99% of the time. The permit was issued only for this one-time trip. Recently, however, the SDC has been integrated into public transport: In the city of Ionnopolis, two SDCs operate within five stops. A special legal ordinance has come into force for such an operation in this city.

SDC was tested in Israel. The Israeli Ministry of Transportation granted permission to test the SDC on public roads. However, permission for testing was granted for the application of certain SDC. General rules for SDC testing have yet to be developed.

The European Union

There is no legislation in the European Union that specifically addresses SDC. However, the already existing laws, directives, regulations, etc., are used in the field of design and operation of SDCs according to the European Commission's strategy (EC, 2018) entitled 'On the road to automated mobility: an EU strategy for the mobility of the future'. For example, in 2018, the Directives for Liability for Defective Products Directive 85/374/EEC, for General Product Safety Directive 85/374/EEC, for Machinery Directive 2006/42/ EC, and Directive 2007/46/ EC were modernized. Due to the leadership role of the European Union in the region, it is expected to prepare the framework in SDC regulation on the basis of which member states will have to harmonize their legal measures.

Comparison of EU and USA rules

Comparing the rules in the EU with those in the U.S., one can conclude that the EU rules appear to be stricter than those in the U.S. due to cultural differences. The bases of these rules are different. Namely, in Europe, the focus is on protecting citizens from technological risks, while the focus of U.S. regulations is on the "race to innovate and progress" (Nicola et al., 2018). Thus, testing SDC on public roads in the U.S. does not require compliance with mandatory standards. SDC testing in Europe is typically 'limited to private roads' and 'predefined routes' or 'limited to very low speeds' (Nicola et al., 2018).

4.1.3 Legal status in Asia

In 2016, the Singapore Land Transit Authority, in collaboration with UK automotive suppliers, began preparations for a trial run of a fleet of SDCs for an on-demand automated cab service. UK legislation was adopted in the country, and the Singapore Road Traffic Act (RTA) was introduced in 2017. It is a control-oriented law (Taeihagh & Lim, 2017). According to the Act, the Minister of Transport is responsible for issuing new regulations in the SDC. In addition, the minister is responsible for setting standards for SDC design and for collecting data from SDCs. A five-year regulatory sandbox was created to ensure the safety of the innovation. After that, it is expected that SDCs that demonstrate sufficient competency to the Land Transport Authority (LTA) will no longer require a human driver (CNA, 2017). Currently, an SDC cab operates at a distance of 6 km due to regulations in Singapore's technology business district.

Japan allowed the first test of an autonomous vehicle on the road in 2013, although much of the research by Japanese auto companies took place in the United States. Japan began changing its laws in 2017 based on the prevention-oriented strategy. The laws regulate safety in SDC testing. According to the regulations, the following requirements are mandatory: A human driver with a driver's license who is always ready to apply the brakes, a police permit, clear labelling on SDC test vehicles, and testers who are always ready to apply the brakes are required (Taeihagh & Lim, 2017). To ensure the proper functioning of the SDC, police officers must drive the test vehicle. It is obvious that the Japanese government actively relies on human supervision to avoid the risk of accidents due to technical errors. In Japan, the use of Level 3 automated vehicles on public roads has been allowed since 2020 under the government amendment of the Road Transportation Vehicle Act (RTVA) and the Road Traffic Act (RTA) (Nepaulsing et al., 2020). The RTVA defines the technical specifications (sensors, artificial intelligence to replace the driver's skills, and a recording device to continuously record the trip) and the required equipment of the vehicle. The conditions for the use of the vehicle are limited by the road (expressway, highway, special or general road) and the geographical conditions (special areas, mountains, urban area). In 2021, the Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of Economy, Trade and Industry of Japan launched a new project called 'Road to the L4' with the goal of introducing the use of Level 4 autonomous vehicles by 2025.

In 2017, the South Korean government stated that the lack of universal standards prevented its own legislation from enforcing new domestic regulations. However, once international standards are established, South Korean legislation would be similar to international standards. A Smart Car Council has been established in South Korea to coordinate actions among ministries and to draft the rules (West, 2016).

China's Ministry of Industry and Information Technology has issued a plan for highly automated vehicles, as 10 percent of all cars sold are expected to be fully automated by 2030. China's "Made in China 2025 Plan" also includes SDC legislation. The Chinese government has developed a lighting control-focused strategy that addresses safety risks. Some preventive measures are taken to avoid exposing SDCs to realistic road conditions. It is required that a human driver be in the vehicle with his hands on the steering wheel. The test of SDC on public roads can only be conducted if the government does not give permission (West, 2016). To date, there is no firm regulation on this matter. In 2021, China's Ministry of Industry and Information Technology published the "Draft of Administrative Measures for Road Testing and Demonstration Applications" (the "Draft Road Testing Regulation"), which was converted into a law. The law regulates the requirements for road testing of SDCs. However, most of the regulations on SDCs are still in public consultation, and significant legal developments are expected to take place in the near future.

4.1.4 Legal status in Australia

The SDC statutory scheme in Australia is also inadequate. The National Transport and Infrastructure Council of Australia has published non-binding guidelines for the safe testing of SDCs (NTC, 2017), but it lacks regulation for inclusion in public transport. However, the document containing the lighting control strategy has been prepared.

4.1.5 Conclusion of the state-of-art in legislation all over the world

In the recent future, SDCs are expected to navigate the roads completely autonomously without human intervention. Appropriate legal regulations for SDCs are required to be included in public transport not only for testing but for regular operation.

Generalization of the legal system on the application of SDCs on public roads throughout the world is necessary. Some initial actions in this area have already been carried out based on a comparative analysis of the laws on SDCs in the U.S. and Europe (Kim et al, 2014). The results need to contribute to the standardization of legal regulations around the world. This would provide the opportunity for undisturbed inclusion of SDCs in real life.

The use of SDCs is expected to increase, and this will undoubtedly raise new legal issues. The revolutionary change in technology will require new legal responses. The paper by Vila et al. (2021) reviews the status of recent regulatory developments in the United States, Canada, the European Union, the United Kingdom, and Asia (Japan and China), as well as the state of the regulatory landscape for SDCs in these countries. Examination of the regulatory developments in the various countries indicates that the focus continues to be on developing and updating existing regulatory frameworks to support the adoption of SDCs. It is expected that the regulatory landscape for SDCs and collaboration between jurisdictions worldwide will continue to evolve. Regulators in each country will adapt conventional vehicle safety, liability, and insurance legislation to SDCs.

4.2 Collision legislation

Despite the complexity of SDC's automation, navigation, and decision-making systems, accidents cannot be completely ruled out. For example, some incidents occur during SDC testing, some of them even fatal. For example, the Waymo car is known to have been involved in 12 collisions during the Google project: 8 of these involved rear-end collisions at a stop sign or traffic light, 2 involved the vehicle being sideswiped by another driver, 1 involved another driver running a stop sign, and 1 was allegedly caused by the car's software. Three Google employees suffered minor injuries when their vehicle was rear-ended by a car whose driver failed to brake at a stoplight.

The Tesla car with hardware automation according to SAE Level 5 has been tested on public roads since 2015. The first known fatal accident involving a Tesla car occurred in 2016 in Hubei province in China. The car was severely damaged, but it was not proven whether the car was driving on Autopilot. A similar fatal accident occurred four months later in Florida when Autopilot was active. The driver of the Tesla was killed. That same year, the second fatal accident occurred in Willston, Florida, when a Tesla Model S electric car collided with an 18-wheeler semi-lorry. In the accident, the driver was killed. In 2018, the person died when his Tesla Model X crashed into a concrete barrier on a California freeway while in Autopilot mode. In the three seconds before impact, he did not brake or attempt to steer around the barrier. As a result, Tesla improved the perception system and the level of safety. Simonite's (2016) study analyzing the safety of the Tesla vehicle states that 'Autopilot is more than three times safer than a human driver in terms of fatalities per mile travelled'. However, there are insufficient data to support this claim. The RAND report (Shwall et al., 2020) also raises doubts, concluding that SDCs would have to travel hundreds of millions or even billions of miles before their safety could be meaningfully compared with that of conventional vehicles.

In 2018, an Uber self-driving car killed a female pedestrian in Tempe, Arizona, USA. The car hit the woman while she was crossing the street on a bicycle. Uber's automated system failed to recognize the pedestrian and her bicycle. The accident occurred due to inadequate vehicle safety risk assessment procedures and inadequate monitoring of the vehicle by the driver. The question arises as to when the automatic mode needs to be converted to manual control. Usually, the autopilot is deactivated when a fault occurs in the SDC or when safety is interrupted while driving with the SDC, and then manual control of the vehicle is immediately assumed (Favaro et al., 2018). However, as long as SDCs require a human safety driver behind the wheel, there will be confusion about whose fault it is when something goes wrong. The move from automated to fully autonomous SDC will be a huge step, posing enormous challenges for even the best technology companies.

