Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

Current and potential negative effects of autonomous vehicles

Carlo Polidori[a]*, Paola Di Mascio[b], Giuseppe Cantisani[b], Marco Petrelli[c]

[a] AIPSS, Piazza del Teatro di Pompeo 2 – 00186 Roma, Italy
[b]Sapienza Universitá di Roma, via Eudossiana, 18 - 00184 Roma, Italy
[c]Universitá Roma Tre, Via Vito Volterra 62- 00146 Roma, Italy

Abstract

There is a general enthusiastic approach toward autonomous vehicles, e.g. they are claimed to be the breakthrough solution for a drastic reduction of road accidents, largely caused by human errors. However, their current and potential negative effects have not been adequately addressed yet: decreasing driving skills, new "*automotive digital divide*", additional reaction time, "*last mile*" issue for automated HGVs are only some examples of still pending issues that can jeopardize the expected advantages. This paper analyzes the levels of automated driving defined by SAEJ3016 according to the current literature and resumes the main issues not yet adequately solved, in order to give a clear picture of the current and potential negative effect of each level, starting from "Level 2 - Partial automation" up to "level 4 –High automation". Level 5 is not analyzed because its deployment appears too far in the time and there are not enough data for an effective discussion. The position of the automotive industry and its need to re-invent the business is related to the present market approach and may have a relevant influence on the incoming paradigm shift.

.

Keywords: Automated driving, Connected vehicles, Truck platooning, Current and potential issues, Industry needs.

* Corresponding author. Tel.: +39-06-9293-9418
E-mail address: c.polidori@aipss.it

1. Introduction

There is a general enthusiastic approach toward autonomous vehicles, e.g. they are claimed to be the breakthrough solution for a drastic reduction of road accidents, largely caused by human errors. However, their current and potential negative effects have not been adequately addressed yet. In fact, even assuming that all the main technical issues inside the vehicles will be solved (e.g. reliability of the sensors in any weather conditions and their range of action), several “recognition” problems are still remaining, e.g. construction worker using hand gestures to tell a car to either go or to stop, or seeing distracted children close to the road without knowing if they will cross or not: autonomous car cannot reliably make the right decision at the present.
According to a near future scenario, people driving from cities in rural areas with an automated car will drive in an environment asking more tasks and skills than usual, with increased safety risks. On the other hand, people driving from rural areas in cities with less automated (respect to the city ones) cars will deal to an environment where their usual way of driving could be dangerous, too. Moreover, since they cannot benefit of several advantages of automated driving, their presence could be an actual obstacle to the urban traffic.
The issue of decreased driving skills also refers to people used to drive an autonomous car for long time, that may need a new certification if they have for any reason to drive a “normal” car.
This paper analyzes the levels of automated driving defined by SAEJ3016 [1] according to the current literature and resumes the main issues not yet adequately solved, in order to give a clear picture of the current and potential negative effect of each level, starting from “Level 2 - Partial automation” up to “level 4 –High automation”. Level 5 is not analyzed because its deployment appears too far in the time and there are not enough room for an effective discussion.

2. Level 2 – Partial automation

Table 1. Level 2 “Partial Automation” according to SAEJ3016 [1]

Narrative definition	Execution of steering and acceleration/deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving tasks	System Capability (Driving Modes)
The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	System	Human Driver	Human Driver	Some driving modes

Several manufacturers already produce and sell cars with “Partial Automation” that currently run on the roads; a first issue is represented by the sensing effectiveness in all possible driving conditions. Adverse weather conditions tend to confuse LiDAR sensors and also cameras [2]: LiDAR refers to the light sensing radar that uses lasers to map the car's surroundings so it can "see" the world.
When it is hardly raining or there is snow on the ground, cars' LiDAR sensor and camera have difficulties in recognizing the lane markers and other markers that help the system to drive safely. In addition, lane markers and all horizontal road signs result less effective, especially during the night, when a film of rainwater covers the road [3]; this is due to the different condition (diffuse reflection instead of retro-reflection) for the light emitted by vehicles’ projectors.

