Impact of Autonomous Vehicles in Cities: User Perception

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***Abstract* — Autonomous driving is a very important topic aiming on changing mobility in smart cities. A lot of research has been dedicated to development of vehicles without drivers and quite many tests and real world demonstrations have been reported especially in the last years. The first expectations were very optimistic. Researchers as well as general public expected high positive influence in the congestions, travel time and other mobility aspects. However, the latest research questions these purely positive expectations and suggest that autonomous driving might have positive or negative effect based on city policies in place.**

In order to gain a better understanding about the current expectations of general public about the impact of autonomous driving, a survey has been conducted as part of a European project MAVEN. This paper provides a short description of the survey design and then summarizes the main findings and results of this survey. The results can get us a better way to understand the feeling of citizens about autonomous vehicles and the transition to full automated cities.

The results confirmed the general trends and at the same time gave us more insight into the special questions related to MAVEN use cases. These findings will be further validated in simulation experiments.

***Index Terms* — MAVEN, Autonomous Vehicles, Survey.**

I. Introduction

THE European H2020 project MAVEN (Managing Automated Vehicles Enhances Network) focuses on the integration of autonomous vehicles and their platoons into a city infrastructure. Apart from implementing different use cases with respect to control algorithms enhancing the cooperative behaviour of intersections as well as vehicles, the project also addresses the impact of autonomous vehicles on cities. The impact assessment in the project focuses on four different dimensions:

a) Verification of a vehicle as well as controller's prototypes and their interactions in field tests;

b) Enhancing the field tests by emulating extra virtual vehicles to overcome limitations related to low market penetration of automation and cooperative vehicles in the experiments;

c) Using traffic microsimulation models to evaluate the expected impact for different penetration rates, different ration of vehicle classes or, for example, different intersection layouts. A microsimulation model can measure many different performance indicators incl. delay (sec), travel times (sec), or for example produced emissions (g);

d) Using different surveys (mainly online survey and PAPI (Paper-and-Pencil Interviewing) during field tests), or interaction tools (e.g Mentimeter) to assess the user expectations and perceptions. And the last dimension (user assessment), particularly the results of an online survey are addressed in this paper.

The state-of-the-art analysis (the following section) clearly shows that quite a lot of studies have focused on the user perception of autonomous driving. Within the MAVEN project and MAVEN survey, we did not want to repeat the previous studies. Our aim was to be focused on two main hypothesis groups:

1. To identify some fundamental questions from other surveys (mainly with respect to perception of possible impact of autonomous vehicles) and verify whether the respondents in other target groups and regions have similar perception (i.e. verification).
2. To prepare unique set of questions, particularly important and relevant for the MAVEN project (i.e. uniqueness).

With this in the mind, the proposed questionnaire consists of several parts, aiming on different aspects of autonomous driving. The structure of the questionnaire is described below.

Autonomous driving is experiencing a huge boom. It is linked together with developments in technology, but also with a strong focus on Smart Cities, where automated vehicles, shared economy, as well as for example electromobility shall play an essential role. In the early years of development of autonomous vehicles (AVs), most researchers expected mainly positive impact of automated vehicles. A selection of such expected impact adopted from [1] includes:

- Fewer traffic collisions, due to elimination or minimization of human errors.
- More smooth and comfortable, and less stressful, rides.
- Greater mobility freedom for the disabled, fatigued, drunk, inattentive, senior, or children.
- More accessible, reliable and flexible shared rides for personal transit and mobility service.

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- Reduced number of on-road vehicles via ride sharing or car sharing of automated vehicles.
- And many others.

In the last years however, researchers started to doubt the expected positive impacts and often refer back to them as "wishful thinking" [2][3]. David Metz [4] confirms the expectations that the impact of AVs cannot be simply just positive or just negative. He concludes that it is to be expected that individually owned AVs will add significantly to the overall distance travelled by car and hence to increased traffic levels. In contrast, AVs operating as robotic taxis would not be expected to have such an impact, given that conventional taxis travel without passengers between paid trips. Wadud et al. [5] explore the effects of automation on congestions, energy consumption and emissions through several illustrative scenarios, finding that automation might plausibly reduce road transport emissions and energy use by nearly half; or nearly double them; depending on which effects come to dominate.