When an accident with an SDC occurs, a new regulation is needed to shed light on who is at fault: the inventor or supplier of the algorithm for SDC or the human operators or both. The answers to the following questions need to be settled: Who is at fault when there is an accident between two SDCs or an SDC and a conventional car? Is the manufacturer of the SDC or the vehicle owner liable for the accident? To what extent is the manufacturer or the party producing the software liable? Who is liable if the accident is due to a sudden failure of cyber or physical parts?

Most legal scholars assume that an accident will lead to a major design defect lawsuit. Then the manufacturer would be held responsible for the accident. This worries car companies for several reasons. First, the outcome of such a lawsuit is difficult to predict. Second, any court case is expensive, no matter who wins. Interdisciplinary investigations are needed to determine criminal liability in the event of an accident (Martinesco et al., 2019). The lawyers need from the technicians the definition of the autonomous levels and the event record, which is crucial for the reconstruction of the accident or the event. After that, the relevant law can be applied.

Unlike conventional vehicle accidents, where driver behavior is analyzed on a case-by-case basis, SDC accidents can be evaluated as a function of the systemized performance of the entire group of vehicles running the same operating system.

In a world with SDCs, there will be no more driving errors, but the problem of human error will remain. SDC driving performance will be determined by computer software. The source of error will be shifted from the human driver to the people who programmed, designed, and built the SDCs.

4.3 Legislation and data necessary for SDC

An enormous amount of data is required for the SDC to function, not only that from the sensors, but also the passenger's personal data. Personal data include the year, the ID number for entering the vehicle, the locations where the passenger is to be picked up and dropped off, etc. Thank you to a large number of sensors and powerful computers, newer vehicles can collect and record data about how, when, and where people ride. The exact location and route of all passengers is known in real time. The data is relayed not only to a central station, but also to other locations connected to the SDCs. The SDCs are constantly monitoring other drivers on the road, and the information gained cannot only be used in a positive way. If the information is stolen or mishandled, it could be an invasion of privacy. The computer, the 'brain' of the SDC, can also be hacked. Some of the data may directly compromise security conditions.

The handling of data in SDC must be regulated by law. Data security and data protection must be given special legal treatment. The question is whether the gigabytes of generated information have to be stored permanently. How can the stored information be used later? Is it possible to delete the data and information? How to protect the system from hacking and regulate cyber-security? How to prevent cyber-security from being disrupted despite constant monitoring? Is it possible to introduce a legal regulation for cyber-security and protect SDC from insecure systems?

These aspects of data manipulation in SDC have not yet been clarified.

Due to the novelty of SDC as an autonomous vehicle without a human driver, the complete change and adjustment of the legal regulation of road traffic involving SDCs is necessary. The legal framework needs to be improved and expanded, but also new documents need to be included in the legal system. Based on the benefits and pitfalls of the already applied regulations for semi-autonomous vehicles and the already applied traffic and motor vehicle laws, it is important to determine the challenges we will face in the near future and how to avoid them.

4.4 Aim of legal regulation

It is very difficult to create coherent laws for SDC because the problem of SDC in road transport is very complex and raises a large number of issues.

The ultimate goal of this section is to create a plan for an approved licensing and testing framework and standards for SDC, liability standards, safety standards, privacy standards, and personal travel standards, as well as regulations for impacts and interactions with other components of the transportation system. Thus, technological advances in SDC require the development of new laws and regulations, i.e., potential legislation by governments and ministries. Legislation must provide answers to and regulate an enormous number of problems. These include, but are not limited to: moral, financial, and criminal responsibility for accidents and violations of the law; privacy issues, including the potential for mass surveillance; the potential for massive job losses and unemployment among drivers; de-skilling and loss of independence among vehicle users; and the further concentration of market and data power in the hands of a few global corporations that are able to consolidate AI capabilities and lobby governments to facilitate the offloading of liability onto others and the potential destruction of existing professions and industries.

Particular attention in the legislation needs to be focused on privacy issues arising primarily from the interconnectivity of SDCs, which makes them just another mobile device that can collect all the information about an individual. This information collection ranges from tracking distance traveled, voice recording, video recording, preferences in media consumed in the car, behavior patterns, and many other information streams. The data and communications infrastructure needed to support these vehicles can also be used for surveillance, especially when coupled with other data sets and advanced analytics.

4.5 Legal regulation aspects

As the technical development of SDCs reaches a high level, this is the moment when the legal and regulatory questions need to be answered by the legislator with the support of insurance companies and manufacturers. In general, according to Taeihagh & Lim (2019), the aspects of legal regulation are:

1. Liability and Product Liability

2. Security including Cyber Security

3. Data protection

4. Safety issues

The involvement of SDC in road transport requires the standardization of the legal regulation of transport throughout the world. This is a complex requirement because the degree of regulation varies widely from state to state. Differences in road traffic and transportation also make uniform legislation difficult. Standardization between companies and countries is needed. Currently, two contrasting legal systems can be observed for SDCs: an extremely detailed legal system and a second without laws (Anderson et al, 2016). In some parts of the U.S. (California), certain laws have been passed, while in other parts there is no legal regulation of SDC at all. The law must regulate SDC driving in normal circumstances.

Depending on the importance of the problem, it is suggested that the laws be grouped as follows:

1. Laws for testing and driving of SDC on public roads

2. Liability in traffic accidents

3. Laws for privacy and data protection

4. Additional laws for SDC

In this section, the first, second, and fourth groups of laws are considered, while the third group is dealt with in the following section.

Laws in SDC must include positive moral and ethical aspects, such as:

- Safety and prevention of harm
- Moral issues
- Autonomy
- Responsibility
- Rights
- Insurance and discrimination

- Privacy

All these aspects are considered in the text.

4.5.1 Legal liability

If everything goes well with SDC, there is no need to mention the liability issue. But if something goes wrong without human intervention, SDC must be included in the legal liability. The main questions are: How can the traffic accident caused by the SDC be legally regulated? Who is responsible: the vehicle manufacturer, the manufacturer of the installed software or hardware, or someone else? It is important to determine who is responsible for the vehicle and under what circumstances.

There are differing opinions on who should be held liable in the event of an accident, especially if people are injured. Many experts see the car manufacturers themselves as responsible for those accidents that occur due to a technical defect or a faulty design. Aside from the fact that the automaker would be the cause of the problem if a car crashed due to a technical problem, there is another important reason why automakers could be held responsible: It would encourage them to innovate and invest heavily in fixing these problems, not only because of brand image protection, but also because of the financial and criminal consequences. However, there are also opinions that argue that the users or owners of the vehicle should be held responsible, as they know the risks associated with the use of such a vehicle. Experts suggest introducing a tax or insurance that would protect owners and users of SDCs from claims by accident victims.

Incident liability involving SDCs is an evolving area of law and policy that determines who is liable when a car causes personal injury, property damage, or violates traffic laws (Mrcela & Vuletic, 2018). Indeed, as control over driving shifts from humans to SDCs, changes to existing liability laws are needed to fairly determine the parties responsible for damage and injury and to address the potential for conflicts of interest among human occupants, system operators, insurers, and the public sector.

- At automation levels 0-2, the driver is responsible and liable for the behavior of the vehicle. At levels 3 and 4, SDCs become a liability issue. It is important to determine who is responsible for the vehicle and under what circumstances. Currently, few countries have adopted their general liability policies for SDCs, which vary from country to country. However, the most commonly mentioned are:No-response strategy

- Control-oriented strategy
- Toleration-oriented strategy

For liability purposes, Japan uses the no-response strategy, while Germany, China, and Singapore use the control-oriented strategy. The United Kingdom is the only country that uses a tolerance-oriented strategy for liability and insurance risks.

In contrast to the EU, the German government enacted permanent accident liability legislation for SDCs in 2016, following the light control strategy. According to the law, SDCs must install a black box and record the entire trip (JDSUPRA, 2017; Wacket, Escritt, & Davis, 2017). This document must be the basis for assessing liability between the manufacturer and the driver in the event of a collision. For example, if a system failure is determined to be the primary culprit, the manufacturer will be held responsible for accidents (Wacket et al., 2017). Despite the positives of the law, there is a gap in determining the owner of the data collected in the black box (JDSUPRA, 2017).

In Japan, the no-response strategy is used for legislation in SDC. Recommendations on liability risks, which are not mandatory, have been prepared by the National Police Agency (Nikkei, 2018). In the event of an accident, documents describing SDC structures and accident mitigation plans would be added to black box data and would be of interest to authorities. According to regulations, SDC operators or supervisors (via remote systems) are responsible for operational errors (Jiji, 2017; Japan Bullet, 2017), while manufacturers are liable for errors in the system. According to the regulations, the software developers and other parties involved in the original design of the vehicle are not held responsible for accidents (Japan Bullet 2017).

