Autonomous driving

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Abstract: ***The future of the modern world faces the appearance of different ways of mobility. Huge strive in today's world have obtained self-driving robotic cars powered electrically. The paper explains how autonomous vehicles function as well as their position and importance in new mobility concepts. New developments in autonomous vehicles are being accomplished and introduced to users' demands. Many car companies have developed their own driverless vehicles and detected some problems with them. The major flaw of autonomous vehicles is cyber security and safety which will be discussed throughout this paper.***

Autonomous vehicles have modernized the mobility of people which means that people no longer have to come to the vehicle but the vehicle comes to them and are able to share transportation and thus lowering the traffic congestion and cost. Smartphone applications have been developed and are facilitating the carsharing system. Acceptance and trust play important roles in the development of self-driving cars. A producers must gain confidence that users (drivers) are well-educated not just with the concept of driverless cars but also with the digitalized developments needed in order to use the new mobility concept. A research on the acceptance of driverless cars will be presented within this paper.

Furthermore, autonomous vehicles reduce pollution and are environmentally friendly.

It is anticipated that autonomous vehicles will take over the roads and are the future of transportation. They offer comfort, safety, and good driving conditions. However, an area where autonomous vehicles are used must possess a proper infrastructure such as good roads, charging lanes, internet etc. Hereafter, this paper presents important characteristics, developments, and features of autonomous cars.

Index Terms: ***autonomous vehicles, mobility, cyber security, carsharing, developments, software system, acceptance.***

1. Users and Use of the New Mobility Concepts

New mobility concepts entail innovative programmes and the usage of new technology, which leads to the digitalization of transportation. The key enabling technologies of digitalization of transportation have three basic processes: automation, digital data, and digital user interface and system interconnectivity.

The key enabling technologies of smart mobility are defined as follows:

- *Automation* – sensors and systems (e.g. navigation, speed control etc.).
- *Digital data* – information distribution, automotive vehicle data management, driver information system.
- *Digital user interface* (driver, operator, vehicle) – driver-vehicles interaction, task optimization, maintenance.
- Interconnectivity – vehicle fleet management systems, peer to peer networking, artificial intelligence, knowledge accumulation.

It may be concluded that autonomous vehicles are the main elements of smart mobility based on the key enabling technologies mentioned above. Figure 1 shows a fully automated intelligent vehicle and its interaction and communication with

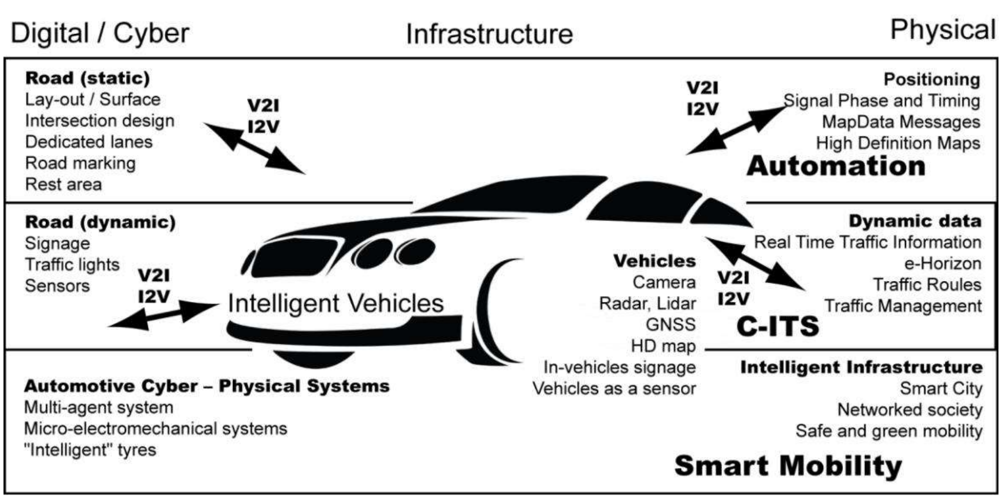

Figure 1. Strategy model of Cyber-Physical Vehicle Systems and Infrastructure

physical and cyber infrastructures. The inevitable fact is that automation is the element needed for digitalization of the automotive industry. Vast automation also has a goal to lower, as much as possible, the risk of human errors in the process of transportation [36]. On the other hand, these tangible systems must be carefully examined in order to avoid any plausible mishaps and ensure the driver's safety.

