Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 45 (2020) 708–715

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 2nd International Congress on Transport Infrastructure and Systems in a changing world (TIS ROMA 2019), 23rd-24th September 2019, Rome, Italy

Investigation on human factors and key aspects involved in Autonomous Vehicles -AVs- acceptance: new instruments and perspectives

Martina Sciaccaluga[a]*, Ilaria Delponte[a]

[a]*CIELI, University of Genoa*

Abstract

The enormous audience that will be impacted by the spread of autonomous vehicles (AVs) will count individuals with different ethnicity, culture and understanding; many disciplines are involved in order to intercept key-aspects of their introduction. According to a "post-disciplinary" approach, training all of them and helping them accept and take advantage of this new technology will be a huge challenge for the years to come. Human factors influence all the process too: which are the most common obstacles to the AVs technology acceptance? What are the main causes? What are the best ways to overcome these barriers?
An analysis based on the demographic differences -such as age, gender, culture, personal experience- and abilities of the users can give a huge contribution to the matter; in the paper, an investigation and a possible application of new instruments and techniques is also provided. The aim is understanding if an innovative approach like gamification can help in collecting the new kind of data and in analyzing user fears, limits and needs. With the support of cognitive ergonomics principles to formulate new synergic solutions, it could be possible to create a virtuous circle composed of preventive profiling -understanding how people perceive the AVs and what they want from them- and targeted training -to grant the necessary knowledge everyone need through emotional involvement-.

Keywords: Human factors; Autonomous vehicle; User behavior

* Corresponding author. Tel.: +39 3387945398
E-mail address: martina.sciaccaluga@cieli.unige.it

10.1016/j.trpro.2020.02.107

1. Context: AVs introduction

Autonomous cars are no longer science fiction. Most major car manufacturers already market and sell high-end vehicles, racing to develop fully autonomous vehicles (AVs). Moreover, many transit agencies and airports already have decades of experience operating driverless trains on fixed guideways, and the EU CityMobil2 has already begun testing driverless transit on public streets (2015).

The world-wide trend does not make an exception in Italy.

On International rules a wide consensus is going to build up, specific urban policies, regulations and plans adopted for AVs are sporadic initiatives, although they will influence a lot the scale and perhaps even the direction of the impacts. In this perspective, investigation on human factors and key aspects involved in autonomous vehicles acceptance can be crucial, for both cities and society.

Three evidences immediately give the idea of the potential applications urban introduction of AVs can have.

- Ian Bremmer and his TEDtalks about driverless cars are among the most watched on web: this wide audience is only a signal of the current social thirst and attractiveness towards a new way of thinking and living mobility
- In Italy, the "Smart Road" Decree was just signed at the beginning of March 2018 by the Ministry of Infrastructures and Transport; it will allow to test vehicles equipped with driverless systems on the road. The MIT may authorize the testing of prototypes created by manufacturers, research institutions or university institutes, analyzing each project to ensure that road tests are carried out in suitable conditions
- Since March 2017, Toronto and Sidewalk Labs (a branch of Google Alphabet) have been conducting a thought experiment with leading urbanists and technologists. The Waterfront will be the first district where the only vehicles are shared and self-driving ones

Cities always demand services to enhance the quality of life of citizens and make services more efficient. In the last few years, the concept of smart cities has played an important role in academia and industry. As known, in recent months, several Municipalities have tried to experiment the introduction of AVs setting up pilot tests: policymakers, guided by Boston, Singapore and ITIF Washington experiences (2014-2018), tried to match digital applications, economic constraints, vehicles' ownership and management models within their city context, in order to outline an urban strategy favoring AVs introduction.

AVs introduction is one of the most disruptive ways that, nowadays, can even accelerate the key principles of urban planning, accessibility, inclusivity and sustainability, into the digital age.

Many efforts were effectively done in technical fields such as automation, computer science and traffic simulation. Such technologies, together with rules and investments, are fundamental elements of the change: these have been nowadays hugely deepened by International Organizations in dialogue with enterprises, and they will influence a lot our urban life from now on. But there are some gaps in the process that needs to be understood and explored. At the same time literature seems to be quite unarmed to cope with it. Sector disciplines and specific fields were deepened (automation, energy, remote sensing…), but a wider scope is now apt to be discovered.

According to a "postdisciplinary" approach, in the second paragraph of the paper, methodological strategies are adopted in reference to challenges rather than to disciplines.