A critical question is whether autonomous vehicles increase or reduce total vehicle travel and associated external costs. It could go either way, depending on public policies. By increasing travel convenience and comfort, and allowing vehicle travel by non-drivers, they could increase total vehicle mileage, but they may also facilitate vehicle sharing, which allows households to reduce vehicle ownership and therefore total driving.

Many surveys have been conducted in the past years to address the public and find out what is their view to AVs. The surveys have been done not only by universities but by private companies as well (e.g. Cisco). The most frequently identified concerns/expected impacts are described below and we want to verify them in our research.

The research of Cisco [6] shown that 57 % of consumers, globally trust in automated cars and would like ride driverless. This trust is even bigger in emerging markets. The trust in AVs is as high as 95 % in Brazil, 86 % in India or 70 % in China. On the other hand, the overall trust is only 28 % in Japan, 37 % in Germany and 45% in the UK. The study by J.D.Power and associates [7] measured a vehicle owner interest and purchase intentions for emerging automotive technologies, both before and after market price is revealed. Not unexpectedly, purchase interest declines across all respondent groups when the price of automated features is revealed. In the mentioned study, mentioning the estimated additional cost of $3,000 lead to a decrease from 37 % to 20 %. It shows that the price of the technology will be crucial, which is certainly a challenge for car manufacturers. This trend confirms also another study by Howard and Dai [9]. There is also an assumption that autonomous vehicles will increase the cost of vehicle ownership as showed in the research [10]. After an introduction of autonomous vehicles, there will not be such need for selling vehicles as for renting them and getting payments for the services. There will not be the main goal to sell vehicles but to rent them.

On the other hand, the Seapine Software study [11] finds out that 88 % of adults would be worried about riding in a driverless car. The public has generally expressed some concern regarding owning or using vehicles with this technology. The results varied considerably by country and interest levels were consistently lower when respondents were asked about allowing their children to ride in such vehicles.

The research of Bansa & Kockelman [12] shows that the safety and reliability of the system is often rated as people's top priority when judging the desirability of autonomous vehicles. The security of the software makes respondents typically raise the potential for people to hack into vehicle control systems as another serious concern as can be seen from the research of Kyriakidis, Happee & de Winter [13]. The interesting topic is also related to a liability. The several surveys identify concerns around the legal issues associated with use of the technology (e.g. [13]).

In summary, the MAVEN survey addresses and verifies the some main issues that have been addressed in other research, especially:

- Familiarity with and general opinion about autonomous vehicles
- Expected benefits of autonomous vehicles
- Concerns about using autonomous vehicles
- Concerns about safety of autonomous vehicles in unexpected situations
- Concerns about cyber security issues
- Concerns about different possible implementations of self-driving vehicles
- Overall interest in owning and willingness to pay for autonomous-vehicle technology

Additionally, the second set of questions is related to MAVEN project specifically.

II. The Design of the Survey

The design of the questions was based on extensive literature review. Our aim was not to only replicate existing research, but rather address new, MAVEN specific topics. On the other hand, we wanted to confirm that the respondents were comparable in opinions with the other study groups (as discussed in the introduction). Thus few fundamental questions from other surveys were repeated also in this experiment.

A. The structure of the questionnaire

Based on the literature review and in order to provide clarity, the questions were divided into the following main groups:

1. Socio-demographic characteristics.
2. Expected impacts / effects of autonomous vehicles in cities (e.g. expected impact on congestions, safety or others).
3. Integration into a city (e.g. sensitivity to sharing of public space, sensitivity to priorities of the different modes, reaction to MAVEN use cases and others).
4. Transition from the current state to a state with higher penetration of autonomous vehicles.
5. Perception of concerns, potential issues, etc.

