AHP-based Evaluation of the Acceptance of Autonomous Driving

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Abstract: In the world with seven billion people and around one billion cars, autonomous driving has the potential to become a key factor of overcoming pollution and traffic jam when considering big cities. This work discusses safety- and security related factors with simultaneous improving of the acceptance of autonomous driving. The data were obtained from the survey carried out by Deloitte analytics institute located in Germany. The data are analysed by means of the analytical hierarchy process (AHP). The theoretical finding allows concluding that, due to the technology development, the conventional division of factors into external and internal has to be extended with the third groups, namely other factors. A theoretical finding is three clusters of influencing factors. The cluster with the most influential factors includes active driving systems, sensors, car-to-car communications and algorithmic. The limitations of the study are outlined. Directions of further work are proposed.

1 INTRODUCTION

Autonomous driving is one of the greatest goals in the automotive industry. It can be considered as an innovative component of the future of car driving as the whole car industry. Autonomous driving has become a key research in the last decade. There are several manufacturers, which do investigations in the field of autonomous driving in order to create an innovative autonomous driving car for their customers.

In the world with seven billion people and around one billion cars, autonomous driving has the potential to become a key factor of overcoming pollution and traffic jam when considering big cities. Here, autonomous cars using hydrogen fuel for motive power or even electric cars can have the potential to improve the living conditions in big cities significantly.

It is assumed that autonomous cars can drive much faster and at the same time more economically in a convoy while avoiding annoying downtimes. This should also drastically reduce fuel consumption. On the other hand, it might also decrease the stress level for the passengers as autonomous vehicles "know" where the next traffic jam is and drive around it independently or they know already in advance where the next free parking space is available in crowded city centres. An autonomous car would search for a parking space on its own.

However, many people still have doubts regarding the future of autonomous driving.

In previous work some authors examined different aspects of acceptance of autonomous driving. For example, Lee, Chang and Park (2018) point out that the most important influencing factors for general autonomous vehicles South-Korean costumers characterize as usefulness, reliability and legality. The acceptance of full autonomous vehicles is mostly affected by safety, user convenience, and extra expenses. Safety also is important for the acceptance of partial autonomous vehicles (Lee, Chang, Park, 2018). In addition, Kettles and van Belle (2019) show in their work, that Performance Expectancy and Hedonic Motivation (as well known as Enjoyment) are the most significant predictors of Behaviour Intention.

The study of the acceptance of autonomous driving is related to the examination of the supporting trust of autonomous driving. Häuslschmid, von

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Bülow, Pfleging and Butz (2017) carried out a research on this topic. They argue, that trust in autonomous driving could be increased by a visualization, which represent the car's interpretation of the current situation and its corresponding actions (Häuslschmid, von Bülow, Pfleging, Butz, 2017).

Moreover, customers have a conflicting attitude about self-driving vehicles. The further development of this technology is connected to some kind of "posthuman ability" as well as it is connected to hesitation to cede control to machines. Gambino and Sundar (2019) examined exactly this topic. They suggest, that "individuals are much more accepting of technology that can clearly outclass human abilities" (Gambino, Sundar, 2019).

Against this background, there are some aspects such as safety- and security related questions that have not received a proper attention in the implemented research. This work discusses safety- and security related questions with simultaneous improving the acceptance of autonomous driving. The data obtained from surveys are analysed by means of the analytical hierarchy process (AHP). This procedure was introduced by Saaty in the 70's to analyse complex decisions (Saaty, 2008).

The paper is structured as follows: Section 2 introduces the most important factors of autonomous driving classified into intrinsic and extrinsic factors as well as the other factors. Within these factors it will be examined, how the influencing factors affect security- and safety related questions in the acceptance of autonomous driving. In Section 3 AHP will be shortly introduced followed by a subsequent weighting of the defined intrinsic and extrinsic factors with respect to safety and security of autonomous driving. Section 4 is dedicated to the analysis of the acceptance of autonomous driving in our world today using AHP. Finally, some concluding remarks are given.

2 FACTORS INFLUENCING AUTONOMOUS DRIVING

In this section, factors improving the acceptance of autonomous driving are specified. By factor, a reason of phenomenon change is meant. In the present work, it is assumed that factors such as energy consumption, the possibility to use active driving systems and Car-to-Car as well as Car-to-infrastructure play an important role when improving the acceptance of autonomous driving.

Factors are traditionally differentiated into external and internal (Ahrens, Zaščerinska, 2014). In the present research, the factors' influence is classified in intrinsic, extrinsic and the other factors as shown in Figure 1.

It should be pointed that in the present work the "external" and "extrinsic" as well as "internal" and "intrinsic" factors are used synonymously. Whereas intrinsic factors are assigned to the inner area of the vehicle such as the possibility of using active driving systems, extrinsic parameters are assigned with the outer area of the vehicle such as the energy consumption.

