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DOCTORAL (PhD) THESIS BOOKLET

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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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1. Summary in Hungarian language – Magyar nyelvű összefoglaló

A disszertáció az önvezető autók (ÖA) interdiszciplináris kutatását mutatja be: egyrészt mint ember vezetése nélküli közlekedési eszközt, legújabb technológiai kihívások figyelembevételével, másrészt az ÖA jogszabályait. A kutatás során nemcsak a műszaki, hanem az etikai, társadalmi, gazdasági, pszihológiai, biztonsági, természet védelmi és mindenekelőtt jogi szempontok is figyelembe letek véve azzal a céllal, hogy megteremtsék azt a megfelelő műszaki-jogi kapcsolatot, amely az ÖA valamennyi alanya (a gyártók, a járműtulajdonosok, a biztosítók és más ügynökségek, de különösen a járművek használói) biztonságát javítja. A kutatás fontos része a technológia és a jogszabályok közötti kölcsönhatására összpontosít. A dolgozat 5 fejezetre tagolódik. A bevezetőrész után, ahol az ÖA definíciója, az autonóm és automatizált autók közötti különbségek és az ÖA történeti áttekintése következik. Ezen kívül a disszertáció hipotézisei és módszerei kerülnek bemutatásra. A dolgozat célja, hogy következtetéseket adjon a technika jelenlegi állásáról, és objektív műszaki tényeken, a Citizen Science projekt eredményein és a jogszabályi előírásokon alapuló saját kutatási eredményeket adjon a biztonság és védelem területén. Cél továbbá, hogy javaslatot adjon az ÖA közforgalmi jogi személyként való legalizálásához szükséges eljárásra és dokumentumokra. Az 1. fejezet az ÖA technikai vonatkozásait vizsgálja. Az ÖA észlelése, navigációja és vezérlőrendszere a cyber-fizikai rendszer (CPS) tükrében történik. A vizsgálat eredményének bizonyítania kell, hogy az ÖA a CPS egy speciális típusa. A fejezet ÖA rezgésekkel és ezek megszüntetésével foglalkozik. Új fajta metastruktúrák lettek kifejlesztve a rezgés és zajcsökkentésre. Ezek a metastruktúrák használhtók lesznek másik járműknél is. A 2. fejezetben az ÖA előnyeit és hiányait tanulmányoztam az objektív szempontok és a járműről alkotott szubjektív vélemény összehasonlításával. Az ÖA-val kapcsolatos közvélemény rögzítése a kérdőíves felméréssel, mint kutatási eszközzel történt. Az új Citizen Science Project, amely a különböző korú, iskolai végzettségű és nemű, többnemzetiségű és multikulturális lakosság mintáját állította össze, melynek eredménye alkalmas volt arra, hogy következtetéseket vonjunk le az ÖA-val kapcsolatos közvéleményről. Az ÖA jövőbeli felhasználóinak szubjektív becslése és az ÖA, mint a CPS legújabb típusa objektív kritériumai alapján az autonóm járművek előnyeit és kontraitjait tárgyaljuk. A fejezet előrejelzést ad az ÖA jövőbeni alkalmazásáról, valamint az

ÖA lakosság körében történő elfogadottságának javítását szolgáló eljárásokról és feladatokról. Ez magában foglalja az ÖA biztonságának és kiberbiztonságának javítását. A 3. fejezet bemutatja az ÖA biztonságának javítását célzó intézkedéseket. Javasolat van adva az új adatengedélyezési eljárásról. Elemezve van az ÖA-t a magánélet védelmére és az adatvédelemre vonatkozó jogszabályok rendszerét. Különleges szempontként az adatok biztonsága lett tárgyalva. A személyes adatok biztonsága emberi jogi értelemben is vizsgázva van. Ennek eredményeként a GDPR módosítása és az ÖA biztonsági követelményeinek megfelelő átvétele javasolt. A 4. fejezetben figyelembe veszik azokat a jogszabályokat, amelyek az ÖA közforgalomba való bevonásához szükségesek, és minden további protokoll, amely a rendszer ÖA-val való működéséhez szükséges. A törvények és a jogszabályokhoz szükséges dokumentumok listája összeállításra kerül. Az 5. fejezetben a kutatás összefoglalását és következtetéseit mutatjuk be. A disszertációban szereplő hipotézist, módszereket és tudományos eredményeket tartalmazó összefoglaló táblázat lett hozzá adva. A fejezetben javasolt a jövőbeli kutatás.