While most existing surveys concentrate on user perception and expected impacts, the main focus of MAVEN online survey is on the sections (3.) Integration and (4.) Transition.

In order to increase the response rate, the survey was purposefully kept rather short. The average time for completing the survey was 13 minutes including the explanation of MAVEN project ideas and the key terms (e.g. autonomous vehicles, level of automation and others). The total number of questions reached 27.

B. Survey distribution

The survey has been designed in Survey Monkey tool. It allows us to keep a clear structure and add additional explanatory materials, if needed.

A link to the survey website together with request for completion (always personalized for the given group of respondents) was sent to various participants in various countries, among others Czech Republic, Netherlands, UK, Germany, and other countries Worldwide.

The information and link to the survey has been distributed using the following resources:

- Greenwich website and city communication channel to inhabitants (09/2018)
- Helmond website and city communication channel to inhabitants (09/2018)
- POLIS network and distribution channels (10/2018)
- Distribution channels and website of the Operator ICT Prague (an organization dealing with smart city projects in the city of Prague) (10/2018)
- Members of Smart City Cluster Czech Republic (10/2018)
- Participants of the Workshop on Autonomous driving as part of SCSP 2018 (10/2018)
- FIA, the European association of national motorist organizations, or alternatively the national driver's organization directly. We have FIA contacts but not national level contacts.
- ECF, the European cyclists federation (10/2018)
- EPA, European parking association (10/2018)
- EPF, European passenger federation (10/2018)
- Students of CTU (10/2018), or for example
- LinkedIn (09, 10, 11 /2018)

Each of these groups also received a reminder to increase the response rate.

C. Survey execution

The survey was opened by 20th of September and closed by the 31st December 2018, with the total number of 209 respondents who completed the survey. Due to the fact that email distribution and distribution via professional networks was used, it is not possible to obtain the response rate.

The responses were collected directly in the tool Survey Monkey and basic analysis was conducted also here. For more advanced mathematical analysis, the tool IBM SPSS was used.

The complete results of the survey and its detailed analysis will be included in the deliverable D7.2 of the MAVEN project later in 2019. In this article, only the most interesting findings will be provided and the main results commented.

III. RESULTS

The first section of the survey collects socio-demographic characteristics and consists of 5 questions. Respondents come from more than 30 countries. 33% come from the Czech Republic, 8% from the USA and the same from the UK, 7% from Germany and 6% from Netherlands. The rest of nations are below 5%. 70% of respondents were male and 30% were female. 59% of respondents were between 25 and 44. The entire age structure is provided in Table 1.

Table 1 - The age structure of respondents

Answer Choices	Responses
Under 18	0.48 %
18-24	15.38 %
25-34	36.54 %
35-44	22.12 %
45-54	13.46 %
55-64	10.10 %
65+	1.92 %

The respondents have different working status as can be seen in Table 2. The most responses are coming from a public authority/municipality, university or research organization or a private sector. All respondents are economically active.

Table 2 - Working status of respondents

Answer Choices	Responses
Working for a public authority or municipality	19.90 %
Working for a university or a research organization	32.04 %
Working in a private sector	26.21 %
Self-employed or Entrepreneur	6.80 %
Unemployed	0.49%
Retired	0.00 %
Student	14.56 %

The next question (Table 3) focuses on the source of information with respect to automated vehicles. The majority gets information from news and also from existing projects (this can be caused by the fact that most participants of the survey were recruited from professional organizations).

Table 3 - The source of information related to automated vehicles

Answer Choices	Responses
Information from news	80.29 %
Information from existing projects	59.62 %
Social Sites	36.06 %
Workshops	32.21 %
Conferences	49.52 %
Other	21.15%

In this paper, we want to focus not only on the general responses to particular questions, but also to compare them to existing research or show the influence of different socio-demographic characteristics such as age or gender). The responses to particular research questions (RQ) are discussed below:

RQ1 Do public authorities answer differently the question (Q6): *Do you think that automated vehicles decrease the number of traffic accidents?*

The aim of the comparison is to find out whether public authority representatives perceive differently the impact of automated vehicles on the expected accident rate. Figure 1 however suggests, that there is no significant difference and the answers are very similar.