In the third paragraph, the paper is focused on Human factors involved in AVs introduction.

Nowadays the user role and his participation in administration issues and planning are growing more and more, creating a powerful collaboration network able to magnify the active results. Understanding user perception of either urban areas, infrastructures and AVs potentialities is a priority in order to sustain the continuous development of the virtuous established relations and therefore a successful AVs introduction.

The awareness of the territory and of the resources that it offers in terms of infrastructures is a relevant issue for urban innovation. Many questions arise about the user, his perceptions and inhibitions and about new tools and possibilities regarding urban development and citizens involvement. In the fourth paragraph a possible applicative process for a successful AVs introduction is developed with the aim of complementary tools.

Nomenclature

AVS	autonomous vehicles
ML	machine learning
TP	transport planning
UP	urban planning
AQ	air quality assessment
STS	science technology studies
IOT	internet of things
GM	gamification
HF	human factors

2. Disciplinary interaction: a sample process

Policymakers who are interested in creating a smart image of their towns also through AVs' early usage must, in parallel with technical verifications: involve citizens participation from the very beginning, exploring their attitude towards new technologies introduction; plan IoT based data collection strategies and leverage Machine Learning and data analysis for an innovative understanding of urban environments and their inhabitants; focus on wider environmental benefits, considering the improvement of urban quality and beauty as a fundamental part of the expected transport revolution.

For a scientific support, selected competences are needed: machine learning, urban and transport planning, social technologies science and air quality assessment. Their disciplinary contributions (in a postdisciplinary perspective) will be gathered in order to investigate technical feasibility (town planning compliances, dimensional and transport services verifications according to the city-shape), models' suitability (robustness and compatibility of employed models to the case) and social acceptability (stakeholders mapping and monitoring of their adaptive capacity).

Concerning the disciplines involved in an all-encompassed approach, the support of Machine Learning is quite crucial (Le Cun et al., 2015). Deep learning recently revolutionized the ML field with impressive results on a variety of visual monitoring tasks: AVs do not make an exception. For feasibility reasons, often urban strategies must leverage (on-board or environmental) technology easily available, more in general based on IoT technology.

In this sense, in authors' opinion what is relevant is the previous work on traffic control and monitoring in general, where the adoption of ML for modeling and prediction tasks is still limited, even though domain experts agree on the fact that it will become a standard in the near future (Castro et al., 2012; Casas, 2017). The use of video streams allows to gather a more comprehensive view of the environment. Traffic-related aspects will be complemented by a human-centered analysis, with the final goal of understanding human dynamics in a scene (Noceti and Odone, 2012), in this sense, approaches from the surveillance field are factors of interest.

Speaking of urban dynamics, uncertainty domains in planning for local and regional stakeholders: the challenge is trying to interpret correctly the changes in urban land use in the course of autonomous driving introduction, Guerra among first, in 2016. The introduction of AVs is one of the main challenges for cities, but fragile and historical places do not allow for a suitable and profitable technological introduction. While there is a need to analyze what impact autonomous driving might have on long-term plans of urban spaces, the most urgent topic is how can a successive transformation towards this transport system be designed (Pavone, 2016; Fagnant et Hockelman, 2015). Depending on these varying characteristics, autonomous transport modes have the potential to change the transport system in utterly different ways and also land-use and Urban Planning will be affected. While the environmental benefits of electric vehicles is non negligible, the usage of autonomous vehicles results in a strong reduction of transport costs and externalities. Electric AVs have been widely applied in urban transport systems. A first application regards new generation car sharing systems: the relocation of vehicles among stations causes high staff costs, but if shared vehicles are autonomous, a high reduction of staff costs can be achieved, as expressed in Barth and Todd (1999).

At the same time, traffic flows and emissions are fundamental for the employment of pollutant dispersion modelling and Air Quality assessment. The final spatial distribution of pollutants in cities is determined by several factors, such

as the meteorology and the morphological characteristics of the city, as well as the type, nature and spatial location of sources (Barlow, 2014). With high spatio-temporal resolutions, they provide comprehensive information on flow and pollutant transport and thus are widely employed for assessing urban air quality as well as temporal and spatial variations (Thunis et al., 2013).