2. Antecedents of the Research

One of the most important means of transportation for humans is the car. The first car came on the market in 1920, and since then it has evolved according to technical achievements. The car is fast, comfortable and has a beautiful design. Nowadays, there are said to be about 1.4 billion cars on public roads. Despite the many advantages in transportation, the car also has significant shortcomings. Let us name some of them. The large number of cars causes the roads to be crowded and traffic to slow down, which leads to people spending a lot of time in the car. There is also the problem of parking. Recently, pollution caused by combustion products causes a number of problems. However, the main problem with cars is accidents.

Very often, due to the human factor (insufficient attention, fatigue, driving under the influence of alcohol, etc.), traffic accidents occur, some of which unfortunately end fatally.
To eliminate the disadvantages of the conventional car, research is being conducted on a new type of car. The main research tasks were: Reducing the number of accidents, especially those with fatal outcomes, i.e., eliminating the influence of the human driver, increasing safety, reducing traffic congestion, eliminating the infrastructure problem of overcrowded roads and parking lots, optimizing and accelerating the flow of traffic, reducing pollution, and making the ride in the car more comfortable. The result of the research is the newly developed self-driving car (SDC). Usually, the term 'self-driving car' is used in a very broad concept and the definition in the technical sense is necessary to be introduced. In this dissertation, SDC is considered as the "fifth stage" of automated vehicle in terms of the standard AS-IS SAE - International J3016TM, 2014 [SAE, 2014]. "It is an autonomous vehicle that is capable of sensing the environment and moving safely without a driver." It is obvious that the definition implies that the usual car must be redesigned by adding various sensors (radar, lidar, sonar, cameras) for perception, general position signalling (GPS), odometrics and inertial measurement units (mechanical equipment) for navigation, and a set of computers and software for vehicle control, navigation, and propulsion. 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. In these cars, machine-learned artificial intelligence (AI) is used to make decisions. The technical implementation of the project is possible at this stage of development. Indeed, the SDCs represent an advanced cyber-physical system, a vehicle that is navigated, steered, and controlled with the knowledge

of the cyber-system. However, many additional challenges remain unsolved: primarily in terms of safety aspects and secondarily also in terms of ethical and social aspects of the passengers. SDC is not just a new technical contribution, but a system that would affect the economy and social welfare of the whole world. Moreover, it is believed to affect the life of every person in the future.

Since the problem of WDK is complex and multidisciplinary, the intention of this work is to increase the knowledge of WDK from different aspects (technical, ethical, social, legal) and to give a new direction for WDK security, especially in the field of privacy and human rights protection. The goal of sustainable development research is to develop a vehicle that can be introduced into public transport as soon as possible as a replacement for a conventional car controlled by a human driver. However, it appears that before SDC can be applied to road transport, important safety and regulatory issues still need to be addressed.

3.Objectives, Aims and Hypothesis

The objective of this research is to overcome the challenges in SDC, especially in terms of safety and regulation, with the aim of having a vehicle that is accepted by the population without worries and doubts. The objectives are as follows:

- identify the benefits and shortcomings of SDC, taking into account technical, economic, financial, social, ethical, safety, 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
- the legal regulation of the SDC as a legal entity.
- elaboration of documents and measures for the legalization of the SDC
- determination of legislation that should be amended, adopted, modified, or added to existing legislation.

The objectives of the dissertation can be understood in the following terms:

1. to show that SDC is a kind of cyber-physical system,
2. to prove that SDC would change not only the technical environment, but also the whole lifestyle and different aspects of human existence, and to draw conclusions in this field,
3. prescribe the list of laws necessary for SDC legislation,
4. develop proposals to amend existing privacy, human rights, and data protection legislation related to SDC. Develop advice on security in the form of strict and detailed rules suitable for application in the EU and other countries of the world, and also.