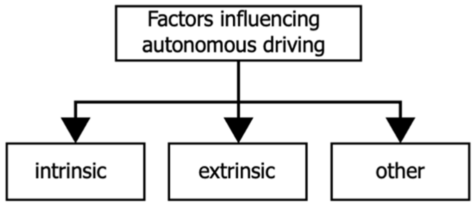

Figure1: Factor classification.

Factors which cannot be assigned to intrinsic and extrinsic are put into the class "the other factors". In this category will put factors influencing the Car-to-Car as well as Car-to-infrastructure communication.

2.1 Intrinsic Factors

Intrinsic factors are assigned to the inner area of the vehicle. The intrinsic factors include

- the behaviour of the vehicles (algorithmic factors),
- physical components of driving, for example breaks and the engine,
- the communication between the vehicle and a mobile device like smartphone or tablet.

These factors are in particular physically located, or work to a large extent in the inner area of the vehicle.

It is not possible to create a safe autonomous driving system by ignoring this kind of influencing factors.

2.2 Extrinsic Factors

Extrinsic factors are assigned to the outer area of the vehicle.

In this regard the extrinsic factors are

- cheap energy consumption (i.e. prices for gas, electricity or hydrogen),

- sensors (possibility to perceive the vehicle's surroundings, for example light detection and ranging (LIDAR, Sonar or radar),
- locating possibilities (techniques to define the position of the vehicle exactly, for example with the help of GPS and/or Galileo) and
- service infrastructure (the availability of gas stations and car wash stations etc.).

These influencing factors are in particular located in the outer area of the vehicle. As highlighted in section 2.1 when analysing intrinsic factors, it is not possible to create a safe autonomous driving system by ignoring the extrinsic influencing factors.

2.3 The Other Factors

Other factors cannot be assigned to the classes of intrinsic and extrinsic factors. This category includes

- Car-to-Car communication (standardized communication between vehicles),
- Car-to-Infrastructure communication (standardized communication between vehicles and infrastructure like traffic lights) and
- Car-to-Remote site (possibility to communicate with the workplace or home)

3 UTILITY ANALYIS AND ANALYTIC HIERARCHY PROCESS

After considering the factors of security- and safety issues related to autonomous driving it is essential to analyse today's acceptance of autonomous driving and the potential of the influencing factors to improve the acceptance of autonomous driving. There are several ways to examine the aspect of autonomous driving, especially the acceptance of autonomous driving vehicles. A suitable tool to identify this potential is a survey-based utility analysis. Additionally, an analytic hierarchy process is used to prioritize the influencing factors.

The utility analysis is divided into the phases: firstly, to identify the main criteria of autonomous driving, then, to prioritize these criteria and, finally, to link them to the influencing factors.

The main criteria of autonomous driving are identified as Conformity gain, Safety, Security, Degree of automation increase and Costs. In order to determine the importance of these criteria the probands had to prioritize them against each other. Percentage describes the importance of these criteria.

The results are:

- Conformity gain – 15%,
- Safety – 35%,
- Security – 35%,
- Degree of automation increase – 5%,
- Costs – 10%.

In addition to that, the probands judged the impact of the influencing factors to these criteria. The results of the utility analysis are shown in Table 1.

The average potential percentage is 64,25%. The influencing factors which reach a higher percentage are algorithmic, active driving systems, sensors, locating, communication with mobile devices, car-to-car communication and system integration in the vehicle. The highest utility reach active driving systems and sensors with 78% each.

Table 1: Potential of the influencing factors to improve the acceptance of autonomous driving.

Influencing factor	Potential [%]
Algorithmic	73
Car-in-the-Cloud	64
Cheap Energy	39
Active driving systems	78
Sensors	78
Locating	67
Communication with mobile devices	68
Car-to-Car communication	68
Car-to-Infrastructure communication	54
Car-to-Remote site	61
System integration in the vehicle	67
Service infrastructure	54

Table 2: Priority percentage of the influencing factors.

Influencing factor	Potential [%]
Algorithmic	16,03
Car-in-the-Cloud	2,26
Cheap Energy	1,65
Active driving systems	21,05
Sensors	9,87
Locating	6,01
Communication with mobile devices	2,87
Car-to-Car communication	12,92
Car-to-Infrastructure communication	13,51
Car-to-Remote site	3,00
System integration in the vehicle	9,07
Service infrastructure	1,75

Analytic hierarchy process is a tool for a reasonable decision making. The working method is aimed at creating a matrix in which the rows and columns are the influencing factors. After that it is necessary to compare every pair of influencing factors. Determining an (to one standardized) eigenvector is the step to generate the factors priority percentage (Saaty, 2008). The results of the analytic hierarchy process are shown in the Table 2.

4 IMPROVEMENT OF ACCEPTANCE OF AUTONOMOUS DRIVING

The survey shows that the survey participants are interested in autonomous driving as 85% of the respondents state that autonomous driving (full automation) is going to be pushed through in the future (Deloitte analytics institute, 2016).