Furthermore, due to the fact that smart vehicles will share the same road with traditional vehicles infrastructure plays a significant role. In the planning of intelligent transportation systems the infrastructure such as fast and smart roads, smart parking places, charging lanes, transport hubs, overpasses etc. must be taken into consideration. Smart mobility also entails static data (e.g. digital maps, traffic regulations) and dynamic data (e.g. real-time traffic information). The intelligent infrastructure ensures safety and, if an accident occurs, the driver is able to react quickly and get help. Intelligent lightning, surveillance, and security cameras systems provide additional help, which allows further automation in operation. Communication between various systems of an intelligent vehicle must be achieved. A person driving a smart vehicle needs to feel safe and comfortable while on the road. After that, users must be provided with the explanations and instruction on how to connect and integrate the vehicle into the electric charging system as well as providing charging lanes as frequently on the road as possible.

Also worth of mentioning is the fuel efficiency of self-driving vehicles. These vehicles are eco-friendly and spend lesser fuel than traditional cars because they have an electrical power. An energy-

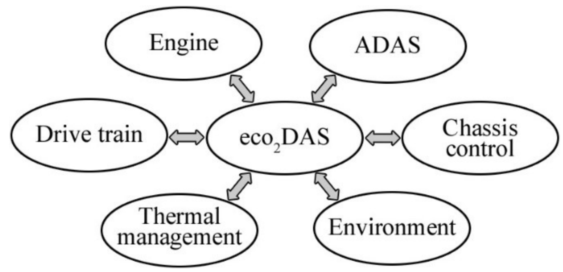

Figure 2. Networked system of function units

efficient vehicle has two advantages for the driver i.e., reduces the costs of fuel (fuel is becoming more and more expensive these days) and increases the length of the road being able to pass. Other relevant benefits are comfort, economy, and no emission of toxic fumes. Advanced Driver Assistance Systems are increasingly becoming important for the driver and automotive industry. A research of the eco-friendly system architecture of self-driving vehicles, eco$_2$DAS is meant to develop such a system that is universally applicable to the current infrastructural conditions and supports each possible set of eco functionalities. The system is both ecological for the environment and economical for the driver.

The eco$_2$DAS system means the communication signals, interfaces for information exchange, and core modules on the system level (Figure 222). This system is able to carry out complex optimization functions with its large number of links and within it has got a framework for many possible eco functions.

Since there is a large number of companies and institutes which are currently developing better and better autonomous vehicles, it is believed that

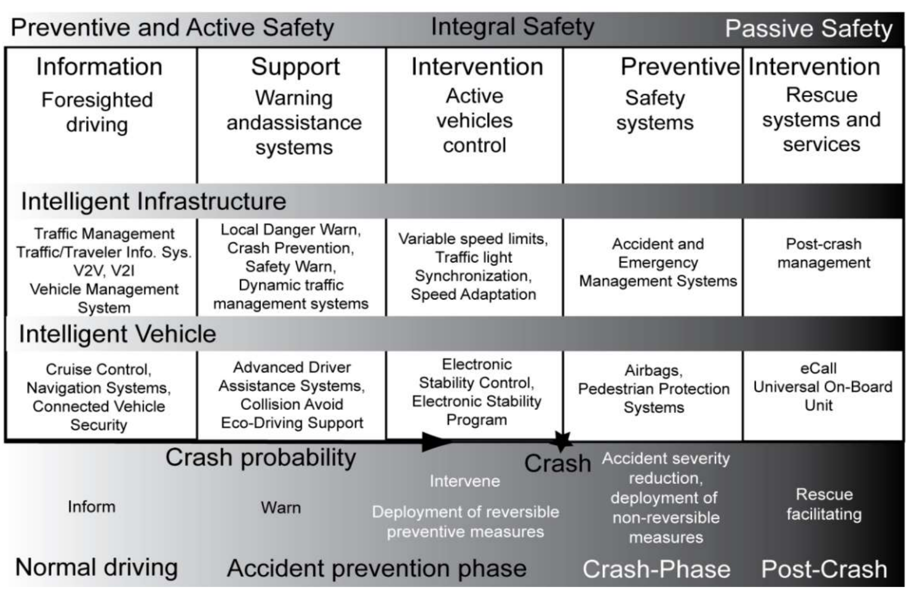

Figure 3. Safety phases of the Autonomous Intelligent Cyber-Physical Vehicle Systems