A fatal crash happened on 7 May 2016 in Ohio (USA) after the driver put his Model S into Tesla’s autopilot mode (Level 2). Against a bright spring sky, the car’s sensors system failed to distinguish a large white 18-wheel truck and trailer crossing the highway, thus the car attempted to drive full speed under the trailer.[4].
After eight months, the US auto-safety regulators said their investigation of the car found no defects in the system that caused the accident [5]. US Transportation Authority stated that drivers have a duty to take seriously their obligation to maintain control of a vehicle, and automakers must clearly explain the limits of semi-autonomous systems: in fact the autopilot system demands driver's supervision, their hands should remain on the wheel and their eyes on the road, according to the above definition of level two.

A relevant contradiction is that by one side these system are being pushed on the market, but on the other side the driver is asked to maintain the full control of the vehicle, so it is not yet clear why a customer should spend more money for this kind of system.
The current issue is that, without a clear and extensive communication about what the technology does and what it does not do, drivers are confused by current self-driving system and tend to misuse them, generating risky behaviors on the roads.

3. Level 3 Conditional automation

Table 2. Level 3 "Conditional Automation" according to SAEJ3016 [1]

Narrative definition	Execution of steering and acceleration/deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving tasks	System Capability (Driving Modes)
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene	System	System	Human Driver	Some driving modes

This level "jumps" from the environment monitored by the driver to the one monitored by the on board system; the human driver is however requested to "*respond appropriately to a request to intervene*": this constraint generates a relevant problem related to the driver reaction time.
Reaction time in literature has been mainly studied in relation to the time to stop or time to collision: this issue is now partially solved by the automatic braking systems, while the new kind of reaction time to a request of a generic human intervention has not been adequately addressed yet. The diagram below (Fig. 1) reports the distribution of a driver's brake perception–reaction time, on the basis of a test run on 321 people [6][7]. The time that passes from when the driver begins to brake and the brake system begins to act as well as the reaction time of the braking equipment, preceding the deceleration phase, have not been considered.