When analyzing the liability laws mentioned above, it becomes clear that determining liability in SDC is a very complex and difficult task (Lohmann, 2016) and is far from a clear-cut solution. Liability for accidents in SDC and damages require the consideration of the

- civil liability shifts and
- liability of manufacturers,
- liability of owners and
- users of SDC.

The proposed aspects suitable for considering SDC-induced damage liability are (Liivak & Lahe, 2018):

- delictual liability,
- strict liability and
- product liability.

In most European countries, the regime of strict liability is implemented for traffic accidents (RoboLaw, 2014) and for the keepers of the vehicle (EU Directive 85/374/EEC on product liability). (The "keeper" is the person who uses the vehicle). The basic theses on strict liability are as follows:

1. Throughout Europe, the vehicle owner is liable for accidents and for all damage caused by the operating risk (incorrect operation of the automatic system, technical defects of the system leading to an accident, etc.). It is irrelevant whether a human or a machine was at the wheel, since the injured party takes action against the vehicle owner on the basis of the strict liability of the driver. It is assumed that the owner or operator of the SDC is liable, even if the client or owner is not driving himself.
2. The manufacturer would be liable if the product does not provide the safety 'that a person may expect, taking into account all the circumstances" (Article 6, EU Directive). Other potential parties that could be held responsible in the event of a technical failure include the software engineers who programmed the code for the automatic operation of the vehicles and the suppliers of components to the SDC.
3. In the event of an accident, the risk and liability issues must be determined on a case-by-case basis and, if in doubt, the damage should be borne by those in whose interest the SDC was operated. If the manufacturer proves to be the bearer of the risk, liability shifting and risk sharing is possible.

In some jurisdictions, the driver's liability is fault-based, in contrast to the vehicle owner's strict liability. The EU has not changed its legal framework to include fault-based liability. However, the EU's European Commission (EC) launched GEAR 2030 to explore solutions to the SDC issue and made recommendations for the use of EDRs in 2017. In addition, members of the European

Parliament recommended EC, a proposal for SDC liability status in the event of accidents (EP, 2017; EPCLA, 2016).

4.5.2 Product liability

Product liability was first addressed in the legal system thirty years ago. At that time, the Directive on Liability for Defective Products (Council Directive 85/374/EEC) was introduced (Nottage, 2019), and several EU countries adopted the Directive into their law. Experiences with the importance of product liability are quite varied (Machnikowski, 2016), but by and large, the Directive provides good results in promoting the safety of people using goods manufactured with new technologies. Based on this observation, a new annex needs to be added to the Directive to address SDC as a product of new technology. Product liability consists of the following elements:

- defect in the product,
- defect in the design and
- lack of warning or lack of instructions.

SDC product liability must be modified and tightened according to these considerations. The fundamental question in a product liability lawsuit is whether the product had a "defective condition" that was "unreasonably dangerous" The issue is often whether the product developer could have made the product safer with reasonable effort. In SDC, the level of safety for new technology is not easily defined and differs in several respects. Although the SDC is assumed to be free of defects, the technology in the SDC is so complex that there is an uncontrollable residual risk of malfunction. Then the manufacturer should be held liable for injuries and damages caused by the functioning of the SDC.

The particular type of liability is associated with SDC's artificial intelligence AI. Since AI is not human, the dilemma is whether it is a legal entity. Solum's (1992) question was the breaking point in AI law: "Can an artificial intelligence be a legal person?" To date, there is no clear answer. For this reason, various legal solutions have been proposed. It is known that AI absolutely routinely follows the rules/regulations and basically serves as a huge library for SDC. But because of its knowledge, AI can do everything on its own, without additional consultation with the operator, and it is a candidate for 'legal entity" status. However, Bostrom (2003) said that AI does not think like a human being and cannot be considered a legal entity, but predicts the need for a change in the concept of legal entity.

There are different software from different vendors, and it is difficult to prove which of them contributes to SDC negligence in the accident. For SDCs, the software problems can override the hardware problems. Software defects are often more difficult to attribute, but it is even more difficult to find the causal link with the required standards of proof. The software that is not trivial often has bugs. Bugs are referred to as errors in the software. In SDCs where Deep Learning is a standard, a bug is not necessarily programmed from the beginning, but may have been learned by the machine. In these cases, the defense can help the manufacturer out of liability (Cummings, 2017). Plaintiffs can attack the defendant's software by looking for bugs and criticising the quality of the software. If they can find flaws and show that these flaws caused the accident, they can prove causation. Arguing that the quality of the software is not adequate is very difficult. The assessment of the quality of the software is subjective. Moreover, the number of solutions to nontrivial problems with software is infinite, so it is not easy to prove causality between the errors in the software and the cause of the accident.

SDC liability can be likened to product liability in private law and based on a simple mechanism of risk allocation rather than intent. It is a principle of private law that is opposite to the principle of criminal law. In common law, the driver is liable under the rules of negligent tort only if he was negligent. For this reason, the plaintiff must show and prove proximate cause of the accident (Petervari & Pazmandi, 2018). If it is proven that SDC is at fault, the defendant may be exonerated. With SDC, the driver is the car itself. Therefore, the manufacturer is highly motivated to give SDCs some legal personality. Then the autonomous vehicle would be held liable.

4.6 Civil Law

Civil law covers a wide range of legal challenges related to SDC. The most important aspect is the issue of civil liability. Civil law must answer the plaintiff's dilemma in a motor vehicle accident caused by an SDC. The question is whether the developer or manufacturer of an SDC algorithm is jointly liable with the human drivers for the behaviour of the vehicle. There is also liability for damages and/or injuries, and it must be further related:

- the product liability law (a specific type of liability for damage and/or injury, caused by a defective SDC)

- the insurance law,

which identify the possible conceptual approaches that would help achieve clear liability rules with respect to SDCs and insurance coverage. The result of clear rules is to minimise litigation.

4.6.1 Insurance law

The problem with insurance law is very current. Due to the decrease in the number of accidents at SDC, it is assumed that there will be savings in accidents. It is predicted that the sharp decline in accidents would disrupt the automobile insurance industry itself (Murphy & Mullins, 2019). The question is whether a change in insurance regulations is necessary and how it should be done. The parameters of traditional automobile insurance need to be changed, moving away from standard user liability and opening up new potential limits and exclusions. Insurance needs to cover third party and technology damage as it has in the past, but beyond that, it also needs to protect companies from third party lawsuits and cyber-security sanctions from regulators.

One possible approach to insurance regulation could be based on mandatory automobile liability insurance under strict liability by requiring SDC manufacturers to provide a portion of the insurance for each vehicle. This would exempt manufacturers from product liability for bodily injury and property damage covered by mandatory motor vehicle liability insurance caused by a product defect that impairs the functionality of the SDC, unless the defect is due to gross negligence. This approach seems to be a good one, but difficulties in administration could arise.

4.6.2 Product liability law

As Villasenor (2014) notes, "product liability law provides the framework for seeking remedies when a defective product causes harm to persons or property." According to this definition, product liability law, which specializes in SDC, must be the legal system that assigns responsibility for accidents caused by SDC. It is suggested that the law be a mixture of:

- Contract law

- Tort law
- No-Fault Compensation Schemes (NFCS)

Contract law applicable to conventional vehicles would not be changed. However, tort law is expected to be transferred to SDCs.

4.6.2.1 Tort law

Most tort researchers approach the questions: how should the legal system assign responsibility for accidents caused by SDCs? Most of them suggest replacing the standard rules of product liability and introducing special new rules for SDCs. Two premises are important in SDC liability. First, because SDCs are expected to be much safer as autonomous vehicles than conventional vehicles, there is a possibility that SDC manufacturers will be liable to their customers for accidents they cannot avoid. From a tort law perspective, however, the statistical safety of SDCs compared to human drivers is irrelevant to deciding whether and when manufacturers of SDCs are liable for car accidents. When SDCs are used reasonably, it is difficult for plaintiffs to identify and define the design defects that can cause injuries (Owen, 2008). Second, because SDCs are mainly machine learning algorithms that may exhibit unexpected behavior due to their nature, it is not possible to label them as faulty. The question is what behavior should be defined as erroneous and whether it is possible to compare it with errors of a car controlled by humans.