people will accept them even more than it is the case today. It is needless to say that people are reluctant into adopting new mobility concepts for the reasons of safety and security. These issues will be discussed in the following chapter.

2. *Safety and Cyber Security Issues in Self-Driving Robotic Cars*

After appearing on the market, self-driving robotic cars have soon caught the attention of many drivers who were not reluctant to buy one and try it out. However, people are used to drive the cars by themselves and to have an absolute control over it, so the concept of self-driving cars may raise couple of crucial questions – the security and safety. Needless to say, self-driving robotic cars are state-of-the art and nowadays most of top car companies are producing them (Tesla, BMW, Volkswagen etc.) and yet, the question of safety and cyber security is still present [1-9]. The vast number of these cars can experience problems with cyber security which furthermore may affect the functioning of their networking system. A proper protection at some instances is not provided or in the worst case scenario there is no protection at all. These security omissions may lead to more serious issues such as disruption of operation or taking over the control of the vehicle without being in a direct physical connection.

Safety in self-driving vehicles or any other vehicle can be defined as endeavor to keep the vehicle in an excellent condition which ensures the highest level of safety and protection for the person driving it. Additionally, every fundamental part of the vehicle such as brakes, steering, airbags, crumple zone of a car, also electronic assistants, such as ESP or ABS, must be in perfect conditions. Checking safety is crucial for autonomous vehicles and, thus, several points are taken into consideration: functional safety, active safety, safety and reliability (e.g., hardware and software), and human factors. From the point of cyber security, types of security have been outlined in Figure 3 [36].

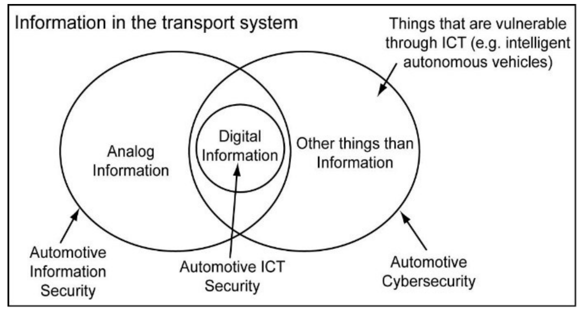

Figure 4. Venn diagram of the difference between Automotive Cyber security and Automotive Information Security [36]

Also, the vehicle must be protected from stealing. As we protect our credit cards, mobile phones, lap tops, or any other technology with a password, in the same manner autonomous vehicles must have cyber safe system. The software being used by an autonomous vehicle needs to be constructed to protect the vehicle from malfunctions and external attacks. The security within a vehicle contains information which focuses on confidentiality, integrity, and availability of information. Figure 4 shows the availability of information in cyber security system. Figure 5 shows the phases of safety and security while designing autonomous intelligent vehicle systems.