Finally, the importance of social engagement in innovation stems from a paradigm shift within Science Technology Studies, precisely addressed as the 'Science Mode 1 versus Science Mode 2' change, as reported in Gibbons et al. (1994) and Novotny et al. (2001). The STS is such a diverse research domain that it would be a losing battle to try and put together every single proposal/review/study addressing the postacademic-science turn. Within this context, what we can do is underline which social mechanisms push social actors (i.e., the citizens) to invest energy and time to engage in innovative smart cities projects. Literature identifies at least two factors: the micro dimension of self-reflection on personal preferences (tension among moral/ethical values and personal utility) and at a macrolevel, where private closure may under certain circumstances turn into collective action (Sciolla, 2004; Tajfel and Turner, 2004; Turner and Reynolds, 2010). So, while discarding the paternalistic approach, the public debate on social engagement in SciTech innovation becomes more focused on how technoscience and society influence each other, leading to challenges, tensions, conflicts and, hopefully, new forms of cooperation. Science communication thus plays a relevant role in bridging the gap between scientific knowledge and common sense, heading towards a model of public engagement based on an open, lay and multidirectional communication process between Science and Society.

3. Human Factors

The advent of autonomous vehicles can change ones and for all the transport system as we know it.

Both automotive industries and policymaker need to have a clear vision of the user and his way of living the city, developing a framework with the aim of building a user centered schedule.

When speaking about AVs introduction, many different factors influence the judgement of the potential user. They can be classified as below (König and Neumayr, 2017):

- "People-oriented" factors: resistance is due to user-internal factors such as gender, age or cultural background
- "System-oriented" factors: technological features such as user interface, reliability or design are the origin of resistance
- "Interaction" factors: resistance is developed by the interaction between users and the technology and its magnitude is varying according to settings and typology of user

To estimate the reaction of the users towards the AVs, different methods have been reinterpreted and revised to comply to the contemporary issue. One of the most quoted is the technology acceptance model (TAM)(Davis et al. 1989). According to the model, the intention to use a technology is determined by perceived ease of use and perceived usefulness, and they are linked to the level of relevance and trust perceived by the user (Zhang et al., 2019). Trust can increase when the user acknowledges information related to past performances of the technology, results of reliability tests and reputation of the manufacturer (Adnan at al. 2018, Kyriakidis et al. 2015).

The development of a proper user formation process and of a complementary informative marketing campaign seems crucial to create a first, competent layer of knowledge, ready to welcome innovation to come. For this reason, recently, a wide range of studies has been conducted on the automations potential users and their attitudes in order to predispose the AVs incumbent advent, below some of the research results are reviewed.

The first main discriminative people-oriented factor analyzed is sex and its relation with age (Hohenberger et al., 2016). The existence of a wide gap between men and women AVs perception has been proved.

The key factor of this difference lays on affective reactions, both positive and negative, towards the AVs. The research underlines that women are more worried than men about autonomous vehicles and therefore less prone to use them, the same goes for aged people (Kyriakidis et al., 2015).

Emotions are important psychological markers, especially when processing new information. Other factors may be considered as moderators in the tendency to use autonomous vehicles; according to the studies of Hohenberger et al. (2017), one of them is the self-enhancement.

The intention of using a new technology depends on its own perceived characteristics. User cognitive evaluation determines the proneness to use the technology and any kind of affective responses can influence the cognitive process.

The social component and the decision making of drivers have a relevant role in the mobility system. As stated in the studies of Brown and Laurier (2017), the road is a social and socially organized environment, drivers as social actors are sensitive to the actions of the other drivers who are interpreted by them.

Driving is not just a functional action but a communicative one, driving movements can indicate not only drivers' intent but also their mood, character and tendencies On the road it is possible to establish relationships of cooperativity or competitiveness, the established equilibriums are influenced by the actions of individuals and can easily be damaged (Zimmermanna et al., 2018). For these reasons a system of user training and education in order to create an urban sensitivity is needed.

4. AVs introduction process

One of the objectives of the study is to make recommendations for the successful introduction of AVs in urban tissue, especially in historical and complex ones.

Thanks to the now available tools, already mentioned, the process aims to have a high level of monitoring and a feedback system able to provide concrete and realistic data and capable to start constructive iterations based on the results. Of great importance will be the collaboration of local authorities as well as the active involvement of the population, the final road user.

Following, a flowchart concerning the possible actuation of the plan for the AV introduction is presented. (Fig.1)

The first goal is to identify adequate target areas for the introduction of AVs. A set of ruling criteria for the choice will be identified through a state of art analysis. According to the criteria, areas, path and services will be chosen. The data collection in the above-mentioned areas with Iot strategies and environmental, contextual, and social analysis will be of major importance for the success of the implementation. The aim of this step is to identify the best way to collect data from the territory.