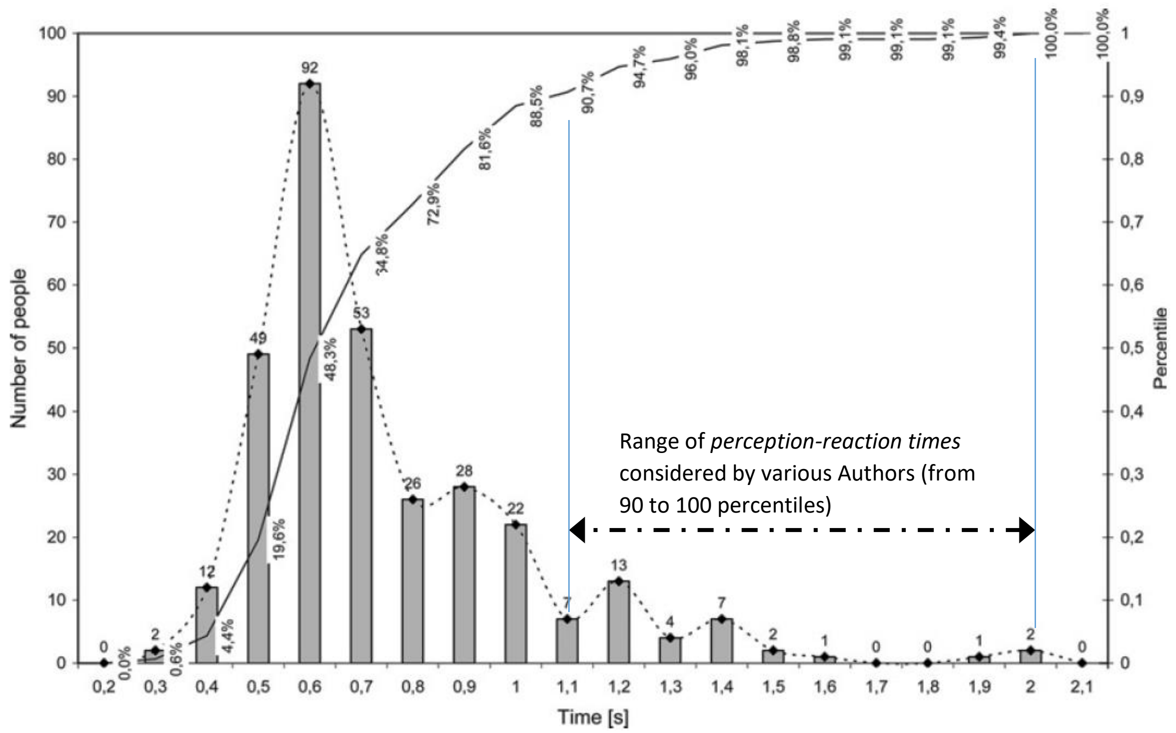

Fig. 1 Drivers' perception and response times and related percentiles (analyzed by [6] on the basis of [7])

[8] suggests that the mean perception–reaction or brake response time to an unexpected object scenario under controlled and open road conditions is about 1.1 s.
The arrows in Fig 1 highlight the range of different reaction times adopted by various authors, as a mean value taking into account different physical and psychological conditions of the drivers such as age, health, etc.
However, the range 1,1 – 2,0 seconds is related to drivers fully concentrated in performing their driving tasks, looking at the road and with their hands on the steering wheel. A more conservative value is adopted in practical applications: e.g. the perception–reaction time adopted by the American Association of State Highway and Transportation Officials for design reasons is 2.5 seconds [6].

According to the [1] definition of level 3, the driver is allowed to do other activities like reading or chatting on the smartphone, thus a new total reaction time Trt should be considered as

$$Trt = Art + Drt \tag{1}$$

where:

Art= Alert reaction time, the time taken by the driver to react to the warning

Drt= Driver reaction time = 2 seconds (conservative approach)

In order to preliminary define a value for Art, [9] noted that the automation of one or several driving tasks entails potential mental underload, meaning that the driving task may become oversimplified, resulting in boredom, cognitive underload, and eventually increased drowsiness and loss of situation awareness. In the long run, there is also a risk of skill degeneration. Also [10] found that car driver response to critical events was much slower in automated than manual driving. Waiting for specific studies and on the basis of the above consideration, a preliminary reasonable value no lower than 1 second can be assumed, meaning that the value of Trt in (1) is 3 seconds or more.

Since in a car running under level 3 the driver can be requested to intervene in specific situations, even different from the simple braking (that should be handled by the automatic subsystem), the vehicle speed becomes once again the critical factor. In fact, a car running at a speed of 50 km/h runs in 3 seconds about 41 meters, meaning that the corrective action taken by the driver happens after such a distance from the point in which he/she has been advised by the system. Higher speeds imply longer distances that may not be handled by the car sensor in a reliable way. In these conditions, if the road also presents some visual obstacles or geometric inconsistencies, the driver intervention can be further delayed and the management of road/traffic situation can result not effective in terms of speed and trajectories [11][12].

The definition given by SAEJ3016 [1] of System capability (reported in tables 1, 2 and 3 specifies that “Driving mode” is a driving scenario with characteristic dynamic driving task requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.); however, the indication “some driving modes” is too generic and does not give the exact limits of this system. Depending on the action requested to the driver by the system, a safe distance may require lower speeds, thus limiting its full application only to some specific areas where low speeds are considered as acceptable by the driver.

A relevant potential negative effect is the lack in clearly understanding the limit of the system, thus leading to a risky driving behavior. In fact, a recent comprehensive report [13] underlines that most manufacturers will not launch a level 3 vehicle, preferring to jump straight to level 4 to avoid re-engagement and liability issues.

4. Truck Platooning

A recent simulator study [14] on driver behavior in partial and fully automated truck platooning pointed out that for all workload measures, partial automation produced higher workload than did the full-automation or baseline condition; both levels of automation led to a higher degree of sleepiness than in the baseline condition.