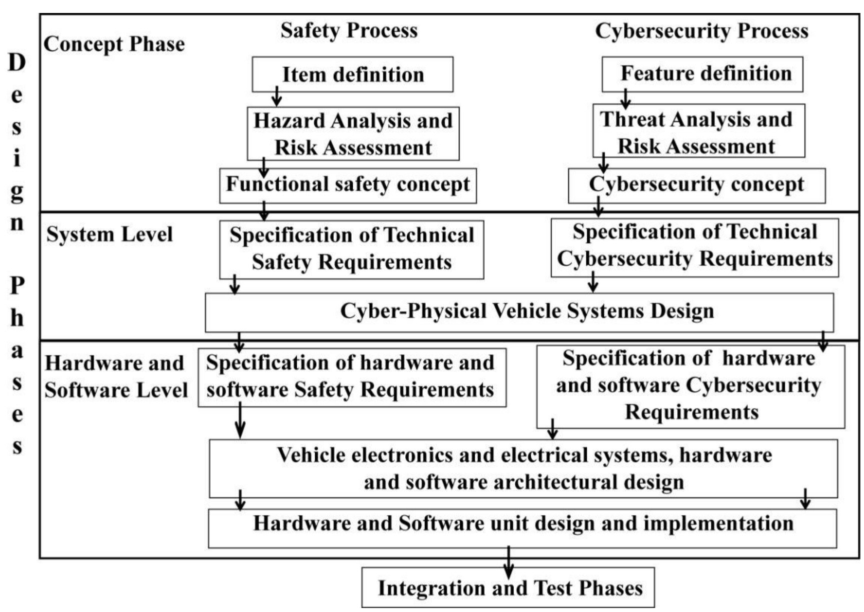

Figure 5. Safety and security through the design of autonomous intelligent vehicle systems and intelligent infrastructure

3. *CYBER SECURITY DEVELOPMENTS IN SELF-DRIVING ROBOTIC CARS*

As said in the previous sections, security and safety play very important role in smart mobility developments. Since smart vehicles contain complicated software as well as hardware, any manufacturer has to ensure that no one (except the owner or a driver) can obtain the access to the vehicle. Cyber security is not something that should be taken for granted but should have a serious role in the processes of planning and development of a smart vehicle.

Smart vehicles are often subjected to the risk of being attacked by hackers and, thus, the product safety and security, performance, data integrity, access, privacy, and interoperability must be on the highest level. For these purposes standards are being introduced to provide rules and planning guidelines for functional safety of the electronics systems of smart vehicles. Specifically, standard for the recommended practice in safety and security of smart vehicles J3061TM was already issued in January 2016. Figure 6 shows the process of development of prototypes of smart mobility. However, this field is still at the beginning of development and other standards are yet to be introduced.

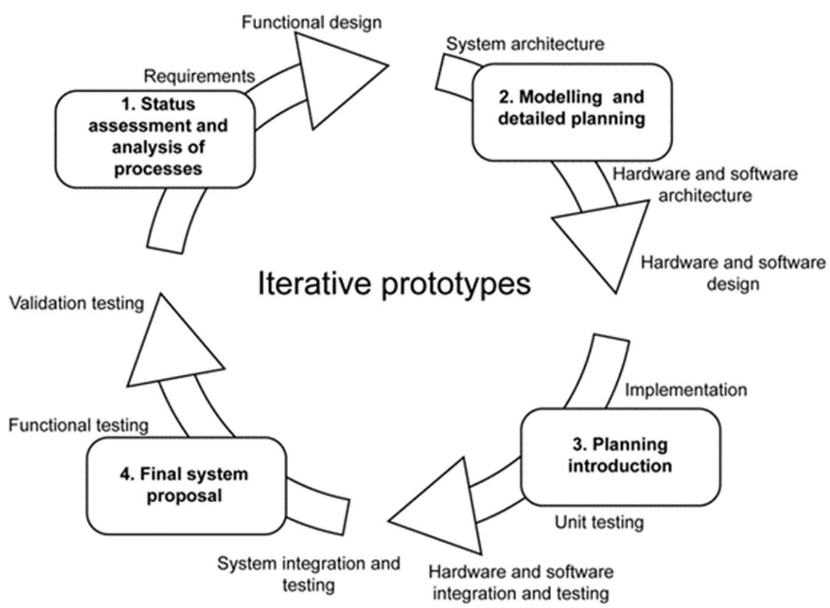

Figure 6. The development process of the iterative prototypes of smart mobility [36]

A variety of researches have been carried out since the breakthrough of the autonomous vehicles to ensure their safety and security. One of these researches was carried out by the Institute of Control Engineering and the Institute of Engineering Design at TU Braunschweig in Germany. They built an experimental (a prototype) vehicle MOBILE which is meant to serve as a tool for different researches on vehicle dynamics and mechanical or electric/electronic components (EE system). MOBILE is analyzed in the terms of functional safety. Furthermore, in terms of simple hazard analysis according to ISO 2626 standard, which the design of the drive-by-wire system has to provide [10-16]. The aspects which are investigated on that vehicle are the details of the architecture of the part of the EE system essential for vehicle control: displays, inputs, brakes, battery management, cooling system and knowledge management. Figure 7 illustrates the core requirements for the MOBILE set-up.