The second goal of the project is the development of a functional monitoring data driven system, propaedeutic to the scene setting for the AVs introduction. The creation of the system will be articulated in different steps:

First, the pinpointing of the right tools resulting from the study of data analysis methods and Machine learning State of art. The aim of this step is to understand what kind of efficient knowledge can be extracted from the environment

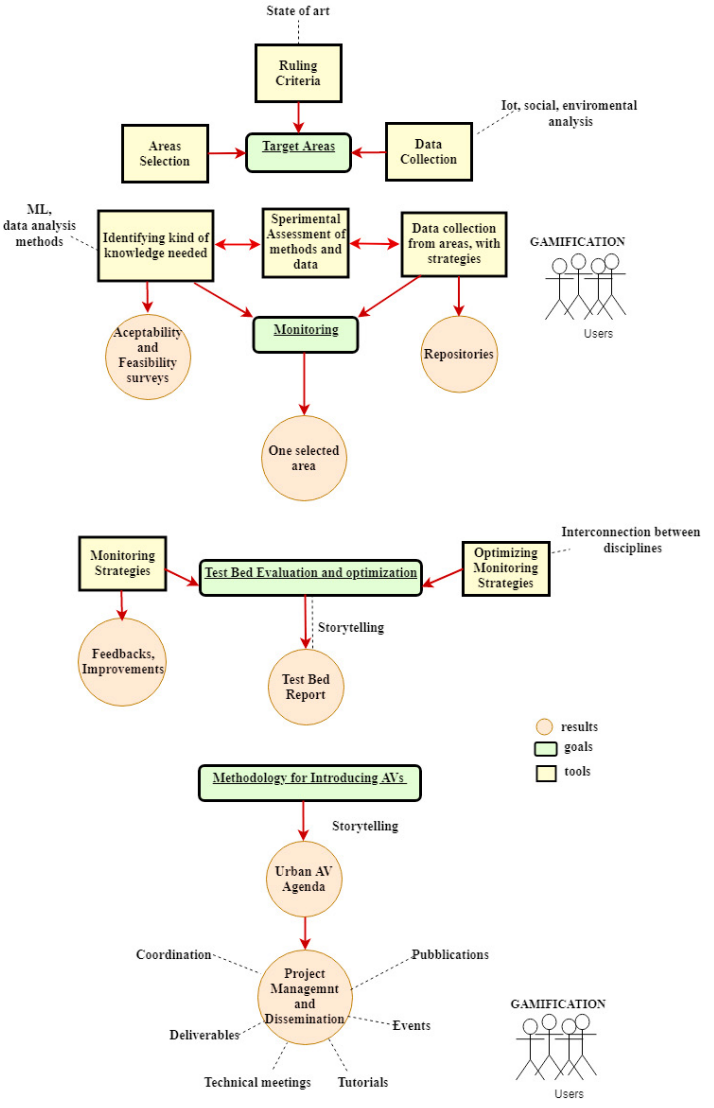

Figure 1 Flow Chart AVs Introduction Process

and then the production of KPI such as acceptability and feasibility surveys.

In the second step, the previous identified methods and strategies for the analysis will be applied to the identified target areas to create repositories.

The tools selected will be applied to the repositories in order to make an experimental assessment of the methods themselves to confirm the best approach to use. At the end of this phase the final choice about the area will be taken in order to proceed with the tests.

The third goal consist of a test-bed evaluation and optimization.

The monitoring strategies developed will be applied to obtain a test bed evaluation during which arising feedbacks and possible improvements. The monitoring strategies will be optimized and conclusions will be drawn from the test bed, considering feedbacks and possibilities. This phase results in a concrete storytelling of the test bed in all its aspects.

The fourth goal focuses on the main output of the project: presenting a complete methodology for introducing AVS in urban scenarios, this phase ends with the creation of an Urban AV strategic Agenda.

The last goal is developing a project management and dissemination system with the actuation of activities such as coordination, technical meeting, deliverables, publications, tutorials and events.

The gamification tool can support some of the phases described. The data collection and the dissemination system, in particular when involving users and citizens, can take advantage of it in order to reach the user in the most efficient way, managing the resistance and acceptability matter as will be explained in the next paragraph

4.1. Gamification for user analysis

According to Hohenberger et al. (2017) it's necessary to design specific campaigns tailored on the needs of population in order to implement a successful introduction schedule able to cohabit with part of previous urban tissue.