The hypotheses associated with the above objectives that need to be proven 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 designed control system with artificial intelligence. Then SDC is a cyber-physical system (CPS) in the technical sense (Putnik et al, 2019). Finally, it must be demonstrated that the SDC can drive as a fully autonomous vehicle without a human driver.

Hypothesis 2: For the 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 discover the reasons for the population's concern and opinion against the use of SDC.

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 reorganisation and amendment of the GDPR, the laws on privacy and human rights, especially those related to security aspects. The objective 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 the SDC by including it in the already existing documents and regulations on human rights. The new data authentication system and data deletion procedure must be developed.

Hypothesis 4: In order for SDC to be included in public transport, appropriate legal regulations must be developed in the areas of civil, criminal, labor, and administrative law 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 current documents for the legalization of the SDC as a legal entity.

4.Research Methods and Challenges

Various qualitative and quantitative methods are used in the dissertation. These are the following methods: Analysis method, synthesis and generalization method, description method, comparison method, questionnaire survey method, statistical methods (cross-tabulation analysis, factor analysis, correlation analysis).

To prove the first hypothesis, the analysis method and the comparison method are applied. Namely, the state of the art in the technical sense of SDC is analyzed [1]. A comparison is made with the requirements of CPS [2]. The applied methods present challenges for the improvement of the SDC in a new direction: the research of the acoustic and vibration characteristics of the SDC with the aim of improving not only the comfort of the vehicle, but mainly the efficiency of the system, reducing the noise pollution and improving the environmental protection.

The dissertation develops the method of opinion research on SDC in the form of the Citizen Science Project (Halday et al., 2021) and explores the level of awareness of SDC among the population. A questionnaire will be used to determine public opinion about SDC. The main question is whether people are aware of SDC, whether they want to use it in transportation, and what benefits they expect from SDC. For the questionnaire survey [3], the existing questionnaire (Qu et al., 2019) was modified by taking into account the specifics of the multi-ethnic and multicultural population in Vojvodina (northern part of Serbia) [4]. The language of the questionnaire was Serbian [5]. The questionnaire contained two sets of questions: one about the individual (participants were stratified by gender, age, and education) and a second

about SDC. The survey consisted of ten questions. Two items required the traditional type of one-dimensional bipolar scaled yes/no response (Marletto, 2019). One item was a single-select multiple-choice question and two items were multi-select multiple-choice questions in which responses could be neutral, i.e., uncertain, in addition to positive or negative (Hulse et al., 2018). For example, the gradation introduced for the responses is significantly less - less - neutral - more - significantly more. The remaining five items were Likert-scaled items that were conceptualized as multi-part (Rosenberg & Hovland, 1960). The conceptualization of the items is to indicate the cognitive, affective, and behavioral components: cognitive - through perceptions, beliefs, and thoughts; affective - describing the feelings and emotions associated with the SDC; behavioral - including behavioral intention and verbal statements. The collected cognitive, affective and behavioral data were processed using the descriptive method, which brings new challenges for the research: the requirements of security and legality must be met. In addition, the statistical method is used for data interpretation. The software SAS JMP r14 was used for the statistical analysis. The method performed the cross-tabulation and correlation analysis of the questionnaire data. Chi-square test was used as an indicator of independence. In order to determine similarities and differences in opinion about SDC between scientists and the population, the comparative method was used.

For the consideration of SDC 'in its entirety' the synthesis method is applied. Based on the results and using the decision-making method, the conclusions for the research are drawn.

5. New Scientific Results

This booklet presents four groups of main dissertation contributions. The research and the scientific results support the 4 hypotheses mentioned in the previous section.

5.1 New Scientific Result in Technics of 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.). 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 [6] and the second with mass-in-structure unity [7]. Both metastructures are said to have periodic structures, but the first one is suitable to absorb vibrations in certain frequency ranges (even low ones), while the second one is said to be a vibration isolator.