MOBILE has got an electric drive and control of propulsion, braking and steering. This electric drive aids to a powerful base configuration and provides flexibility in the long-term behavior of the vehicle. The four-wheel steering ensures areas where the vehicle may be applied. For example, the steering wheel may be implemented with a tie-rod to be able to steer each wheel separately and thus the different steering geometries and steering concepts may be imitated by simple software application [17-24]. The electro-mechanical braking system within MOBILE is built to outperform the hydraulic brake systems when it comes to reaction times. Additionally, MOBILE is powered by a modular power supply which consists of two independent units. The principal source of power for each unit is based on lead-acid batteries of 300 V. The flexible design allows user interface which means that all input devices can be exchanged if needed.

In the process of development and manufacturing a smart vehicle, issues such as hazard analysis, risk assessment, threat analysis, safety

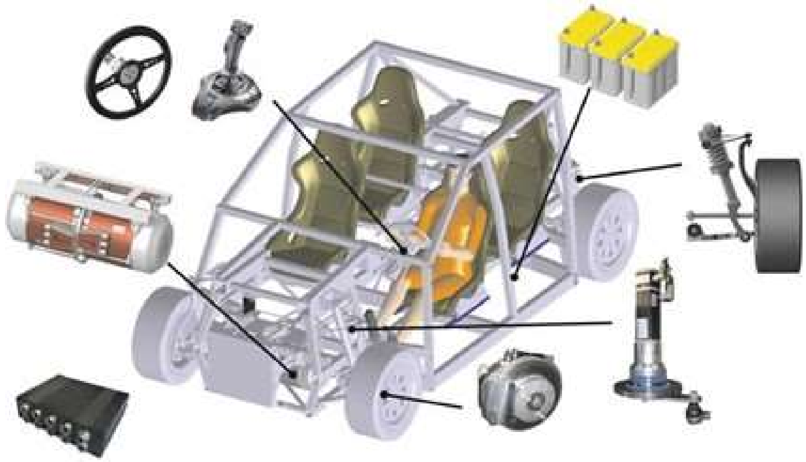

Figure 7. Mechanical set-up of MOBILE

concepts and requirements, system design, as well as defense-in-depth system planning must be given close attention. Also, this field is still at its infancy and other standards and requirements need to be introduced.

4. *New Mobility Concepts and Autonomous Driving – Carsharing: "Core Application" of New Mobility Concepts*

Mobility matters and it is a fundamental need of every human being. We are constantly on the move to meet our friends and family, travel on holiday, or simply, go to the store. There are long established means of transportation in everyday life such as bicycles, manual cars, buses, trams, etc. Autonomous vehicles represent a new mobility concept. The driver has little or no action to perform. People most often like to experience a convenient, affordable, and unremarkable journey. The marketing of smart city mobility focuses on providing additional services which are not available in traditional systems.

Car companies have recognized these desires. For example, Volkswagen has developed a shuttle-on-demand (MOIA) which was proven to be highly efficient and flexible. This electric vehicle can be booked by a customer via a smartphone app by simply entering start location and destination and the MOIA vehicle comes at a virtual stop up until 250 meters away from the customer and the app navigates the customer to the vehicle. This concept of mobility promotes sharing a journey with other people who are traveling in the same direction and, thus, preventing traffic congestion, saving environment by having fewer cars on the roads, and reducing traffic. This way of transportation is known as carsharing. Carsharing existed long before autonomous cars started to emerge, but the difference is that the user no longer has to come to the vehicle but the vehicle comes to the user. Any person who has a valid driver's license can register to the application and use this service upon payment of the registration fee. The concept is pretty simple. Such a concept of carsharing has developed by UBER. A person can install an app through which they can order a car whenever they need a ride. Additionally, via UBER one may order food, groceries, and travel around the city etc.