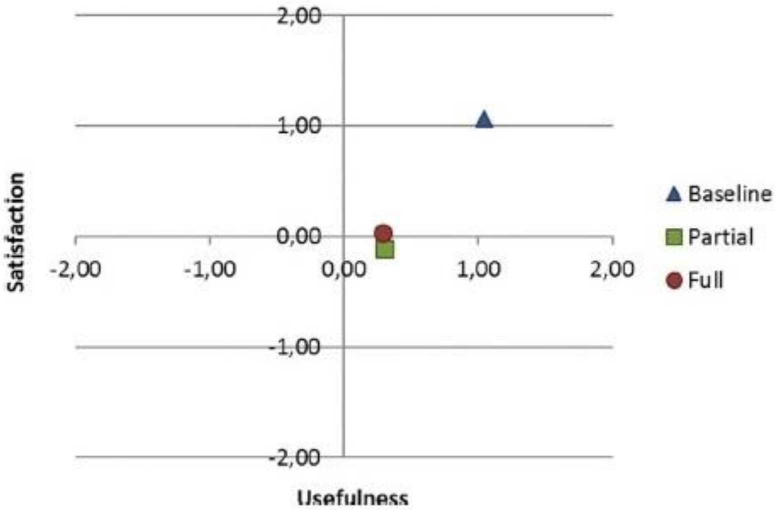

Fig. 2 Scale of acceptance by truck's drivers - Source: [14]

Trust and acceptance were generally highest in the baseline condition, and did not differ between partial and full automation, as shown in Fig. 2. Drivers may believe that they have more situation awareness during automated driving than they actually do. This current issue leads to a potential future one: as already pointed out by [9], the automation of some driving tasks implies the lowering of driving skills of professional drivers, with a loss of competencies and expertise of a relevant workforce; moreover, in the short and mid-term scenario for the deployment of automated HGVs, drivers must still drive in no automation mode in the so called "*last mile*", thus generating higher road safety risks.

In fact, after a long travel on a motorway they should take control of the vehicle through an abrupt change of tasks and workload: a recent debate in a dedicated workshop at the European Parliament [15] highlighted that a credible approach towards this relevant issue is still missing. Therefore the expected advantages of truck platooning, such as cutting fuel consumption, reducing carbon emissions, saving money, etc. are at the present mainly theoretical and far to be properly demonstrated, if compared with the increased "*last mile*" risk.

5. Level 4 High Automation

Table 3. Level 4 "High Automation" according to SAEJ3016 [1]

Narrative definition	Execution of steering and acceleration/deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving tasks	System Capability (Driving Modes)
The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	System	System	System	Some driving modes

This level implies the system is able to handle all aspects of the driving tasks, even if the drivers does not respond to a request of intervene, meaning that the system will be able to put autonomously the car in a safe situation (e.g. driving up to a lay by or in a parking area) when a dangerous situation occurs.

[16] pointed out that some adaptation in the road infrastructures are essential to allow a proper deployment of autonomous cars (for example by providing a continuous path of sensors along roadside elements [17]), thus shifting the main issue from the vehicles to the infrastructures, where cross sections, pavement and signs should be adequate for a proper deployment of autonomous vehicles and particularly for their co-existence together with normal ones.

Adequate infrastructures need huge public investments that at the present cannot be done in an uniform way on the entire road network and it is logic to assume that the first adaptation will be made in large urban areas and main road infrastructures. Moreover, costs and times needed for infrastructure upgrading will vary in each state and in each region, also considering other needs and criteria to correctly allocate future investments [18]; even when affordable systems will be developed, their wide application will take decades, so people living in rural areas will not have any stimulus to spend more money for automated cars without any actual benefit. There is therefore a risk of a new “automotive digital divide” with relevant impact on automotive market, socio economic aspect and road safety generated by differences in driving behaviors and skills between people living in urban and rural areas. [9], [10] [19] and [20] agree that automated driving systems may lead to problems of inattention, reduced situational awareness and manual skill degradation, thus compromising the safety of manual control, when needed.