The metastructural layer for vibration damping is assumed to have a honeycomb base structure with additional masses in the voids, while in vibration isolation the base structure is rigid and of low mass. In both metastructures, the added mass is connected to the basic

structure by a spring, which is solid (e.g., seat in a vehicle) or rigid (microelectromechanical system). The main part of the metastructure is 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 oscillation energy sets the added mass in oscillation, and the movement of the basic structure comes to a standstill or has a low level.

The question was whether vibrational energy is just waste, or whether it can be transformed and used. In the thesis it is shown that with the help of the energy harvesting system the absorbed kinetic energy of the metastructure can be converted into electrical energy suitable for powering sensors and other microelectromechanical systems in the SDC. The special case of powering a LiDAR by an energy harvester is tested. The efficiency of the system is demonstrated [6].

5.2 Results of Survey in Pro and Contra in SDC

The pros and cons research was conducted by means of a questionnaire survey on a sample of multiethnic and multicultural groups of people of different gender, age and education. To examine the relationship between gender, age group, and educational background in relation to the ten SDC implementation questions, a survey was designed and administered to a sample of 450 individuals, i.e., 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).

Statistical analysis and the chi-square test revealed that there is a significant relationship between gender and familiarity with SDC: a greater proportion of men (79.1%) than women

(46.2%) reported being familiar with SDC. There is also a significant relationship between age group and familiarity with SDC: the 19-30 age group was most likely to be familiar with SDC (78.1%), compared to all other age groups. A significant relationship was also found between education and familiarity with SDC. In the group with technical education, the percentage of those who were familiar with SDC was greater (66.3%) than in the group without technical education (56.0%). Gender, age group, and educational background showed a significant relationship with opinion about SDC. However, for non-technical education, there is no significant relationship between gender and opinion. For technical education background, the conclusion is just the opposite. Respondents' opinions were tested in terms of the estimated amount of time spent introducing SDC to the public. The result was that all groups showed a significant relationship with the time taken. One of the more interesting questions was about the estimated accidents of SDC. It turns out that there is no significant relationship between gender and age group and estimated SDC accidents, but this is not true for the educational background group. A special case of accidents is that with mortality. Gender and estimated fatal SDC show a significant relationship, age group does not. Accidents and between educational background and estimated fatal SDC accidents. The results of the chi-square test show a significant relationship between gender and estimated pollution and between age group and estimated pollution, while the relationship between education level and estimated pollution is not significant. The results of the chi-square test show a significant relationship between age group and estimated pollution, but no significant relationship with estimated fuel consumption. There is a significant relationship between education level and estimated pollution. Chi-square test results indicate a significant

relationship between gender and concern (worry) about SDC implementation. A greater proportion of male respondents expressed concern about SDC implementation (70.2%) than female respondents (48.0%).

The results of the chi-square test showed no significant relationship between the age group and the group with educational background and concern (worry) about SDC. The same was true for the relationship between gender and concern within the group with non-technical educational background. In contrast, there was a significant difference between genders in the case of technical education background. In terms of the possible activities that subjects might prefer during the SDC trip, gender was significantly related to the following choices: phone/email, reading, resting/sleeping, playing games, street watching. In contrast, there were no differences between men and women in movies/ TV, working, and sightseeing. Age group was significantly related to use of phone/email, resting/sleeping, movies/ TV, games, working, eating, street viewing, and sightseeing. The only choice that was not related to age group was reading. The smallest difference between subjects was observed in terms of their education, where a significant difference was found only for two choices - working and sightseeing. Among the reasons for not adopting SDC, gender was significantly associated with experience, safety, long trip, pleasure, and technical problems. A significant association was found between age group and long travel, distrust, technical problems, safety, and privacy. Finally, educational background was unrelated to most of the issues, while it was significant in the case of long journey and privacy protection.

Finally, the survey shows that the population is not ready to accept SDC in its current form. The biggest concerns are security conditions and cybersecurity. Moreover, the population has no influence on the decisions made by the AI. However, in order to get a better and more objective insight into the issues, the subjective opinions of the population about the SDC are compared with the objective statements of the scientists. Using scholarly reports on SDC in technical, social, economic, financial, and security terms, as well as the results of my own survey, the challenges posed by SDC's advantages and shortcomings will become clear. Based on the discrepancy between what the public says and what scholars say, the dissertation identifies the following major themes for further research on SDC [3]:

1. How can the security aspects of SDC be improved?
2. Improve security to protect individuals and privacy in SDC
3. Legalization of the SDC as a legal entity
4. Regulations for the SDC on public roads

Improving the security aspect of SDC focuses on cybersecurity of data and legislation, with the goal of protecting privacy and personal security.