5. *Users and Usage Conditions*

New technologies are based on and managed through software, digital platforms and applications. The same thing is applied to new mobility concepts such as carsharing. Mobile applications are inevitable if a person desires to access carsharing vehicles [25-32]. These apps give the user an insight of the available vehicles and their locations. Next, users decide whether or not they want to hire the vehicle. Then, the app books a vehicle and shows the route to it.

To use this mobility concept, a person must be technically educated, what means to own a smartphone and to be a little bit technologies savvy, just enough to know how to use the app. However, people's hardware and software skills are increasing and almost every person in modern society has at least some knowledge to use it. In today's digitalized world this is a must.

Well known app for carsharing Car2Go made a survey in 2014 and discovered that the users find

Figure 8. Google and Lexus autonomous vehicles

the digitalization of mobility quite useful. Users say that cars are available at any time and are able to use them spontaneously. These facts may explain the rapid success of flexible carsharing.

Autonomous vehicles are expected to become a trivia in lives of human beings. Until that happens, producers must take into consideration people's needs and preferences. Whether a person will or will not adopt the usage of autonomous cars, widely depends on how they feel while driving the car and how safe are they while driving. Any company which produces AVs must meet users' expectations and coax them to transfer from manual to autonomous cars.

The advantages of AVs for the users are many. They will liberate those who dislike driving, make life easier for those who are not able to drive, the car can act as an important aid to people who are disabled visually or physically… Moreover, elderly people will be enabled to move more quickly and it is not less important for parents distracted by young children.

It should be anticipated that people will change their perspective of vehicles and eventually not notice the difference between driven and driver-less cars [33-38]. Users will realize that mobility is very important and driven cars will eventually be dropped.

Car producers believe that there are three things to be accomplished in order for the society to accept autonomous vehicles. Those are: trust, comfort, and control. It is out of high importance that the user actually trusts the safety of the vehicle, that it is familiar with their surroundings, journey as well as the user. In other words, the user must be well informed about what is the vehicle doing and its operations. Comfort is something that is always expected. Users will probably anticipate a car which has a premium-feel interior, long lasting and easy to maintain, flexible seating configurations and a modern dashboard with a screen intuitive to use.

Great conditions for the driver and better control of the vehicle were confirmed with the research carried out by Google on their autonomous vehicles. The research proved that their self-driving Prius and Lexus cars are safer and smoother when controlling themselves rather than a human. Additionally, a dashboard has been developed to help people comprehend what the vehicle is doing. Hereafter, it may be concluded that the driving conditions for the user are impeccable.

6. Digitalization of the Everyday World As a Basic Precondition for New Mobility Concepts

Digitalization of the environment and infra-structure around us is inevitable due to the appearance of self-driving robotic cars. In previous paragraphs it was discussed how do software and hardware function within a vehicle but now close attention must be given to networking with the environment. The autonomous vehicle has to be connected to the internet, to the infrastructure and to the other vehicles and thus the digitalization of the environment has to take place in order for people to be able to drive an autonomous vehicle or use the carsharing concept. Countries and areas where autonomous vehicles and carsharing apps are used must be technically equipped i.e. stations where AVs may be charged and internet to access the app. Another point is that people who would like to use these apps must own a smartphone and nowadays the rate of the people owning one has significantly risen. Similarly, the users have to be educated on how to use a smartphone, internet and apps.

Digitalization of everyday world also means flexibility of transportation. Practically, the users almost have no barriers in movement around the city. Besides, the cost of transportation is lower because the users may employ the concept of carsharing and split the ride with another passenger.

Acceptance and trust of smart vehicles throughout the world is also something worth mentioning. Many people around the world are not willing to adopt smart vehicles because they are used to being in control of the vehicle itself. A research has been carried out to increase the acceptance of self-driving cars which will be explained in the next paragraph.