Data privacy, data security, insurance and liability have been extensively addressed in literature. Their main aspects are resumed in [20], where the conclusion is that there is still a long path to ensure safety and efficiency. Fig. 3 in the following summarizes these conclusion and underlines several potential issues.

Fig.3 Reflections motivating the need of shifting from Connected Vehicles to Coordinated Automated Road Transport (C-ART) Source [20]

There has been a lot of public discussion on the potential ethical dilemmas that an AV could face, but clear conclusions are still lacking. To encourage reflections on this area, the MIT developed a Moral Machine [21] that guides users through a set of scenarios to understand what they would do in front of such circumstances. In this context, Mercedes Benz stated that they would always prioritize saving the driver and passengers of the car [22]: the discussion, as well as the issue, is still open.

6. The industry motivation

Due to the still pending issues resumed above, the public acceptance of autonomous cars is quite low, as reported by [23], even if the automotive industry is pushing them, sometime with announcements that seem too much optimistic [24]; this approach is reasonable from the point of view of OEMs, because the automotive market is mature and the only way to avoid, or at least delay, its decline is a re-invention of the business, according to [25].

In fact, this industry sector has reached his peak of business optimization in the 90s, as shown in Fig. 4, and is now facing the need of re-inventing the business in order to avoid or at least limit its decline.