5.3 Results in privacy protection and data authorization

To address challenges 1 and 2, cybersecurity research methods in unmanned vehicles [9] and large-scale privacy protocols have been applied and redesigned [10]. This dissertation contributes to SDC privacy and cybersecurity by developing a new system for authenticating individuals. The proposed system aims to protect the personal data and privacy of SDC users.

The authentication method based on personal data encryption is an appropriate way to protect privacy. In addition, the real-time data deletion method described in the dissertation improves personal security. A new system for authenticating individuals has been developed to improve cybersecurity. The problem with authentication and login credentials in SDC is that they are fixed and can be easily hacked. The proposed method for authentication is based on the form of a unique passcode. The idea is not new (Horizon, 2021) but has not yet been implemented. Authorization of travel by SDC would occur without names or personal information. The new technology is intended to provide a cyber-secure system that does not require additional hardware. It is proposed that the new technology use the screen with the grid of repeatable numbers. Users can simply drag random strings of numbers from a randomly numbered grid on the screen to create a new passcode. All the user needs is a predetermined pattern or shape that tells them which numbers to read. Because each digit in the grid is repeated several times, it is extremely difficult for attackers to decipher the user's secret. Users could set up authentication accounts to use whenever they need to prove their identity uniquely. Such a link to existing databases would allow people to go about their daily lives knowing that they are able to prove their identity in a way that cannot be used against them. It is believed that such strong authentication would reduce criminality for both people and SDCs [9].

A contribution to increasing the level of security in the individual's SDC will also be made by amending and expanding the text of the GDPR to include SDC and introducing new articles to the existing privacy and human rights document, especially with regard to security aspects [11].

5.4 Results of SDC Research in the Field of Law

In order to respond to the aforementioned challenges 3 and 4, an investigation of the existing legal regulations for unmanned vehicles in comparison to conventional vehicles was necessary [12]. As a result of using the analysis method, new regulatory documents for SDC are being developed. The regulations and documents required for the legalization of SDC are as follows:

- Registration document
- Operator license
- Operating permit
- Driving authorization

Taking advantage of the specificity of the SDC, the so-called

- Special driving rules and regulations,

is formulated.

The paper proposes the following regulations:

Regulation and document package for the legalization of SDC

The potential use of SDCs for civilian purposes 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 make a proposal to integrate all SDCs into the transportation safety framework. There is a need to harmonize

the laws or temporary regulations already adopted on SDC activities and the various regulatory and legislative proposals developed by some countries (see, for example, Slone, 2016; Aarhang & Olsen 2019; Nepaulsing et al. 2020) . Procedures and legislation in most countries need to be aligned to enable the movement of SDCs without barriers. 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. Based on the research results presented in the dissertation, the procedure for legalization of SDC as a legal entity is derived. The list of licenses and certificates required to drive SDC on public roads is as follows [13]:

1. Registration of SDC with indication of the owner
2. Operator license
3. SDC approval for individual or public use
4. SDC registration for management and control of the SDC
5. SDC registration is not permitted without liability insurance..

SDC must comply with the rules prescribed by the authorities in road transport. These rules are the responsibility of the national government, but local authorities in different countries may also play a role in approving SDC operations in their jurisdictions.