Figure 9. Charging a self-driving car and MOAI smartphone app by Volkswagen

The participants who participated in the research were recruited via Amazon Mechanical Turk (AMT). All the participants were required to be licensed drivers. The material being used was vignettes. Two vignettes described hypothetical scenarios concerning a close friend or family member's experiences during the first 6 months of owning a self-driving car and scenarios where the driver has little or no role during vehicle automation. There was also a realistic vignette which described a balance of positive and negative experiences with the vehicle but it was written to emphasize a scenario in which the driver needed to monitor the car carefully during vehicle automation, human intervention was needed to avoid the accident. Both vignettes said that the car was safe. Participant were assigned to read randomly given vignettes. The participants have also done a survey created for this experiment called Self-driving Car Acceptance Scale (SCAS) (see Table 1). Participants read the situations and questions from their vignettes and provided responses for SCAS. After finishing the experiment the results outlined that the scenarios which participants have described fits, firstly, to urban/city driving, then rural/small town driving and distance/interstate/freeway driving. The results also showed that participants, on average have 18.23 years of driving experience, drive 8.29 hours per week and spend 1.79 hours in traffic jams per week. Participants have also reported having read articles about self-driving cars and have seen advertisements on television. Participants rated their familiarity with self-driving cars on

Table 1. SCAS Items and Descriptive Statistics

Item	*M*	*SD*	*Mdn*	*Mode*
Perceived reliability/trust				
1. Self-driving cars will be safe.	5.08	1.27	5	6
2. I would trust a self-driving car to get me to my destination.	5.01	1.46	5	6
3. People will need to watch self-driving cars closely to be sure the computers don't make mistakes.	5.09	1.42	5	5
Cost				
4. I would be willing to pay more for a self-driving car compared to what I would pay for a traditional car.	4.28	1.88	5	6
5. The benefits of a self-driving car would outweigh the amount of money it would cost.	4.30	1.73	4	6
6. The cost of a self-driving car would be the most important thing I would consider before purchasing one.	4.76	1.72	5	6
Appropriateness of automation/compatibility				
7. I do not think that computers should be driving cars.	3.33	1.72	3	2
8. It is important for a human to be able to take back control from a self-driving car.	6.17	1.03	6	7
9. There are some driving scenarios that will be too difficult for a self-driving car to handle.	5.02	1.59	5	6
Enjoyment of to-be-automated task				
10. I enjoy driving a car.	5.33	1.47	6	6
11. I prefer to be the driver rather than the passenger in a car.	4.55	1.86	5	6
12. I enjoy cruising or going for joy rides.	5.07	1.62	5.50	6
Perceived usefulness of automation				
13. A self-driving car would allow me to be more productive.	5.18	1.59	6	6
14. A self-driving car would allow me to be more safe while in the car.	4.82	1.46	5	6
15. Self-driving cars will reduce traffic problems.	4.93	1.57	5	6
Perceived ease of use of automation				
16. Self-driving cars will be easy to use.	5.24	1.28	5	6
17. It will be a lot of work to figure out how to use a self-driving car.	3.38	1.61	3	3
18. It would take me a long time to figure out how to use a self-driving car.	3.14	1.61	3	2
Experience with automation				
19. I like to use technology to make tasks easier for me.	6.09	0.86	6	6
20. I have bad experiences when I try to use new technology instead of doing things "the old-fashioned way".	2.35	1.29	2	2
21. There are tasks in my life that have been made easier by computers doing the work for me.	6.37	0.76	6	7
Intention to use automation				
22. I would like to own a self-driving car.	4.91	1.84	5	6
23. Even if I had a self-driving car, I would still want to drive myself most of the time.	4.29	1.78	5	5
24. In a self-driving car, it will be important to me to have the option to turn off the computer and drive myself.	6.20	0.96	6	7

Notes: N 288. All questions rated on a Likert scale with end anchors 1="strongly disagree" and 7 "strongly agree".

a scale from 1 (not at all familiar) to 7 (extremely familiar) and the final result was 4. When it comes to the acceptance of self-driving cars, people may accept them under idealized rather than realistic scenarios at the initial stages of development.

7. Conclusion

To summarize, we may conclude that the precondition of smart city is smart mobility. In order for the smart city to function properly there are two main elements and those are autonomous intelligent vehicles and vehicle systems, and intelligent transport infrastructures. Smart mobility development has become essential since the demand for creating cooperative intelligent transport systems has risen. Besides, smart mobility increases productivity (transport capacity, comfort), reduces the numbers of accidents and the emissions of harmful materials. The last but not the least issue to be resolved is to persuade people to trust driverless technologies.

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