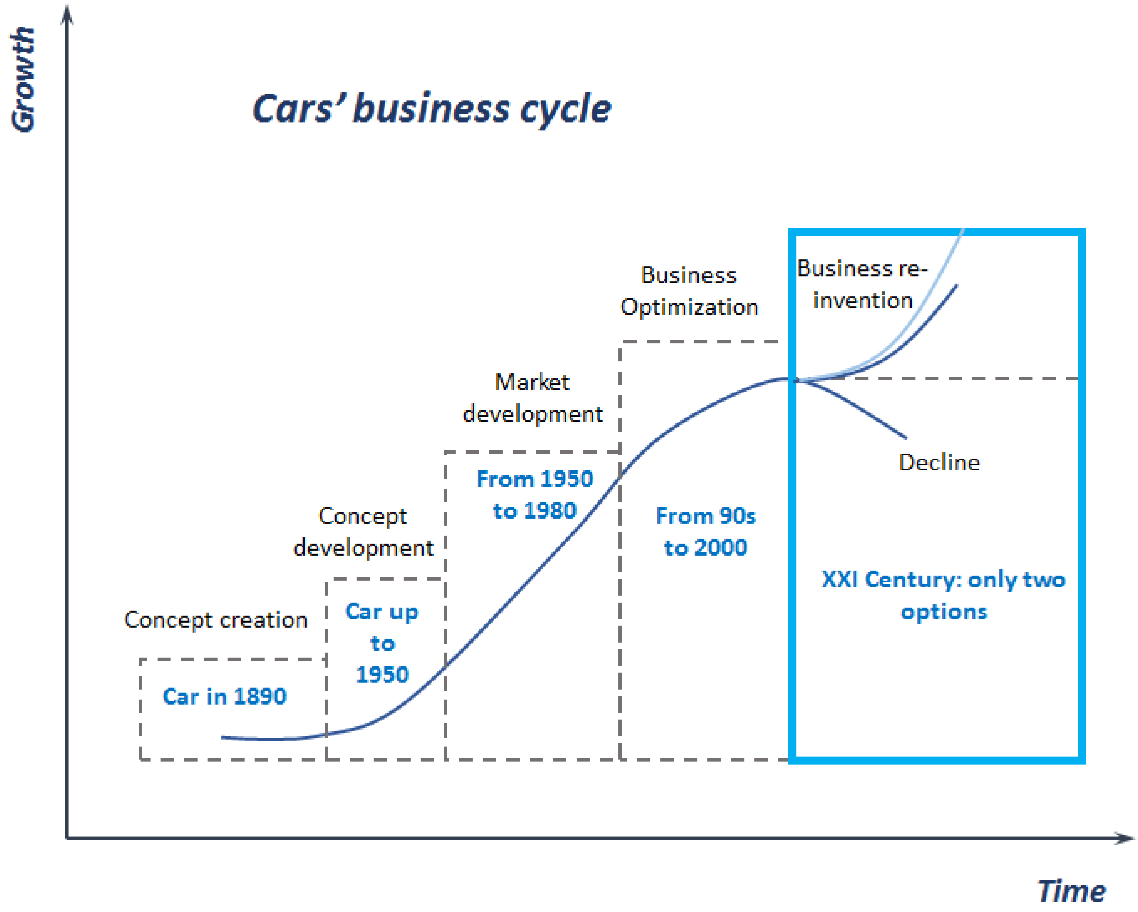

Fig.4 The Automobile business cycle. Source [25]

However, the needs of the automakers, if not complemented by policy guidance, may cause the major risk for the future: autonomous cars, when broadly deployed, will generate a paradigm shift in several human activities and in the next decade this process should not be regulated by the market only. SUVs deployment in our cities, too big cars often going off road only in a gravel carpark, are the example of a solution increasing congestion, fuel consumption and pollution, but largely adopted everywhere after a strong marketing approach. Applying the same approach to the future autonomous cars may jeopardize all the actual advantages their correct deployment could lead to.

7. Conclusions

Current and potential issues of autonomous cars have been analyzed with reference to the levels 2,3 and 4 according to the definition given by SAEJ3016, where level 2 "Partial Automation" refers to system currently in use in some new cars. Level 5 "Full Automation" has not been discussed, because its actual achievement seems still too far and there are not enough data or case studies.

Current issues given by level 2 are mainly resumed in the analyses of the TESLA fatal crash on 2016 in USA, where investigation of the car found no defects in the system that caused the accident, that was caused by a misuse of it by the driver. An incorrect or not effective information about what the technology can do and what can do not, may cause serious accidents.

The main pending issue of level 3 "Conditional automation" is given by the reaction time of the driver when he/she is requested by the system to intervene: such time, added to the usual reaction time when the control has been taken, may imply very low speed in order to guarantee safety. This issue also depends on what actually the driver is entitled to do while the system drives the car; further investigations in this sense are needed.

The acceptance of truck platooning by professional drivers appears quite low and a wide deployment of this system will lead to a loss of competencies and expertise in a relevant workforce, together with increased risks when driving in no automation mode in the "last mile".

The effective deployment of level 4 needs some adaptation of the road infrastructure that will be reasonably initiated, due to their cost, only in urban areas and main highways of richest countries: this scenario may generate a new kind of *digital divide* between people living in different countries, as well as between those living in countries and cities of the same country.

The future broad deployment of autonomous car will take several years and generate a paradigm shift in several human activities: such process should be regulated by the policy makers and not simply left to the market driven forces.

8. References

[1] Summary of SAE International's Levels of Driving Automation for On-Road Vehicle www.sae.org/misc/pdfs/automated_driving.pdf

[2] Muoio,D.- 6 scenarios self-driving cars still can't handle - Business insider UK aug 25, 2016 - http://uk.businessinsider.com/autonomous-car-limitations-2016-8?r=US&IR=T

[3] Hofmann, F. (1979). The improvement under wet conditions of the night-time visibility of carriageway markings. Straßenverkehrstechnik, 23(5).

[4] www.theguardian.com/technology/2016/jun/30/tesla-autopilot-death-self-driving-car-elon-musk

[5] www.theguardian.com/technology/2017/jan/20/tesla-model-s-cleared-auto-safety-regulator-after-fatal-autopilot-crash

[6] Dalla Chiara B. et Al. "Assessing the effects of inter-vehicle communication systems on road safety" Published in IET Intelligent Transport Systems doi: 10.1049/iet-its:20080059 - http://ieeexplore.ieee.org/document/5071792/

[7] Johansson G., Rumar K.: 'Driver's brake reaction times', Hum. Factors, 1971, 13, pp. 23–27

[8] Green M.: 'How long does it take to stop?'. 'Methodological analysis of driver perception-brake times, transportation human factors'. vol. 2, pp. 195–216