Promoting AVs for men means elicited status motives, underlining the hedonistic and self-enhancement factors, whereas for women it's important to reinforce the safety feeling, emphasizing the comfort in terms of protection and safety conditions. Given the pronounced difference of perception in young men and women, a practical and specific training to mitigate the relevant gap between sexes should be conducted in a proper and specific way. Elderly people seem to be less prone to pay for automated technology, it's important to underline the enhancement of their mobility conditions, smoothing the first approach between elderlies and AVs.

The type of view and community style embraced by the user have repercussions on the expectations and on the fears towards AVs. It's crucial to find the right social drivers to develop a collective sensitivity about the issue of innovative mobility systems.

In such a new field, new tools can make the difference: Gamification can give a mayor contribution in reinforcing the traditional data collection system.

The term "Gamification" refers to a practice that consists of using mechanics of game design in contexts beyond the game ones, or, in other words:

"A process of enhancing services with motivational affordances in order to invoke playful experiences and further behavioral outcomes" (Huotari and Hamari, 2012).

With deeper motivations than just "having to", it's easier to obtain psychological response, which, in turn, will naturally lead to the desired behavioral response actuation.

GM works by satisfying some of the deepest human desires: awards and rewards, status, achievement, competition and collaboration, free expression and altruism. Through GM, the user can learn what he needs to approach and use correctly the upcoming automations. GM can also help in creating a new sensitivity toward urban territory and infrastructure in order to develop a collective citizens awareness, encouraging road users to reflect on their daily mobility routine and on the feature of the path, usually taken for granted. With the purpose of fulfilling playful objectives, the user will have a smoothed perception of the learning effort, overcoming the barriers of rational ignorance and predisposing the knowledge triggers able to make new information relevant and to stimulate creative and conscious urban thinking. Tools based on GM can be applied to different stages of the virtuous circle of innovation introduction. As Ratti (2012) said, there are two main moments: one of sensing, during which information is gathered, and one of actuating, where specific actions are implemented as answer to the previous collected data. By mean of

GM the user can express his sensations, perceptions and fears in a more instinctive and natural way and, at the same time, can be driven into a rationalization process about urban environment. Data collected this way, in addition to the traditional ones, can provide a clear overview and a powerful framework on which building a strategical and tailored training program for the user. Even the training session can be performed with the aid of GM tools. This method can fill the gap between research results about urban and mobility system and users knowledge about it. The implementation of new analysis, educational and promotional techniques can underline and help current and relevant issues such as:

- Enhancement of security in mobility-on-demand
- A decrease of air pollution due to electric and shared vehicles introductions
- An increase in the mobility factor for elderly and impaired people
- Possibilities of improvement of urban and infrastructural tissue with a consequent higher life quality
- Revaluation of over congested city areas

5. Conclusions

Two main aspects are deepened in the paper: key aspects of a scientific approach by which collocate AVs in a post-disciplinary perspective, and human factors and related future instruments useful for AVs urban introduction.

About the former, by integrating ML, TP, UP, AP, as well as STS, AVs introduction can follow an “harmonious integration of scientific and technological endeavor and associated research policies into European society”, as it was advised since the European Commission's 7th Framework Program. To build an effective and democratic European knowledge-based society, communication and dissemination activities are pointed out as “a key added value of research and innovation funded at the Union level”. Recent updates from the EU with the Horizon2020 Program even more explicitly stress the need for “dissemination, communication and dialogue actions with a strong emphasis on communicating results to end-users, citizens, civil society organizations, industry and policymakers” (Horizon 2020 - Communication and dissemination).

Concerning the latter, it's clear that HF impact is huge when speaking of urban environment and AVs introduction.

Demographic, relational and behavioral factors, all together, contribute to the kind of vision that the user has about innovations in mobility technology. The way he lives the city and its infrastructures can influence the proneness to change the system. Making innovation a public and participatory issue can enhance the policy system and make the discussion a present concrete issue from the citizens point of view.

The need of a new kind of instruments is strong, it must be able to fill the gap between research, policymakers and citizens and, at the same time, it must fulfill different functions such as collecting data, extrapolating the inner vision of users and overcoming their natural resistance. It can make them see the territory from a different point of view, educating and training them to a new way of living mobility solutions and the city itself.