SDC Registration and Identification

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

correctness of the vehicle and the operator. The information required for SDC registration is as follows:

- Name and address and mailing address (if different from address) of owner
- E-mail address of the owner
- Telephone number of the owner
- Address of the operating center (physical address, e-mail address and telephone number)
- Make and model of SDC (indicating drriver side and maximum number of passengers)
- Specific remote control serial number provided by manufacturer ID (specify non-human driving car)
- Indication of whether SDC is responsible for individual or collective transportation

The following documents are required for SDC registration:

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

The following procedures are required to certify the technical correctness of the SDF:

1. Verification of the technical correctness of the SDC as for a conventional automobile

2. Verification of the characteristics of the vehicle, , which can drive on the left, right or both sides of the road
3. Verification of the sensors and the sensor system to perceive the environment at a certain distance
4. Verification of liaison between SDC and operator responsible for propulsion and monitoring
5. Verification of the alarm system in case of malfunction, fire, collision, security breach (e.g. hacking), etc
6. Technical validation in the event of an autopilot run

Once the SDC is registered, the registration certificate will be issued. The owner must be in possession of the registration certificate (either paper or digital copy). The owner of the SDC must be able to provide proof of registration in the event of an inspection. The SDC operator must also have the SDC registration certificate (either paper or digital) and its own operator's license. SDC operators who are required to register must show their registration certificate to any law enforcement officer upon request. The 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. After registration or licensing, commercial use of SDCs is allowed.

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

SDC Operator License

The ordinance provides that anyone may purchase and own an SDC. However, special operator qualifications are required to operate and use SDCs for the transportation of third parties. Operators must have a license to drive outside vehicles, i.e., a driver's license.

In order to obtain the license, the person wishing to work with the SDC must submit an application for approval to a specific directorate. After the directorate approves the application, the candidate takes a professional exam on the knowledge of the regulations set out in the regulations and answers various questions on the function of the SDC, but also on the safety aspects of the SDC. Depending on the score, the person receives the 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 permit from the relevant ministry. Authorization is required because SDCs can seriously compromise both the security and privacy of individuals or groups. Operators must maintain a link to the operated vehicles at all times. If the SDCs are used commercially, additional testing and qualifications of operators are required.

Only SDC registration, operator's certificate, and driver's license are required for SDC participation on public roads. (The operator's certificate must demonstrate that all SDC safety drive systems are correct and in good working order.) However, for trial and test purposes of SDC 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 at the relevant authority.

The trip must be scheduled with 5 to 10 days' notice for the particular service. A person holding a permit to operate SDC during the trial run must notify the authority of the location, route, start and end time, and purpose of the run. SDC operation is not possible until the permit is obtained.

Additional Requirements

Real-Time Supervision System. Because SDCs allow for the transmission of data in real time, SDCs must be equipped with an electronic identification system. In addition, a system for storing SDC driving data must be installed. Storage of all SDC monitored data and driving conditions is required. The use of the collected passenger and vehicle data must be regulated.

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

Special driving rules and regulations

In addition to normal traffic rules, special rules may be prescribed for SDCs:

- Maximum allowable speed on the highway and in the city
- Prescribed distance between vehicles
- Minimum distance to objects
- Distance to certain places

- Additional safety distance (to crowds, public events, stadiums and emergency operations, etc.)
- Possible driving bans according to the regulations that can be imposed by the city, the country and the time of movement
- Driving bans refer to streets where SDC driving is not allowed (busy streets with people, streets with special government organizations, etc.)
- Bans on driving refer to specific areas (military areas, prisons, certain industrial areas, nuclear power plants, national parks, areas designated as sensitive, etc.)
- Respecting the privacy of others (except with permission of the owner)
- SDC with special order approved by the Directorate of Transportation

The prohibition of movement is related to the fact that SDCs can record/transmit optical, acoustic or radio signals. Driving in uncontrolled space is not subject to restrictions, but in the aforementioned control space, special permission is required for movement. SDCs are also not allowed to be driven on fires, in accident zones, or near emergency services. The contribution of the dissertation is also the development of principles for the inclusion of SDC in civil, criminal, labor and administrative law with the determination that SDC is a legal entity [14].

6 Possibility to Utilize the Results

The results obtained are suitable for practical application. Let us mention some of them:

1. The mechanical metastructure considered in the thesis would be applicable not only in SDC but also in conventional vehicles for vibration and noise elimination.

Depending on the basic unit of the metastructure, it is suitable for vibration isolation in the seat of the vehicle [6] or vibration damping in certain frequency ranges in the small devices installed in the vehicle [7].