It is well known that SDCs are safer than conventional vehicles because of the additional safety and protection systems built into them. For this reason, some researchers propose a liability exemption for SDCs. However, because of the Product Liability Act, it is suggested that SDC manufacturers should not be exempt from liability for selling defective products. It is difficult to see why SDCs should enjoy some degree of liability immunity simply because they may be safer overall than conventional vehicles. SDC manufacturers should not be exempt from liability if their products are defective, regardless of whether they are safer than conventional vehicles. Some researchers believe that absolute liability for manufacturers and mandatory insurance should be introduced. However, the actual state of affairs is in the middle: there is a wide range from general immunity to strict liability to rejection of the tort system in favor of new compensation schemes.

4.6.2.2 No-Fault Compensation Schemes (NFCS)

Victim protection has long played a major role in traffic accident liability law. Traffic accident liability law is a means of providing compensation to victims. Financial support for compensation has been realized through insurance companies. However, it is well known that it is very difficult for the accident victims to get compensation under the tort system. It usually takes a long time for compensation to be paid, and the distribution of compensation among victims is sometimes unequal. Victim protection has long played a major role in traffic accident liability law. Traffic accident liability law is a means of providing compensation to victims. Financial support for compensation has been realized through insurance companies. However, it is well known that it is very difficult for the accident victims to get compensation under the tort system. It usually takes a long time for compensation to be paid, and the distribution of compensation among victims is sometimes unequal. The most important features of the NFCS are the strict distinction between compensation for personal injury and property damage, the absence of fault as a basis for liability, the very limited possibility of recourse to the courts, and financial protection. The scheme covers virtually all persons involved in an accident: the owner, the passenger, the motorist, the pedestrian, and the cyclist and motorcyclist. The occupants and driver of another car involved in an accident may file claims through their own insurance. In addition, certain persons may apply for compensation in the event of death.

NFCSs have been established in various jurisdictions to protect victims and reduce litigation in traffic crashes. For example, NFCS for car accidents already exist in many countries such as New Zealand, Israel, and Sweden. In many other countries (in Canada, Australia, and the U.S.), there is a combination of tort law and NFCS. There are many minor and major differences between the systems in these countries, but the basic concept is the same.

Following the NFCS for victims of traffic crashes that already exist in a number of jurisdictions, this paper designs an NFCS for SDCs. Although the needs of victims of traffic fatalities are not significantly different from those of victims of accidents involving human-driven vehicles (the victim's interest in adequate compensation is as relevant with respect to traffic fatalities as it has been in the past), the actors for liability are different.

The NFCS rule for SDCs states that the insurer is liable for damages if: (a) the accident is caused by an SDC travelling on a highway, (b) the vehicle is insured at the time of the accident, and (c) an insured person or another person suffers injury as a result of the accident." This provision does not define the responsibility or liability of the operator, owner, or manufacturer of the SDC, which is a fundamental feature of the NFCS.

Traditionally, the owner of a vehicle generally takes out insurance, and an accident victim is compensated by the insurer. The owner of an SDC is also required to purchase insurance in order to be included in the NFCS for traffic accidents, knowing when the SDC is used, the time of use, the route of travel, etc.

In traditional traffic accident liability, the manufacturer of the vehicle is not involved in the compensation process, whereas in an SDC accident, it cannot be left out. For human-driven vehicles, approximately 94% of accidents are caused by human error (NHTSA, 2020), and the vehicle manufacturer is not relevant. However, in SDC accidents, the vehicle may be a relevant cause. Therefore, the manufacturer should at least face the economic consequences of an accident to provide an additional incentive to design and build safer vehicles. A counter-argument to this point of view could be that manufacturers already do not produce unsafe vehicles out of concern for their reputation.

In the context of NFCS for SDC, the manufacturer has to take out insurance on the SDC because he assumes responsibility for his product and indicates that want to take responsibility for accidents with their SDCs which happen because the driving technology in SDC does not function adequately. The insurer pays to the victim without to prove that grounds for liability. However, this insurance has not to protect the manufacturer from the consequences based on product liability.

4.7 Criminal law

When SDCs are used, crimes against life and health (specifically, unintentional crimes such as causing the death of another, causing bodily harm, or creating a danger to another) are the primary consideration. In this case, establishing liability is the main problem in prosecuting an accident in court. Liability for a crime is different for a human-driven car than for an SDC. For example, a sleeping person in an SDC is not at fault for a traffic accident, whereas in a conventional car, the driver who falls asleep at the wheel is at fault. These differences make it necessary to change the criminal law and adapt it to the special characteristics of SDC.

In general, research in the area of criminality is dealing with the following questions:

- What crimes may be committed in context of SDCs?
- Who should be held responsible if an offence is committed while using an emission control device (the manufacturer of the emission control device, the owner of the emission control device, the operator or person responsible for the function of the emission control device, the mechanic who attached the autonomous technology to the vehicle, or any other entity)?
- What are basic model scenarios of incidents related to the use of SDCs?
- The incidents may happen under various circumstances. Will the responsible subject change depending on these circumstances and if so, how?
- How should the law react, if the criminally responsible subject is a legal entity?

The problem raised by criminal justice systems arises from the fact that it is not known who is liable for a crime when the autopilot mode is activated. So who is held liable if a traffic violation is found to have occurred when autopilot is active? According to current case law in most countries, the recognition of a person other than the driver (or the holder of the registration certificate) can only be changed by legislative means, i.e., by amending the penal provisions, due to the principle of individuality of punishment, the principle of legality, and the general principle of presumption of innocence, according to which the person who committed the offense is responsible.

1. In accidents involving SDCs, criminal responsibility is a complex and topical issue (Martinesco et al, 2019). In accident criminal law, three different causes can be assumed:
2. Negligence of the operator or supervisor of SDC
3. Design of the system is inappropriate (that may lead to an inappropriate behavior of the SDC)
4. Fault in the system (function of the sensor stops or there is wrong identification of the obstacle, etc.).

Regarding criminal responsibility for damage caused by an SDC, the SDC owner can be charged with negligence under the criminal laws of most European countries, even if the control is in autonomous mode. There is no uniform legislation in this area in the countries of the European Union. Some countries have criminal codes based on the idea of personal guilt (see the Criminal Code of the Slovak Republic, 2005). However, in SDC this thesis cannot be implemented without a human driver. These codes are in need of change, so any research questions that focus on corporate criminal responsibility are of great importance. In the case of SDC, responsibility may be placed on the SDC operator if he has been negligent, or on the owner if he has failed to exercise reasonable care. But what does reasonable care mean for the SDC owner? At what regular intervals must the operation of the elements of the SDC be reviewed? All of these questions need to be included in the law. If negligence is not proven, the manufacturer is criminally liable. Since in most cases a vehicle manufacturer is a legal entity, it is essential to consider the issue of the company's criminal responsibility. Because accidents can occur under a variety of circumstances, it is difficult to separate the fault of the manufacturer from that of the operator or supervisor and to assess the cause of an accident. Only negligence could be considered as the responsibility of the operator or supervisor, but the question is how to qualify it. For this reason, the inclusion of Event Data Recorder (EDR) to reconstruct events is of particular importance to attorneys (Kohler & Colbert-Taylor, 2015). EDR would provide information about the current state of the SDC design (its algorithms, functional levels, components, sensors) and possible errors (technical errors, but also hacking of data, etc.). The analysis of the data will distinguish the negligence in the SDC devices. Certainly, one cannot speak of negligence on the part of the operator or supervisor if the time to act is too short. It is imperative to include in the legal framework the parameter of "reasonable time." In the courtroom, the use of data stored in EDRs may be the subject of judicial security. Prosecutors should be prepared for challenges related to this use in criminal courts. Responses from experts involved in the process should clarify how responsibilities can be divided between SDC owner, operator, supervisor, manufacturer, etc. (Melquiond & Guilbot, 2017). However, the criminal responsibility of other entities indirectly involved in a traffic accident must also be included in the assessment process.

Currently, there are some technical issues with EDR. EDR devices receive untreated data from the environment (air pressure, temperature, humidity, camera images, etc.) and from the SDC (speed, acceleration, engine temperature, etc.), while they do not collect treated information coming from the perception, localization, local and global navigation and control systems. The storage of the data is not standardized and due to the complexity of the data, the visualization of the recorded scenario can be difficult. International standardization of storage methods should be introduced and visualization should be improved.

The SDC suggests addressing legal challenges in the area of criminal law, particularly on the issue of protection from cybercrime and hackers. Cybercrime is a relatively new phenomenon. Since SDC is a type of software that can be subject to various hacking attacks, it is particularly important to ensure adequate protection of vehicle users. This protection has two aspects: one is the criminal aspect - protection from cybercrime by criminal laws - and the other is the development of an appropriate security system regulated by technical norms and standards. For security reasons, it is necessary that SDC data is also stored in EDRs. These platforms can alert security teams to threats and enable rapid intervention at the endpoint.