Infrastructures and urban spaces must be reconsidered as functional to new possibilities and their use can be rethought, being them a living part of the city.

References

Mahdavinejad, M. S., Rezvan, M. Barekatain, M., Adibi, P. Barnaghi, P., Sheth, A.P. (2017) Machine learning for Internet of Things data analysis: A survey, Digital Communications and Networks. In press (Online version).

LeCun, Y., Bengio, Y., Hinton, G. (2015). Deep learning. Nature 521, pp. 436-444.

Castro, P. S., Zhang, D., Li, S. (2012). Urban traffic modelling and prediction using large scale taxi GPS traces. In Proceedings of the 10th International Conference on Pervasive Computing, pp. 57-72). Springer, Berlin, Heidelberg.

Casas, N. (2017). Deep Deterministic Policy Gradient for Urban Traffic Light Control. arXiv preprint. arXiv:1703.09035.

Noceti, N., Odone, F. (2012). Learning common behaviors from large sets of unlabeled temporal series. Image and Vision Computing 30, pp. 875-895.

Guerra, E. (2016). Planning for Cars That Drive Themselves: Metropolitan Planning Organizations, Regional Transportation Plans, and Autonomous Vehicles. Journal of Planning Education and Research, 36(2), pp. 210–224.

Pavone M. (2016) Autonomous Mobility-on-Demand Systems for Future Urban Mobility. In: Maurer M., Gerdes J., Lenz B., Winner H. (eds) Autonomous Driving. Springer, Berlin, Heidelberg.
Fagnant, D. J., Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. Transportation Research Part A: Policy and Practice, 77, pp. 167–181.
Barth M., Todd M. (1999). Simulation model performance analysis of a multiple station shared vehicle system. Transportation Research C 7(4), pp. 237–259.
Barlow JF (2014) Progress in observing and modelling the urban boundary layer. Urban Climate 10, pp. 216–240.
Thunis, P., Miranda, A., Baldasano, J.M., Blond, N., Douros, J., et al. (2016) Overview of current regional and local scale air quality modelling practices: Assessment and planning tools in the EU. Environmental Science & Policy 65, pp. 13-21.
Gibbons, M., Limoges, C., Nowotny, H. (1994). The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Society. SAGE Publications, London.
Nowotny, H., Scott, P., Gibbons, M. (2001). Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Polity Press, Cambridge..
Sciolla, L. (2004). La sfida dei valori. Il Mulino, Bologna.
Tajfel, H., Turner, J. C. (2004). The Social Identity Theory of Intergroup Behavior. In: Jost, J.T., Sidanius, J. (Eds.), Key readings in social psychology. Political psychology: Key readings. Psychology Press, New York, pp. 276-293.
König M., Neumayr L., (2017). Users' resistance towards radical innovations: The case of the self-driving car, Elsevier
Davis, F.D., Bagozzi, R.P., Warshaw, P.R., 1989. User acceptance of computer technology: a comparison of two theoretical models. Manage.
Zhang T., Tao D., Qu X., Zhang X., Lin R., Zhang W. (2019). The role of initial trust and perceived risk in public's acceptance of automated vehicles. Elsevier
Hohenberger C., Spörrle M., Welpe I. M. (2016), How and Why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups, Elsevier
Hohenberger C., Spörrle M., Welpe I. M., (2017). Not fearless, but self-enhanced: The affects of anxiety on the willingness to use autonomous cars depend on individual levels of self-enhancement.
Kyriakidis, M., Happee, R., de Winter, J.C.F.,(2015). Public opinion on automated driving: results of an international questionnaire among 5000 respondents. Transp. Res. Part F: Traffic Psychol. Behav. 32, 127–140.
Brown B. and Laurier E. (2017), The trouble with autopilots: Assisted and autonomous driving on the social road, CHI
Zimmermanna M., Schopfa D., Lüttekena N., Liua Z., Storosta K., Baumannb M., Happeec R., Benglera K.J., (2018) Carrot and stick: A game-theoretic approach to motivate cooperative driving through social interaction, Elsevier
Huotari K., Hamari J., (2012). Defining gamification: a service marketing perspective, In Proceedings of the 16th International Academic MindTrek Conference.
Ratti C. Smart City and Smart Citizens, (2012), Egea.
Adnan N., Nordin S., Bahruddin M., Ali M. (2018). How trust can drive forward the user acceptance to the technology? In-vehicle technology for autonomous vehicle. Elsevier