2. The results of the questionnaire survey [3,4] can be used by the designers and manufacturers of SDC to improve the vehicle characteristics. In addition, SDC sellers can use the results to improve their offerings to potential customers in regions that have a similar multiethnic and multicultural structure as those studied in the dissertation.
3. The proposed authentication system [8] has yet to be elaborated and applied.
4. The document sets and regulation templates can be used by state and regional authorities to prepare identification and legal acts for SDC legislation on public roads [8].

7.References

Aarhang, J. & Olsen, S. (2018) Implication of ride-sourcing and self-driving vehicles on the need for regulation in unscheduled passenger transport, Research in Transportation Economics 69, 573-582

Halday, M.M., Dorler, D., Heigl, F., Marizoni, M., Hecker, S., Vohland, K. (2021) What is citizens science? The challenges of definition, in The Sciences of Citizen Science, Eds.: Vohland, K., Land Yandstra, A., Ceccaroni, L., Lemmens, R., Perello, J., Ponti, M., Samson, R., Wagenknecht, K., Springer, Open Access, 13-33.

Horizon Europe CL3-2021 FCT-01-12 (2021) Online identity theft is countered (project) https://lawahead.ie.edu/what-law-best-allows-effective-automation-through-legal-tech-a-survey-of-europes-law-markets/ (2021)

Marletto, G. (2019) Who will drive the transition to self-driving? A socio-technical analysis of the future impact of automated vehicles, Technological Forecasting & Social Change 139, 221-234

Nepaulsing, J., Matsushita, N., Ellrott, J. (2020) Autonomous driving in Japan – part 1: road traffic law, Freshfields Bruckhaus Deringer LLP, https://technologyquotient.freshfields.com/post/

Putnik, G.D., Ferreira, L., Lopes, N. & Putnik, Z. (2019) What is a cyber-physical system: Definitions and models spectrum, FME Transactions 47, 2019, 663-674

Qu, W., Xu. J., Ge, Y., Sun, X. & Zhang, K. (2019) Development and validation of a questionnaire to assess public receptivity toward autonomous vehicles and its relation with the traffic safety climate in China, Accident Analysis and Prevention 128, 78-86.

Rahman, M.M., Deb, S., Strawderman, L., Buch, R. & Smith, B. (2019) How the older population perceives self-driving vehicles, Transportation Research Part F 65, 242-257

Rosenberg, M.J. & Hovlan, C.I. (1960) Cognitive, affective and behavioral components of attitudes, In: Rosenberg, M.J. & Hovlan, C.I., Eds., Attiture Organization and Change: An Analysis of Consistency among Attitude Components. Yale University Press, New Haven

Slone, S. (2016) State laws on autonomous vehicles, Capitol Research – Transportation Policy, Council of State Governments, U.S.A.

Society of Automotive Engineers (SAE) (2014) International: Summary of SAE international's levels of driving automation for on-road vehicles, Standard J3016, USA

8. Publications

8.1 Scientific Publications Related to the Thesis Points

1. Cveticanin, L. & **Ninkov, I.** (2022) Sensors in self-driving cars, *Mechanism and Machine Science*, 109, 2022, 595-604
2. Cveticanin, L., **Ninkov, I.** (2021$_4$) Integrisanje zena u savremene projekte iz oblasti sajber-fizickih sistema, *Tehnika-Menadzment*, 71(6), 832-840
3. **Ninkov, I.** (2020) Are people really ready for autonomous vehicles? XXIII. Spring Wind Conference: AI and the Future of Science, Budapest, May 1-3, 2020
4. Cveticanin, L. & **Ninkov, I.** (2021) Pro and contra for self-driving car: Public opinion in Serbia, International Conference on 0Science and Technology, ICONST 2021, September 8-10, 2021, Budva, Monte Negro. http://www.iconst.org/Page/ESTconference
5. Cveticanin, L. & **Ninkov, I.** (2021) Benefits and lacks of the self-driving cars including the aspect of environmental protection, Int. Sci. Conf. – ETIKUM 2021, Novi Sad, 2-4 December 2021, Proceedings, 2021.

http://www.dpm.ftn.uns.ac.rs/images/Etikum/ZBORNIK-ETIKUM-2021---online.pdfCveticanin.