[9] Parasuraman R et Al. (2000) A model for types and levels of human interaction with automation. IEEE Trans Syst Man Cybern Part A: Syst Hum 30(3):286–297 - http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.420.9319&rep=rep1&type=pdf

[10] Merat, N., & Jamson, A. H. (2009). How Do Drivers Behave in a Highly Automated Car?.Proceedings of the International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, 5, 514–521. https://www.researchgate.net/publication/237622858_How_do_drivers_behave_in_a_highly_automated_car

[11] Cantisani, G., & Loprencipe, G. (2017). Reference trajectories of vehicles for road alignment design. In Transport Infrastructure and Systems: Proceedings of the AIIT International Congress on Transport Infrastructure and Systems (Rome, Italy, 10-12 April 2017) (p. 71). CRC Press.

[12] Cantisani, G., & Loprencipe, G. (2013). A statistics based approach for defining reference trajectories on road sections. Modern Applied Science, 7(9), 32.

[13] Ptolemus consulting group: THE AUTONOMOUS VEHICLE GLOBAL STUDY 2017 ; http://www.ptolemus.com/autonomous-vehicle-global-study-2017

[14] Hjälmdahl, M., Krupenia, S. & Thorslund, B. "Driver behaviour and driver experience of partial and fully automated truck platooning – a simulator study" Eur. Transp. Res. Rev. (2017) 9: 8. https://doi.org/10.1007/s12544-017-0222-3

[15] European Parliament Workshop of Driving Future Platform: Acceptance of Autonomous Driving & its impact on society. 07 December 2017 - https://youtu.be/YGQJ4kgVE14 (from 1h05'30" to 1h07'17")

[16] Andrew Ng, chief scientist at Baidu, runs Baidu Research, which includes the Institute of Deep Learning, the Big Data Lab and the Silicon Valley AI Lab. – post on Wired on March 2016 - https://www.wired.com/2016/03/self-driving-cars-wont-work-change-roads-attitudes/

[17] Cantisani G., Di Mascio P., Polidori C. (2017). New research opportunities for roadside safety barriers improvement. In Building up Efficient and Sustainable Transport Infrastructure 2017 (BESTInfra2017) (21–22 Sept 2017, Prague, Czech Republic) IOP Conf. Ser.: Mater. Sci. Eng. 236 012097. doi: 10.1088/1757-899X/236/1/012097

[18] Loprencipe, G., Cantisani, G., & Di Mascio, P. (2015). Global assessment method of road distresses. In 4th International Symposium on Life-Cycle Civil Engineering, IALCCE 2014. CRC Press/Balkema.

[19] Cunningham M. Regan M: Autonomous Vehicles: Human Factors Issues and Future Research - Proceedings of the 2015 Australasian Road Safety Conference - 14 - 16 October, Gold Coast, Australia http://acrs.org.au/files/papers/arsc/2015/CunninghamM%20033%20Autonomous%20vehicles.pdf

[20] European Commission – Joint Research Centre: The r-evolution of driving: from Connected Vehicles to Coordinated Automated Road Transport (C-ART) 2017 - https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/r-evolution-driving-connected-vehicles-coordinated-automated-road-transport-c-art-part-i

[21] http://moralmachine.mit.edu/

[22] http://fortune.com/2016/10/15/mercedes-self-driving-car-ethics/

[23] Kyriakidis M. et Al. - Public opinion on automated driving: Results of an international questionnaire among 5000 respondents - Transportation Research Part F: Traffic Psychology and Behaviour - Volume 32, July 2015, Pages 127-140 - http://www.sciencedirect.com/science/article/pii/S1369847815000777

[24] https://venturebeat.com/2017/06/04/self-driving-car-timeline-for-11-top-automakers/

[25] Dalla Chiara B., Deflorio F., Carboni A., Evoluzione dell'auto verso l'autonomia: collocazione storico evolutiva, motivazioni ed effetti sulla sicurezza, - Convegno AIPSS «Aspetti della sicurezza stradale relativi all'introduzione dei veicoli a guida autonoma», Torino, 24.02.2017 - http://www.aipss.it/DallaChiara.pdf