4.7.1 Cyber liability and Cyber-security Law

It is well known that the most dangerous attacks on the security of SDCs can be carried out by hackers. They operate in two directions (Hickey, 2012): in gathering information or in sabotaging it by interfering with the normal operation of the SDC. SDCs must be protected from cyber security disruptions by technical means, but also by legal provisions.

Cyber liability is one of the most important issues to address legally. Liability for security rests with SDC manufacturers and operators. Methods to verify data in the SDC and detect inaccuracies that may affect the security of SDC operations must be developed and incorporated into the system. This will require further research by scientists and financial support from vendors. According to the cyber-security regulation, the data collected in the vehicle can be used by law enforcement agencies if the SDC is hacked. However, the privacy of innocent people should not be violated.

Most governments have introduced non-mandatory cyber-security guidelines (EU, US, China, and Singapore) and enacted new laws to address cyber-security risks (Taeihagh & Lim, 2019).

The first cyber-security strategy in EU was introduced in 2013. The first wide legislation on cyber-security in EU was in 2016 when the Directive on the Security of Network and Information

Systems (EC, 2017) was established. Since that time various EU organizations provide recommendations on cyber-security issues but the amendment on SDC is missing.

Germany is seeking to adapt cyber-security legislation, drawing on the recent findings of government-organized working groups that have already examined the relationship between SDCs and cyber-security and privacy (ERTRAC, 2017).

The UK government has taken steps to improve SDC resilience to risk and raise awareness, but legal control is not yet exercised (Taeihagh & Lim, 2019). For general cyber systems, the government has developed the National Cyber Security Strategy 2016-2021 (NCSC, 2016), which focuses on promoting cyber security for all systems against cyber threats. In addition, the Department for Transport (DfT) recommended a specific design for cyber-security in SDC to be resilient to attacks and provide appropriate responses when defenses or sensors fail (DfT, 2017).

In 2016, electronic systems security research departments and agencies were established in the United States to assess and monitor potential cyber vulnerabilities in SDCs, developed under a proposal from the National Institute for Standards and Technology (NHTSA, 2018). In SDCs, computers have a great deal of control over the movements of an SDC and are vulnerable to hacking (Lee et al, 2017). If the security is not sufficient, the communication channels between V2V and V2I can be hacked (Dominic et al, 2016; Pinsent, 2016). To hack, hackers use wireless networks such as Bluetooth, keyless entry systems, etc. (Lee, 2017). SDCs are attractive targets for hackers because they are able to store and transmit transactional and lifestyle data that can be sold, used by extremists for physical harm, or even used for illicit purposes, such as by drug traffickers (Koenig & Neumayr, 2017; Lee, 2017). Among the greatest threats to SDC are fake messages from counterfeit global navigation satellite systems (GNSS), as the data can be manipulated to disrupt SDC's security-critical functions (Bagloee et al., 2016). In addition, research shows that threats include tampering with sensors to disorient SDC by blinding cameras with bright lights, or by interference from ultrasound or radar to blind from obstacles, etc. (Page & Krayem, 2017). These findings have raised awareness of cyber security risks. Based on these findings, the Security and Privacy in Your (SPY) Car Act of 2017 (SCA, 2017) was introduced. The National Highway Traffic Safety Administration (NHTSA) initiated the development of vehicle cyber-security regulations that require vehicles manufactured in the United States to be protected against unauthorized access to information collected by the embedded system vehicle.

Thus, data are protected against electronic controls on driving data (vehicle speed, location, owner, passengers, operators), against the transfer of data from the vehicle to another location, and against the storage or use of data outside the vehicle. Under this law, critical and non-critical software systems in vehicles must be separated. In addition, the law addresses the issue of distribution and storage of collected information (in the vehicle, when transferred from the vehicle to another location, or when otherwise stored outside the vehicle). The law requires SDCs to be able to immediately detect, stop, and report attempts to collect driving data or take control of the vehicle. The SDC must demonstrate the extent to which it protects consumers' cyber security and also their privacy.

The Japanese government follows the so-called 'no-response' strategy regarding cyber security in SDC (Nikkei, 2015). Indeed, there is no regulation with recommendations on cyber security risks specifically for SDC. However, there is an intention to raise awareness of cyber security and data protection in SDC in the future by revising the laws on liability and cyber security.

China's cyber security law has a control-oriented strategy that focuses on the protection of personal data, the security responsibilities of network operators, the protection of sensitive information within China, the protection of critical infrastructure information, and also sanctions for violations (KPMG, 2017). There is a requirement that the SDC cyber security law needs to be specified. Another issue is how to protect the stored personal data of network and critical information infrastructure operators in SDC before they leave the country (He, 2018).

In 2017, the Singapore government amended the Singapore Computer Misuse and Cyber security Act and legislation in various aspects of cyber-security risk control with the aim of increasing the impact of response to computer-related crimes (Kwang, 2017). To increase cyber-security awareness in SDC, a link is established between academic institutions, local lifelong learning institutes, and the private sector. Singapore aims to become a leading provider of cyber-security services with an adaptation-oriented strategy. There are plans to establish a national cyber defense organization (Srikanthan, 2017).

Similar measures are being implemented in Australia. SDCs and related systems are being examined with the goal of addressing potential cyber security vulnerabilities. National task forces are being established to prepare the national cyber security strategy, taking into account the cyber-security of SDC and other related systems (SCIISR, 2017).

4.8 Law of intellectual property

Each new step in the progress of SDC technology and artificial intelligence in vehicles raises potential legal issues (Simkin, 2019) and requirements. Some legal regulations already exist, but they must be properly applied. For example, there are regulations to protect intellectual property, but engineers developing new products in SDC must be advised to avoid them. However, the legislation protecting autonomy and intellectual property needs to be expanded to include aspects of patents and innovation in cyber-physical systems. The application of patent infringement and to regulate intellectual property (Jones et al, 2019) is compelling. It requires that these new segments be included in the intellectual property law.

4.9 Working (occupation) law

The use of SDCs raises some additional questions of professional law that require the development of a new or modified legal recommendation. For example, a very interesting question is given: If the employee has the job of checking email or performing other tasks by driving SDC, can he or she increase wages and hours and seek compensation from the employer? Labour law must provide the answer to this.

4.10 Administrative law

The main legal challenges related to SDC need to be included in the Administrative Code (Vdovin & Khrenov, 2019). It must answer the following questions:

- Would operating of SDC require special driving license? Whether so, should it be national or international?
- Would driving of SDC be allowed in all regions and roads or it would be mandatory only on special roads?
- Would SDC have to follow all traffic rules or special rules have to be prepared?
- Would there be an external indicator on the SDC?

The answer have to be given with administrative law, special with:

- road traffic law and
- infrastructure law.

4.10.1 Road traffic law

Traffic law includes road traffic rules, licensing, certification, etc. Until 2016, all legislation adopted by a signatory to the Convention (1998) had to require that a human driver be in control of the moving vehicle at all times (see Articles 8(1), 5 and 13(1)). Nearly all EU Member States (except Spain and the United Kingdom) have signed and ratified the Convention on Road Traffic, also known as the Vienna Convention ("United Nations, Vienna Convention on Road Traffic," November 8, 1968, United Nations, Treaty Series, vol. 1042) In 2016, a new paragraph called '5bis' was added to Article 8. This makes automated vehicles compliant with the Vienna Convention after the amendment, provided that the system can be overridden by the driver or meets the (future) requirements of the ECE regulations describing the cross-border technical requirements for approval and the uniform approval procedures for motor vehicles. Sweden and Belgium have proposed some further amendments. The operation of SDCs is different from human-controlled vehicles. SDCs would be programmed so that they do not violate existing traffic laws. This would apply to driving on highways and in cities, but special traffic rules would have to be introduced for closed areas and quarries. Based on these rules, the speed, direction of motion, and trajectory of the SDC would be calculated. Limits on SDC movement between lanes, rules for parking and stopping, entering and exiting the highway, crossing roads, etc., must be regulated. However, some of the SDC driving conditions do not need to be regulated by traffic laws. These include, for example, driving in emergency situations in urban areas or on rough terrain, etc. It is necessary to prescribe the safety level of the SDC control system. The Road Traffic Act contains safety regulations that are mainly addressed to the SDC manufacturer. These regulations would be quite new, but need to be included in the legal system for protection in road traffic. Some countries in Europe and in the USA have already introduced some laws for road traffic with SDC, which allow SDC to drive on public roads. However, all these rules are quite strict and are not sufficient for traffic regulation.

To include SDCs in traffic law, further amendment of the Vienna Convention (www. wien.com) regarding the notion of 'driver' is needed. 4 different approaches are proposed on how to adopt the Convention for SDCs (Vellige, 2019). One is based on Martin and air transport, the second uses the convention as a living instrument, the third sees the user as the driver, and the fourth assumes the manufacturer as the driver.