6. Cveticanin, L, **Ninkov, I.** & Cveticanin, D. (2022) Self-driving car: Challenges in vibration, Chapter in Acoustics and Vibrations of Mechanical Structures – AVMS-2021, Eds. N. Herisanu and V. Marinca, Springer, Springer Proceedings in Physics 274, (Proceedings of the 16th AVMS, Timisoara, Romania, May 28-29,2021), 15-24.
7. Cveticanin, L., Zukovic, M., **Ninkov, I.** & Mester, G. (2022) Nonlinear lightweight metastructure with effective negative stiffness, Acta Mechanica, 233(11), 4311-4325
8. Cveticanin, L., **Ninkov, I.** & Rajnai, Z. (2022) Self-driving Car as a Legalized Cyber-Physical System on Public Roads – Ethic Dilemmas and Legal Challenges, ISBN 978-620-4-95572-8, LAP LAMBERT Academic Publishing.
9. **Ninkov, I.** & Mester, Gy. (2020) The absolute necessity of reconciliation and protection of human rights and technology in era of the frequent abuse of unmanned aerial vehicles, *VIPSI Conf. 2020*, Budva, 29/12/2019-01/01/2020, pages 4.
10. **Ninkov, I.** & Mester, Gy. (2019) Safety and security aspects in drones regulations, *Int. Conf. on Central European Critical Infrastructure Protection, ICCECR 2019*, Budapest, 18-19 November 2019, Proceedings, pages 6.

11. **Ninkov, I.** (2019) A right to privacy as a fundamental human right in correlation with data protection, *Banki Reports*, Vol. 2, No.1, 59-63.
12. **Ninkov, I.** (2021) Invariance in principles of machine and legal automation, 10th Interdisciplinary Doctoral Conference, IDK 2021, 12-13 Nov. 2021. https://www.facebook.com/IDKPECS/
13. **Ninkov, I.** (2020) Basics of developing of the legal regulation in self-driving cars, *Safety and Security Sciences Review*, Vol.2, No.2, 2020, 85-92.
14. Cveticanin, L. & **Ninkov, I.** (2021) Self-driving car and legal regulation, Sci. Conf. Circular economy and environmental labelling, 29 January 2021, Novi Sad, Serbia

8.2 Additional Scientific Publications (optional)

1. **Ninkov, I.**, Vajdic, J., Milicevic, K. (2018) I ja imam pravo (I Have Rights as Well), Novi Sad, "Rights 4 All", 2018, ISBN 978-86-900349-0-1
2. **Ninkov, I.**, Vajdic, J., Milicevic, K. (2018) Analysis of the concept of gifted students' rights to inclusive education, International Conference: *Giftedness, Education and Development*, Belgrade, Proceedings 2018 376.1-056.26/36-05645 159.928.23-056.45
3. **Ninkov, I.**, Protic, K., Vajdic, J. (2019) The contemporary needs of identification and education of gifted children and youth, International Conference *Giftedness-Needs of the 21th Century*, Krusevac, Proceedings, 2019 37-056.45;061(497.11)

4. **Ninkov, I.** (2019) Inclusive education of talented students: Legal aspects, International Conference, Information Technology and Education Development, *ITRO 2019*, Proceedings,2019, Zrenjanin, 231-235
5. **Ninkov, I.** (2020) Education policies for gifted children within a human rights paradigm: a comparative analysis, *Journal of Human Rights and Social Work*, 5(4), 280-289.
6. **Ninkov, I.** (2019) Legislation against 'fake news': yes or no, *Int. Conf. Adaptive Digital Country* (Adaptiv digitalis allarm), Budapest, October 18-20, 2019.
7. Cveticanin, L., Herisanu, N., **Ninkov, I.** & Jovanovic, M. (2022$_4$) New closed-form solution for quadratic damped and forced nonlinear oscillator with position-dependent mass: Application in grafted skin modeling, *Mathematics*, 10, 2706. https://doi.org/10.3390/math10152706