In addition, three out of four groups of the participants point that they are interested in testing new innovations in the field of autonomous driving. (Deloitte analytics institute, 2016). Approximately 50% of the passengers would like to do other things while driving, for example checking mails, talk to other passengers or sleep (Deloitte analytics institute, 2016).

The influencing factors of the high percentage are active driving systems and algorithmic. Also, Car-to-Car communication and Car-to-Infrastructure communication are above 10% (see Table 2). The highest potential reaches active driving systems with 21,05% (see Table 2). The consistency ratio of the analytic hierarchy process is 0,074. Therefore, the analytic hierarchy process can be seen as consistent, and its results can be considered as usable.

However, all the described groups of respondents would not be fine with a completely autonomous driving vehicle (Deloitte analytics institute, 2016). Therefore, the acceptance of autonomous driving could be improved. A number of actions for the improvement of the acceptance of autonomous driving in combination with security and safety-related questions could be elaborated. For the determination of actions to improve the acceptance of autonomous driving, the influencing factors are clustered into three groups. These groups represent the prioritization of the influencing factors possibility to improve the acceptance of autonomous driving.

First of all, a rating system has to be implemented. For each study (security-safety study, utility analysis and analytic hierarchy process) every influencing factor got a rating between 12 and one, describing how important it is in this specific study. After that, the sum of these three ratings is formed, and the clusters are created. One cluster is created for each of the four high-rated, middle-rated and low-rated influencing factors. Table 3 shows the results of clustering. Cluster 1 receives 121 rating-points, which describes exactly 50% of the possible influence on autonomous driving.

Table 3: Cluster of influencing factors.

Influencing factor	Cluster
Algorithmic	1 (121 rating-points)
Car-to-Car communication	
Sensors	
Active driving systems	
Car-to-Infrastructure communication	2 (80 rating-points)
Locating	
Communication with mobile devices	
System integration in the vehicle	
Cheap Energy	3 (41 rating-points)
Car-to-Remote site	
Car-in-the-Cloud	
Service infrastructure	

In addition, there are some synergies between Cluster 1 and Cluster 2. For example, car-to-car communication and car-to-infrastructure communication using the same technical standards. This shows, that it is possible to influence even more than 50% by improving the factors of Cluster 1.

Actions, whose goal is to improve the acceptance of autonomous driving in combination with security and safety-related issues, should work in Cluster 1. Specifically, they should affect one or more of the influencing factors such as algorithmic, car-to-car communication, sensors or active driving systems.

5 CONCLUSIONS

The theoretical finding of the research allows concluding that, due to technology development, the conventional division of factors into external and internal has to be extended with the third groups, namely the other factors. Another theoretical finding is the clusters of influencing factors.

The empirical finding is the cluster with four most influencing factors or, in other words, Cluster 1. This cluster includes active driving systems, sensors, car-to-car communications and algorithmic. These four influencing factors combine 121 rating-points (50% of all rating-points). These four factors obtain the higher impact. Another finding reveals synergies between the clusters. The empirical finding is that the group of the other factors has the highest impact on security- and safety related issues. This finding proposes that the most important security- and safety related problems will appear in one of the influencing factors of this group. Another conclusion could be drawn about influencing factors with a higher impact: the influencing factors with a higher impact should be firstly considered for the improvement of the acceptance of autonomous driving.

The present work has some limitations. The limitation is the use of the data of only one survey. Another limitation is that the survey was carried out only in one country, namely Germany.

Research on autonomous driving is attracting a lot of interest in the scientific community. However, autonomous driving is definitely under-investigated and not sufficiently presented. There is still a lot to investigate and discuss in the field of the acceptance of autonomous driving and autonomous driving itself. Consequently, the acceptance of autonomous driving and autonomous driving are inter-related. The authors draw the conclusion that the increase in the acceptance of autonomous driving will promote the development of autonomous driving on the whole. Increased research efforts in the field of research on the acceptance of autonomous driving will assist in developing autonomous driving from a number of aspects and perspectives.

Future work will investigate and compare the relation between the present research and similar works in the scientific literature. Adoption of different technologies for autonomous driving will be analyzed in further work.

Other typical analytical approaches will be compared to the AHP algorithm. Further work will also be devoted to the description of the calculation process of the AHP algorithm. The search for other approaches and methods to investigate the acceptance of autonomous driving is proposed.

The further research tends to re-examine factors that influence the acceptance of autonomous driving as along with the technology development, new factors could emerge.

Future research will also focus on the description and analysis of case studies that can help further elaborate the analytic process detail.

Future work also implies the utilization of proper techniques for data collection in order to obtain a relevant description of the contemporary situation of the acceptance of autonomous driving. In these terms, the focus could be more put on the application of qualitative methods for a deeper analysis of influencing factors.

Another research direction is to involve more respondents into the study of the acceptance of autonomous driving.

Insights about how the acceptance is speeding or not in comparison with other technologies, in light of current progress and events will be formulated in future work.

A comparative study on the acceptance of autonomous driving of different countries could be interesting for the research community as well.

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