4.10.2 Infrastructure law and urban planning

The already existing infrastructure law must be adopted for SDC. That is, the transportation infrastructure must be rebuilt to accommodate not only conventional vehicles but also SDCs. At this time, it is not known whether SDC will be the primary mode of transportation. It is expected that SDC will displace public transportation. Policy makers need to take a fresh look at how infrastructure will be built. However, in addition to the problem of infrastructure and road network, there is also the problem of legalizing SDCs on the road.

The design of infrastructure must reduce the risk of traffic accidents and gives suggestions and plans for all types of roads, signalization, etc. to increase traffic safety. Special attention must be given to pedestrians, bicycles and motorcycles in traffic with SDCs. General city policies also need to be modified to meet the needs of traffic with SDCs. For example, it is expected that the number of lanes would be reduced due to reduced traffic volumes, as well as the number of lanes to travel more efficiently. Regulations in urban planning would impact the future livability of the city and sustainability. SDCs would have a profound impact on urban design. Policy reforms to infrastructure would have an impact on traffic congestion (Metz, 2018). It is expected that the road plans and road network for SDC traffic and parking distribution would need to be prepared in the near future (Staricco et al, 2019). Downtown parking lots would be picked up and redeveloped into pedestrian malls, parks, shopping centers, etc. SDCs would park in outlying areas of the city and pick up passengers, just as cabs do today (Chester et al, 2015). Space for public transit needs to be rethought. The need for traffic signals could potentially be reduced through the introduction of smart highways. However, given the uncertainty about the future of public transit, policymakers should effectively plan and implement infrastructure improvements that benefit both human drivers and public transit.

Intelligent highways must be designed. Lighting and other signaling must be unified. It must be redesigned to be recognizable to sensors embedded in SDCs, as well as to pedestrians and other road users. The simplest way is to design existing traffic signs so that they are visible to sensors. This also applies to crosswalks and road signs.

SDC cannot operate without connection to other information systems in different networks. It needs a powerful telecommunications system and a corresponding industry.

Unfortunately, infrastructure laws are not prepared for SDC at this time. It is difficult to prepare a common infrastructure regulation and write coherent laws because there are differences in road traffic and transportation between countries.

4.11 Regulation and Set of Documents for Legalization of the SDC

The potential use of SDCs for civilian applications has presented legal challenges for many countries. These challenges include the need to ensure that SDCs are operated safely without compromising public and national security and violating the private rights of passengers. International standards need to be developed to regulate certain aspects of SDCs. Efforts must be made to harmonize regulations governing the operation of SDCs and to propose a way to integrate all SDCs into the transportation safety framework. There is a need to unify the laws or temporary provisions already adopted on the functioning of SDC and the various regulatory and legislative proposals prepared by some countries. The procedures and legislation in most countries must be made similar so that SDC movement is possible without obstacles. Standardization between companies and countries is needed. However, there are two opposing sides: On the one hand, SDC policy is very detailed and on the other hand, it does not exist.

This Section suggests the regulation set of SDC operations.

Based on the research results presented in the dissertation, the procedure for legalizing SDC as a legal entity is derived. The list of licenses and certificates required to drive SDC on public roads is as follows:

1. Registration of the SDC with the indication of the owner
2. Operator license
3. Approval for SDC for individual or public use
4. Registration of the operation center for directing and control of SDC

SDCs may not be licensed without mandatory liability insurance.

Driving SDCs on the road must comply with rules prescribed by the authorities. These regulations are the responsibility of the national government, but local authorities in different countries may also play a role in approving the use of SDCs in their jurisdictions.

4.11.1 Registration and Labeling of SDC

All SDCs must be registered by their owner on the public portal for users of remotely operated vehicles. Registration not only proves who the owner of the SDC is, but also the technical correctness of the vehicle and the operating device.

Information Needed to Register the SDC

For SDC registration the following is necessary:

- Name and physical address and mailing address (if different from physical address) of the owner
- Email address of the owner
- Phone number of the owner
- Address of the operating center (physical and email address and phone number)
- Make and model of SDC (with indication of the driving side and maximal number of passengers)
- Specific Remote ID serial number provided by the manufacturer (with indication of non-human driving car)
- Indication if the SDC is for individual or collective transportation

Registration Requirements

For registration of SDC the following documents are necessary:

1. Certificate for technical correctness of SDC and
2. Certificate of correctness of the operation center controlling the SDC
3. Confirmation of the paid insurance for a third party
4. Confirmation of the ownership

For obtaining of the Certificate of technical correctness of the SDF the following procedures are necessary:

1. Checking the technical correctness of SDC as for the conventional automobile
2. Checking of the properties of the vehicle which available drive on left, right or both sides of road

3. Checking of sensors and of the sensor system for environment perception at certain distance
4. Checking of connection of SDC with operator responsible for drive and monitoring
5. Checking of the alarm system in the case of malfunction, fire, collision, security breach (for example, due to hacker intrusion) and so on
6. Technical validation for the case of Autopilot drive

Once the SDC is registered, the registration certificate is issued. The owner must be in possession of the registration certificate (either hard copy or digital copy). The owner of the SDC must be able to provide proof of registration in the event of an inspection. SDC operators must also be in possession of the SDC registration certificate (either hard copy or digital copy) and their own operator license. SDC operators who are required to register must show their registration certificate to any law enforcement officer upon request. Registration is valid for one (1) year. When the registration expires, it must be renewed. Failure to register an SDC may result in regulatory and criminal penalties. Once registered or approved, commercial use of SDCs is permitted.

Label of SDC

All SDCs must be assigned a registration number. In fact, the registered SDC is assigned a registration number that must be permanently affixed to the vehicle and visible at all times. It is recommended that the registration number be affixed legibly to an exterior surface of the SDC and maintained in a legible condition.

4.11.2 SDC Operator License

The ordinance provides that anyone may purchase an SDC and become an owner of the SDC. However, operators must have special qualifications to manage and use SDCs for transporting third parties. Operators must have a permit to drive outside the vehicle, i.e. the operator's license.

In order to obtain a license, the person wishing to work with SDC must apply to a specific directorate for approval. After the directorate grants the license to take the professional examination on the knowledge of the rules set in the regulations, the candidate answers various questions on the function of the SDC, but also on the security aspects in the SDC. Depending on the score, the person receives a license and has the opportunity to drive the SDC on the track. If the whole procedure is passed, the candidate receives a driver's license. Sometimes it is necessary to apply for and obtain another license from the relevant ministry.

The permit is needed because the SDCs can seriously endanger both security and privacy of individuals or groups. Operators must maintain a connection with the operated vehicles at all times.

If SDC is for commercial use additional tests and qualification would be required of operators.

4.11.3 Driving Authorization

Only SDC registration, operator's certificate, and operator's license are required for SDC travel on public roads. (The operator's certificate must demonstrate that all systems for SDC safety and driving are correct and in good working order.) However, for SDC experimental and testing purposes on public roads, vehicle registration is not required. In this case, the approval of certain authorities is sufficient.

The test drive permit must be applied for from the relevant authorities. The drive must be scheduled with a lead time of 5 to 10 days for the appropriate service. A person who has a permit to operate SDC during the trial run must notify the authority of the city, route, start and end time, and purpose of the run. SDC is possible to operate only after obtaining the permit.

Additional Requirements

Real-Time Supervision System

Because the SDC allows for the transmission of data in real time, the SDC must be equipped with an electronic identification device. In addition, a system for storing SDC driving data must be installed. Storage of all monitored data and driving conditions of the SDC is required. There must be a regulation for the use of data collected from passengers and the vehicle.

Privacy Protection System

The public-use SDC must be able to ensure the protection of privacy in the work of the SDC in accordance with the strict standards already in place for the processing of personal data and the legislation on the protection of personal data and privacy.

For privacy reasons, passengers in the SDC must be informed of the vehicle's route, but without identifying passengers in the SDC and their location requirements.

4.11.4 Special driving rules and regulations

In addition to standard traffic regulations, special rules according to SDC may be prescribed:

- Permitted maximal driving speed on the highway and in the city
- Mandatory distance between vehicles
- Minimal distance to the objects
- Distance to certain places
- Safety distances in addition (to crowds, public events, stadiums and emergency operations, etc.)
- Possible driving bans according to the regulations that can be prescribed by the city, the country and to refer to the time of movement
- Driving bans refer to streets where driving of SDC is not permitted (crowded streets with people, streets with special government organizations, etc.)
- Driving bans refer to some spaces (military regions, prisons, some industrial areas, nuclear power plants, national parks, areas designated as sensitive, etc.)
- Respect to privacy of other people (unless with owner authorization)
- SDC with special task approved by the Directorate of transport

The prohibition of movement is related to the fact that SDCs are able to pick up/transmit optical, acoustic or radio signals. Driving in the uncontrolled space has no restriction, but in the mentioned control space it requires special permission for movement.