This is an important finding as it validates the results of MAVEN project.

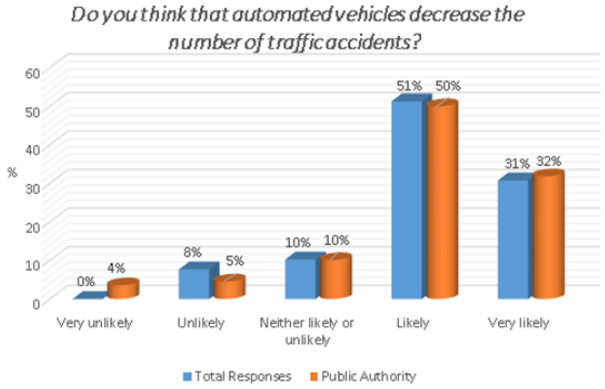

Figure 1 - Total responses vs public authority

RQ2 Are results from the research [12] different to the question(Q7): W*hat are the most important benefits you expect automated vehicles to deliver?*

The answers to Q7 were compared to the research done by The Royal Automobile Club of WA (RAC) [14]. In MAVEN survey, 75 % of respondents expect improvement of road safety. About a half of respondents also expect better prediction of traffic flows and an increase of driving. In the age group 45-54 years, only about 15 % of respondents expect travel time savings of 33% or an increase of driving comfort. The another interesting fact is that only a third of respondents expect emission reduction. The three least expected benefits of our respondents are emission reduction; travel time savings; and cheaper services, such as sending the kids around without paying a taxi driver.

The three most expected benefits of RAC`s respondents are an enhanced freedom and independence for the young, ageing and those with mobility difficulties; travel time can be used more effectively / productively doing other activities; and fewer crashes. On the other hand, the three least expected benefits of RCA`s respondents are less traffic congestion; lower vehicle emissions; and less need for public parking in towns and cities.

The comparison shows that expected impacts are quite different. For example, in MAVEN survey, the second biggest expected benefit is a better prediction of traffic flows. On the other hand, RAC`s respondents do not expect less traffic congestion. The main factor for this difference is that different types of respondents answered.

RQ3 Are results from the research from the Czech Ministry of Transport [15] different to the question (Q12): *If you would ride in an automated vehicle, how would you use the extra time instead of driving?*

This question was also included in the research done by the Ministry of Transport of the Czech Republic (MoT CR) [15]. Table 4 suggests that the most significant difference is between the option – working on laptop/tablet (74 % vs 31 %). This difference could be done by the fact that MAVEN questionnaire attended mainly people working in the research area or public authorities, i.e. professionals. They do not expect to spend much time in social networks or playing games.

Table 4 - How would you use the extra time instead of driving?

Answer Choices	MAVEN	MoT CR
Reading e.g. book	52.41 %	39.50 %
Watching a movie	22.46 %	36.90 %
Working on laptop/tablet/smartphone	74.33 %	31.10 %
Playing games on laptop/tablet/smartphone	17.65 %	23.80 %
Sleeping/Relaxing	55.61 %	35.30 %
Social networking	31.55 %	48.30 %

RQ4 Do public authorities answer differently the question (Q14): *Do you agree that a platoon of five automated vehicles should get an extended green light to allow the full platoon to pass through the traffic signals?*

The most significant difference is in the answers to the "Strongly disagree" choice. This can be caused by the fact that many respondents have background in the research or public authority area. These respondents have also different source of knowledge as can be seen from the socio-demographic question ("The source of information related to automated vehicles") where about 60 % of respondents gained knowledge in research projects and about 50 % from conferences.