SDC may also not be driven in fires, accident zones, or around emergency services.

4.12 Conclusion

Using the aforementioned it can be concluded:

1. At the moment, legislation is the most important task in SDC, since the technology of the autonomous vehicle is almost ready. Some aspects of civil, criminal, administrative, professional, and intellectual property law for SDC have been considered, but more efforts are needed. Legislators should make SDC-related laws on vehicle use and especially liability transparent and accessible to all citizens, as they are of general importance to the entire population.

2. Legal regulations must protect society from the potentially compromising use of SDCs. For this reason, operational and technical requirements for SDCs must be well defined and should form the basis for legal regulations in SDCs to ensure security aspects at the national, regional, and global levels.
3. Specific laws for SDC security must be in place. For example, the legislature should adopt data retention procedures that require a higher level of security and increase safeguards for accessing stored data collected through SDC monitoring. It must be enshrined in law that stored data must be deleted after a specified period of time. It must be required by law that recording devices have a restriction on recording and zooming in on locations that are not relevant to the SDC's action. In this way, locations where citizens have a right to privacy would be excluded from recording. The use of SDC should be regulated in a way that also limits the use of space and time. The purpose of personnel who manage SDCs and have access to broadcast materials must be specified. It must be mentioned in the regulations that the collection, use, transmission, and retention of personal data should be kept to a minimum and the data collected should not be stored or used for purposes other than those for which it was collected. Access to the data necessary to drive a vehicle, from both passengers and vehicle operators, must not be a general public good. It must be defined by law who may have access to this data.

   Legal regulations also need to be harmonized with respect to the results of citizen science projects conducted around the world. Although the participants in these projects are not trained in SDC, they are willing to make valuable suggestions for improving legal regulations in SDC. As part of the Citizen Science project, the public is informed about the reasons for SDC's involvement, as well as policies and procedures. Information is disseminated through print publications, flyers, the website, and social media. Citizen Science activities aim to inform interested citizens in advance of any use of SDCs. This notice includes information about data collection: who collects the data and what data are required for operation. In addition, there is information on how to make contact with the SDC operator.

5. CONCLUSION AND RECOMMENDATION

The dissertation represents the interdisciplinary research on SDC safety in terms of the latest technology on the one hand and legislation on the other. The research considers not only the technical aspects, but also the ethical, social, economic and, above all, the legal aspects, with the aim of creating the appropriate technical - legal link that would improve safety for all subjects in the SDC problem: the manufacturers, the vehicle owners, the insurance companies and other agencies, but especially the vehicle users and all road users. An important part of the research is focused on the interaction between technology and legislation in SDC. As a result, scientific contribution and recommendation follow.

The paper is organized in 5 chapters.

After the introduction, in which the definition of SDC, the difference between autonomous and automated vehicles, and a historical overview of SDC are given, the hypothesis and methods of the thesis are discussed. The aim of the thesis is to present the current state of the art and the results of own research in the field of safety based on objective technical facts, the results of the Citizen Science Project and legal requirements. The aim is also to provide recommendations for the procedure and documents required for the legalization of SDC as a legal entity in public transport.

Chapter 1 examines the technical aspects of SDC. Perception, navigation, and control of SDC are considered in light of CPS. The result of the study must prove that SDC is a special kind of CPS.

Chapter 2 examines the advantages and disadvantages of SDC by comparing the objective aspects and subjective opinions about the vehicle. Public opinion about SDC was collected using a questionnaire as a research tool. The new Citizen Science Project organized for 3 months was suitable to draw conclusions about public opinion about SDC. Based on the subjective evaluation of the future users of SDC and objective criteria about SDC, as a new type of CPS, the pros and cons for autonomous vehicles are discussed. The chapter gives a prediction about the future application of SDC and procedures and tasks to improve the public acceptance of SDF.

Chapter 3 considers the legislation necessary for SDC to be included in public transportation and any additional protocols necessary for the system to operate with SDC. The list of legislation for the legislation is compiled.

Section 4 analyzes the system of privacy and data protection laws in SDC. As a particular aspect, the security of data is discussed. The security of private data is also examined in terms of human rights. As a result, the modification of the GDPR and its adaptation to the security requirements of SDC is proposed.

Chapter 5 presents the summary and conclusion of the research. A summary table containing the hypotheses, methods, and scientific results of the dissertation is included. Recommendations for future research are made in this chapter.

5.1 Summary of research

In this Section the summary of the dissertation is presented.

Topic of the dissertation is the car that would drive without a human driver. The self-driving car is a fully autonomous vehicle where movement is automatic and controlled by a set of machine-learned artificial intelligence computers. SDC is a CPS, an advanced vehicle controlled by a cyber system. Knowledge of SDC encompasses knowledge in many sciences and requires multidisciplinary research. SDC is not only a new technical contribution, but a system that will affect the economy and social property of the whole world. Moreover, it is expected to affect everyone's life in the future.

Purpose of the research was to study all the advantages and shortcomings of SDC compared to the conventional car with human driver, to improve it and eliminate shortcomings, and to make new discoveries in all areas of SDC that would help the vehicle to drive on public roads in a shorter time.

Objectives and aims of the research are: identify the benefits and shortcomings of SDC, taking into account technical, economic, financial, social, ethical, security and environmental aspects, know the opinions and attitudes of the population towards SDC and the possible acceptance of SDC by the population in public transport, propose the necessary measures and documents to ensure the protection of personal data and privacy in SDC with legal support, developing an authorization method for personal data and determining the procedure for deleting data in real time, legal regulation of SDC as a legal entity, drafting documents and measures to legalize SDC, determining legal provisions that should be changed, adopted, modified or added to the existing ones.

Research methods: analysis method, method of synthesis and generalization, questionnaire survey method, statistical methods (cross-tabulation analysis, factor analysis, correlation analysis) Finally, the summary table 1. considers the hypotheses and scientific findings of the thesis.

Table 2. Hypothesis, method, contribution

Hypothesis	Method	Contribution – Scientific finding
1.SDC, being a fully autonomous vehicle, can move without a human driver.	Method of scientific literature survey, Method of synthesis and generalization	SDC is the vehicle with full automation in all modes of drive, with sophisticate sensor system for perception and monitoring of driving environment, with appropriate navigation system and specially developed control system with artificial intelligence which make available for SDC to be driven without human driver control. Hence, SDC is a contemporary CPS which may drive without human driver, The hypothesis is proven. To improve the technical properties of the SDC the vibration suppression is suggested. Two types of metastructures are developed: one, with mass-in-mass unit and second, with mass-in-stiff unit. The energy harvester for transformation of the mechanical energy into electrical is developed. The obtained energy is sufficient to drive the Micro-Electro-Mechanical-Systems and sensors. It is proved for the Lidar.
2. In order for SDC to be accepted by the population, it should have advantages compared to conventional human - driven car in technical, financial, social, ethical, economic, environmental protection aspects, but also in safety and security,	Method of questionnaire survey, Descriptive method, Statistical method	The result of questionnaire survey and statistical analysis proves the hypothesis that the public acceptance of SDC, independently on demographics, is possible only if SDC has benefits in comparison to conventional human driven car in various aspects, like technical, ethical, safety, economic and also in environmental protection ones. However, the contribution of the research is that it shows that the population is not willing to accept SDC until the legal aspects will not be solved. Namely, legalization of SDC, in general, is yet unsolved and the research in this segment is minimal. The finding is that the AI decision in SDC, special in the critical cases in traffic, is not valid if SDC as the legal entity is not included. Inclusion of SDC into public traffic is impossible without: - introduction of adequate legality of SDC, - eliminating of uncertainties in security protection of personal data and - increasing in trust in privacy protection.
3. Only newly developed and adequate measures or procedures for safety	Comparison method	Contribution to this statement is given in the dissertation by creating a new human authentication system with the aim to protect personal data and privacy of SDC users. A new authentication procedure, based on encryption of personal data, represents a suitable way for privacy protection. In addition, the procedure for erasing data in

and security in SDC, would eliminate the worry of population against disturbed personal safety and privacy in SDC.		real-time, prescribed in the dissertation, improves the security of personality. Contribution to increase of the security level in SDC of the person is given also by modifying and extending the text of GDPR by inclusion of SDC and giving the new articles in the existing document of protecting privacy and human rights, special those concerning safety and security aspects. Hypothesis is proved.
4. Inclusion of SDC in public traffic requires appropriate legal regulations in all fields of law with specification that SDC is a legal entity. New registration documents are necessary.	Deductive decision method	Contribution given in the dissertation are in developing principles for inclusion SDC in civil, criminal, work and administrative law with specification that SDC is a legal entity. Regulation and set of documents for legalization of SDC are newly created. There are the new: - Registration document - Operator license - Operation permission - Driving authorization In addition, utilizing the specificity of SDC, the so called - Special driving rules and regulation, is formulated. The hypothesis is proved.

5.2 Scientific Contribution and Recommendation

This study addresses the challenges of SDC, which is expected to be the primary mode of transportation in the coming period. It is assumed that the incorporation of SDCs and the new concept of transportation according to the Industry 4.0 strategy will change civilization and, in general, people's lives. As mentioned above, SDC will raise many issues not only technical, but also ethical, social, economic, environmental and also legal. For this reason, SDC is treated in this dissertation as a complete system, taking into account all aspects: technical, ethical, social, environmental, but also legal and security. (Normally, SDC is examined from only one aspect, and the problem of SDC 'as a whole" remains unclear.)

Scientists note that SDCs would not only change the concept of conventional vehicles, but would have an impact on all aspects of human life. It is well known that nearly 1.25 million people now die in traffic accidents each year, an average of 3,287 deaths per day. Another 20-50 million are injured or disabled. The vast majority of these deaths - about 94% - are caused by one form of human error or another. These numbers are expected to be significantly lower with the introduction of SDF in road transport. Almost all of the scientific literature on SDCs assumes that SDCs are much safer than conventional vehicles. Autonomous vehicles, which either replace human driving with automated functions capable of controlling various aspects of the driving task, are expected to avoid virtually all accidents and usher in a new world of safety and comfort. To get a full picture of SDC, it is not enough to know the opinion of scientists, but it is also necessary to take into account that of the public. In addition to the previously published results of a questionnaire survey in economically dominant European countries, the dissertation sought and analyzed the opinions of respondents in a multiethnic and multicultural community in a country in southern Europe that is not a member of the EU regarding SDC. The research findings differ from those in highly developed European countries: The research pointed out hot issues related to SDC that need to be resolved in order for SDC to be accepted by the population. These are primarily the ethical issue of decision making with artificial intelligence, the problem of privacy and protection of personal data, and the legal regulation of SDC. The presented dissertation contributes to the solution of the protection of personal and private data in two directions: the application of the procedure for encrypted data and the inclusion of the SDC as a legal entity in the already applied GDPR. It is worth mentioning that the research results presented in the dissertation regarding the SDC are focused on ensuring the legalization of the SDC by compiling a set of legal documents for the SDC registration, the operator license for the SDC and the operating certificate with the SDC. The result of the research is also the special driving regulation for SDC on public roads.

Although it is considered that the SDC is technically well equipped to travel on public roads, there are already some doubts and improvements that are needed. Let us mention some of them:

1. A large number of different sensors have been developed to provide a good perception of the environment. However, it has been shown that the sensors see up to 30% less than the human eye. Therefore, there is a need to further develop and improve them.
2. SDCs need relevant information about their current location from the cloud to overcome the limitations of sensor-based information (Kumar et al., 2017). Locations need to have access to 5G technology. Unfortunately, this can be a limiting factor for SDC integration in many places.
3. One of the most responsible jobs in SDC is artificial intelligence. Unfortunately, it cannot be fully tested in the lab. True testing of embedded artificial intelligence is only possible

under real-world conditions. This would require a person to be present in the vehicle and analyze the vehicle's decisions in the most delicate situations. Since a wrong decision by the vehicle can lead to catastrophic consequences, the presence of a human in the vehicle is not recommended. So the problem remains unsolved.

4. It turns out that the problem with fuel has not yet been solved. Due to the increased comfort of SDCs, it is assumed that the mileage and fuel consumption will increase. This will lead to environmental pollution. On the other hand, the use of electric motors will eliminate CO emissions, but the production of lithium batteries will cause new environmental problems. For this reason, it is necessary to increase efforts to find a more suitable fuel for SDC.
5. In cities, conventional vehicles cause high levels of traffic noise. SDCs with electric motors will eliminate this pollution because the vehicles are quiet. It seems that traffic with SDC with electric motor will be convenient in traffic noise elimination, but can cause problems to pedestrians not to hear the vehicle is near them.
6. The legal regime of SDC is one of the challenges for the future application of the vehicle. Currently, there are few laws in some countries that consider SDCs. Many legal aspects have not yet been clarified and are waiting for a solution. However, we must not go too far: Over-regulation, or even uncertainty about possible future regulation, can delay the introduction of SDCs on the road.
7. One of the requirements for SDC use on public roads is that the vehicle is registered (as with drones, see Ninkov & Mester, 2019) and the operators have the appropriate license or permit. Section 4.11 lists the legal acts that the author of this paper proposes for SDC owners and operators.
8. The increasing use of SDCs as autonomous vehicles without human drivers will lead to a gradual shift in responsibility for driving, with the primary goal of reducing the frequency of traffic accidents. Liability for accidents involving SDCs is an evolving area of law that determines who is liable when a vehicle causes personal injury or property damage (Mrcela & Vuletic, 2018) and must be developed before SDCs can be used in traffic. As SDCs shift responsibility for driving from humans to autonomous vehicle technology, existing liability laws must evolve to fairly determine the appropriate remedies for damages and injuries.

9. The SDC movement must be designed to take advantage of the existing potential of roads and infrastructure, but also to rationalize urban and non-urban space (especially parking). In some cities, there are already initial proposals (Elizade, 2021).
10. According to Strategy 4, it is proposed to use automation in the creation of legislation by using the invariance of the principles of machine and legal automation (Ninkov, 2021). It is assumed that this will enable more effective and perspective activity and implementation in the preparation and implementation of laws in SDC.
11. Some additional novelties of research are:

- SDC is proved to be the CPS
- New conclusions about SDC are obtained by comparing of the subjective opinion and objective criteria which have to be the basic statements for approving the vehicle
- Explicit list of regulation and laws in legislation of SDC is suggested

12. Adoption of GDPR to SDC, regulation in data protection and privacy protection in the sense of human rights are registered.

Finally, there is a very high degree of uncertainty about how SDC would affect future life, and it remains unclear how to deal with it. For example, research needs to be done in the area of technology to improve comfort in SDC and protect the environment from vibration and noise pollution (see Cveticanin & Ninkov, 2022_2; Cveticanin & Ninkov, 2022_5) but also in legislation and in the human sciences, to eliminate ethical dilemmas and doubts (Cveticanin, Ninkov, Rajnai, 2022_3). However, SDC poses new challenges for future generations.

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APPENDIX I

QUESTIONNAIRE ABOUT SELF-DRIVING CAR (SDC)

(SDC is an autonomous vehicle which need not the human-driver. Receiving your call the SDC would pick you up and transport you to the willing location in the shortest time, along optimal path and in the most comfortable way.)

Personal questions:

1. What is your gender? a) Female b) Male
2.
3. What is your age?
   a) Under 18
   b) 19 to 29
   c) 30 to 64
   d) 65 or older
4. What is your type of education? a) Non-technics b) Technics

Questions in acceptance of SDC

1. What is your opinion regarding SDC?
   a) Very positive

b) Somewhat positive
c) Neutral
d) Somewhat negative
e) Very negative

2. In how many years do you believe the SDC will be on roads?
   a) Less than 10 years   b) 10 to 50 years   c) More than 50 years
3. How likely do you think that fewer crashes would occur with SDC?
   a) Significant less
   b) Less
   c) Equal
   d) More
   e) Significant more
4. How likely do you think the reduction of sever crashes with mortal would occur?
   a) Significant less
   b) Less
   c) Equal
   d) More
   e) Significant more
5. How likely do you think that lower emission would occur with SDC?
   a) Significant less
   b) Less
   c) Equal
   d) Higher
   e) Significant higher
6. How likely do you think the reduction of fuel consumption would occur?
   a) Significant less
   b) Less
   c) Equal
   d) Higher
   e) Significant higher

7. If you were to ride in a SDC what do you think you would use the extra time doing instead of driving?
    a) Phoning and mailing
    b) Read
    c) Resting and sleeping
    d) Watch movies/TV
    e) Playing games
    f) Working
    g) Eating
    h) Watching road even though I would not be driving
    i) I would not ride in SDC without driver - definitely
    j) Other (please specify)
8. Would you be worried during driving in SDC? a) Yes b) No
9. I would ride in SDC because:
    a) Experience
    b) Can do other things
    c) Long-time trip convenience
    d) Safer than conventional car
    e) Less stress
10. I would not ride in SDC because:
    a) Do not trust
    b) Technology is not ready
    c) Worry of privacy
    d) Enjoy of driving
    e) Hacking
    f) Safety concerns

Thank you for completing this survey about SDC.

APPENDIX II

Final Questionnaire List

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