Table 5 - Total responses vs public authority

Answer Choices	Total responses	Public authority
Strongly disagree	12.90 %	2.78 %
Disagree	15.59 %	22.22 %
Neither agree nor disagree	20.43 %	22.22 %
Agree	45.16 %	44.44 %
Strongly agree	5.91 %	8.33 %

RQ5 Do public authorities answer differently the question (Q15): *How would you react in the following situation? Situation: You are driving manually on the left lane in a city while a platoon of 5 vehicles is driving on the right lane with the same speed. There are no other vehicles and the road is straight. You want to turn right on the next intersection in 200m, where a traffic light just became green, and need to change lane to the right. What will you do?*

As Table 6 depicts, over 40 % of respondents in both groups have selected that the vehicle should break and change the lane behind the platoon. The public authority`s responses are also the same in case of set the indicator. The difference is at the first and fourth choices. This difference can be also done by the fact that public authorities and researches have a different level of knowledge about automated vehicles. Unfortunately, there are not so many samples, so statistical analysis of individual groups cannot be done (due to the fact that total number of responses is 209 and not all of them from public authorities).

Table 6 - Total responses vs public authority

Answer Choices	Total responses	Public authority
Accelerate and change lane in front of the platoon, even if this means to drive faster than allowed.	23.53 %	11.11 %
Break and change lane behind the platoon even if this means that you probably need to drive slowly and might not reach the upcoming traffic light at green.	43.85 %	44.44 %
Set the indicator and hope that the platoon opens a gap quickly.	28.34 %	27.78 %
Just drive to the right as the automated vehicles should be able to react.	4.28 %	16.67 %

RQ6 Do public authorities answer differently the question (Q18): ***You are a passenger in an automated vehicle and you don't have an appointment at a specific time at your destination. Would you accept the vehicle taking a detour to reduce congestion?***

The public authorities would be generally willing to accept 10 % more extra travel time compare to individual shortest travel time. They would use this additional time mostly for working on laptop/smartphone/tablet. The difference between the total responses and public authority`s responses is negligible at choices 5 % and 25 %. The public authorities are also more tolerant to their individual travel time. The results are shown in Table 7 below.

Table 7 - Total responses vs public authority

Answer Choices	Total responses	Public authority
No, I always want my individually shortest travel time	17.84 %	11.11 %
Yes, maximum of 5% extra travel time	17.30 %	19.44 %
Yes, maximum of 10% extra travel time	38.38 %	47.22 %
Yes, maximum of 25% extra travel time	20.00 %	19.44 %
Yes, any delay is acceptable	6.49 %	2.78 %

RQ7 Do the age group 55-64 answer differently the questions (Q20): ***For your business trip, you can order a standard taxi (with a driver) or an automated taxi (without a driver). Both with the same error rate. Which one will you select, if automated taxi is 10% cheaper?*** **and the question (Q21):** ***For your private trip, you can order a standard taxi (with a driver) or an automated taxi (without a driver). Both with the same error rate. Which one will you select, if automated taxi is 10% cheaper?***

All age groups reported the similar results as the total responses (deviation max. 5 %). It does not matter if a purpose of trip is considered. In both cases, three quarters of respondents would select a taxi without driver. The only difference is the age group 55-64 which would consider more driving with a driver as it can be seen in Table 8. The can be caused by the fact that the older respondents have less trust in technology than the younger ones.

Table 8 - A standard taxi or an automated tax?

Answer Choices	Business trip (total responses)	Private trip (total responses)	Business trip (age 55-64)	Private trip (age 55-64)
With a driver	23.76 %	21.11 %	38.89 %	33.33 %
Without a driver	76.24 %	78.89 %	61.11 %	66.67 %

RQ8 Are results from the research [13] different to the question (Q23): ***Would you be prepared to pay more for automated features?***

The respondents from the research [13], on average, were willing to pay more for fully automated driving than for partial and highly automated driving. The Figure 2 shows the distribution of responses, where 22% indicated that they were willing to pay nothing ($0) for fully automated driving. However, 240 respondents (4.9%) indicated they would be willing to pay more than $30,000 for fully automated driving.

In MAVEN, 36 % of respondents would not accept to pay more for automated features as it can be seen from Figure 3. Only 6 % of respondents would accept to pay more than 5 000€.

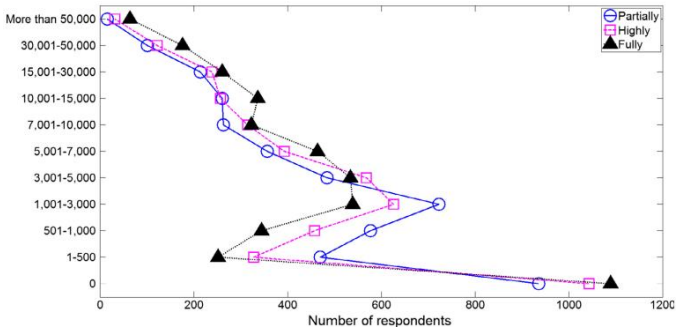

Figure 2 - The willingness to pay for the different levels of automation [11]

This shows that customers will be able to pay a little bit more for automated vehicles, but 5 000€ looks like a threshold for the most of people. On the other hand, 20 % of respondents from second research stated that they would be willing to pay more than 7 000$.

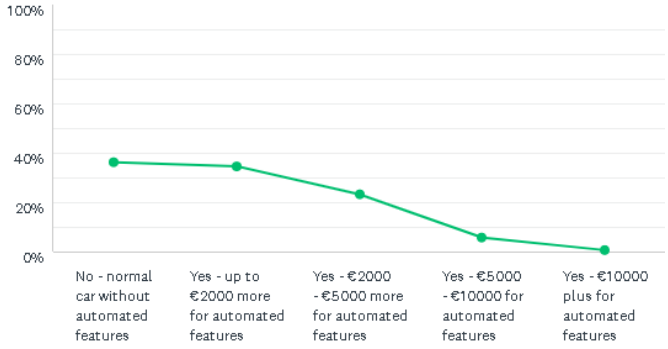

Figure 3 - MAVEN results

IV. Conclusion

This paper discussed selected results of a detailed user survey aiming on understanding the expected impacts and transition of automated vehicles. The survey was based on results of detailed literature review. It does not aim on replicating existing surveys, but rather to fill in existing gaps with respect to integration of automated vehicles into city management. This integration is also the main objective of a H2020 research project MAVEN (Managing Automated Vehicles Enhances Network). The authors did not provided overview of all 27 questions, but rather focused on comparison of the answers with respect to other researches or different socio-demographic groups of respondents. The main group for comparison were 41 respondents working for public authorities as they could get us the best understanding of expectations with respect to integration into city management.

Overall 8 research questions were formulated and discussed. The overall number of respondents reached 209. This is a sufficient number to gain an understanding to the field, but it does not allow for detailed statistical testing of hypotheses.

The responses have revealed some interesting facts. The general expectations that the number of traffic accidents will be decreased corresponded very closely to other research. In the survey, there is in general no significant difference in the perception of public authority representatives compared to all respondents. This can be caused by the fact, that mainly city representatives interested in the topic of automated vehicles were included. In this respect, they are not so different from researchers or industry representatives.

Not surprisingly, age proved to be an important factor with respect to willingness to use automated vehicles. Older respondents are less likely to use automated taxis. Interesting are also the responses about the usage of time when driving in an automated vehicle. Most respondents would be working, reading a book or relaxing. In other research by the Ministry of Transport of the Czech Republic, more people would be dedicating their time to social networking or playing computer games.

The conclusions of this research will be further integrated into the work in MAVEN project. Some additional responses about perception of time or the willingness to contribute to system optimal solutions will be evaluated in simulation experiments.

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