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Acceptance, a Mandatory Requirement for the Transport of the Future

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Abstract

Acceptance is an underestimated element in the adoption of new technologies. User's effective needs become a requirement as far as transport is concerned. The investments in transport from public and private companies/agencies in next-generation tools and infrastructure continues. These, seen as emerging mobility services and automated vehicles (AVs) optimistically expect customer's adoption. Yet, it is public acceptance that can potentialize the expected benefits of a connected and automated vehicles world.

While stakeholders foresee to overcome established premises about traditional public transportation and vehicle ownership, the perceived usability of such advancements are the domain of daily travelers. Consequently, this paper addresses the issue of acceptance of connected automated vehicles by presenting a general view and a practical example from Drive2TheFuture project, where the needs and wants of future "drivers" are mandatory; The findings include relevant risks that affect users' acceptance and exemplary recommendations to an affective, persuasive, and trusted HMI.

Keywords:

Acceptance, Automated Vehicles

Introduction

Global strategic plans converge to zero-pollution ambitions as the green deal at European level (Approval of the European Commission 2019-2024 | European Commission, n.d.), to digitalization as the digital Republic in France (Promoting France's digital Republic | Gouvernement.fr, n.d.), to Cybersecurity as the Cybersecurity Strategy of UK (Office, 2011), to the immediate actions to the COVID-19 pandemic and reforms to immigration systems as in the U.S. (Priorities | The White House, n.d.).

The consolidation of new technologies is a priority, as reflected in the established budgets. 1.4 trillion dollars until 2025 in China (China Has a New $1.4 Trillion Plan to Overtake U.S. in Tech - Bloomberg, n.d.), 9.2 billion Euros until 2027 to the Digital Europe Programme to supercomputing, artificial intelligence, cybersecurity, and digital skills (EU plans to invest €9.2 billion in key digital technologies | News | European Parliament, n.d.), the 2021 U.S. budget reaches 53.36 billion dollars towards the civilian federal agency information technology (• U.S. federal government IT budget 2021 | Statista, n.d.), the UK plans for public R&D investment increases to 22 billion pounds sterling's per year by 2024-25 (Budget 2020 - GOV.UK, n.d.).

At company level, the 2019 EU Industrial R&D Investment Scoreboard identified 7 expending more than 10 billion Euros, 73 exceeding 2 billion Euros, and 159 more than 1 billion Euros in emerging technologies (Grassano, N., Hernandez Guevara, H., Tuebke, A., Amoroso, S., Dosso, M., Georgakaki, A., Pasimeni F., 2020). The focus of such company investments considers largely Information and Communications Technologies (ICT); and while the development of AVs, 5G, and AI is at the forefront, the intention of final users to adopt those inventions is in its early stages. In such context, a global survey conducted with 22,000 people respondents in 11 countries developed by ANSYS, established that almost 1 of each 5 would never be comfortable riding an AVs (ANSYS - Global Autonomous Vehicles Report, 2020), which contributed to consider initiatives and funded projects to study the interests and motivations of AVs as a fundamental part of the research.

Drive2theFuture is an EU funded project which objective is to prepare future "drivers", travellers, and vehicle operators to accept and use connected, cooperative and automated transport modes, as well as the related industry of these technologies to understand their necessities. Thereby, behaviour models of different transport modes, automated driving scenarios, training tools, optimized HMI for "driver"-vehicle handovers, and automated functions developed through 12 Pilots across Europe are under study (Homepage - Drive2TheFuture, 2019).

The present paper starts by introducing different models used to analyse users' acceptance of new technologies, continues exploring acceptance in relation to different European funded projects, and finalizes consolidating experiences and conclusions regarding the acceptance of AVs in Drive2TheFuture project.

Assessing the Acceptance of New Technologies

The effective implementation of any system is a function of its acceptance, and with the rapid technology advancements in topics such as IT at work, mobile health, banking, and e-learning have emerged theories to comprise the behaviors of its users. These, resulted in different models used to understand which are the motivations of users to adopt modern technologies. Such models try to predict consumer intentions and behaviour (TRA (Sheppard et al., 1988; Davis et al., 1989)), consider the perceived ease of use and usefulness as main factors (TAM (Davis, 1989; Davis et al., 1989; Venkatesh and Davis, 2000)),

establish premises assuming that individuals adopt specific behaviours according to the available information (TPB (Ajzen, 1991; Taylor and Todd, 1995)), or a combination of the last two ones (TAM-TPB (Taylor and Todd, 1995)). The creation of the Unified Theory of Acceptance and Use of Technology, known as the UTAUT model is supported for the assumptions and hypothesis of most of them, reaching an efficacy of 70% explaining the user intention variance in the acceptance of technology in an empirical study (Madigan et al., 2017).

The UTAUT model combines six main constructs (performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FI) to use a system, behavioural intentions (BI) of use, and usage behaviour (PE, EE, SI, FC)) and four moderators (gender, age, experience, willingness of use) as depicted in Figure 1.

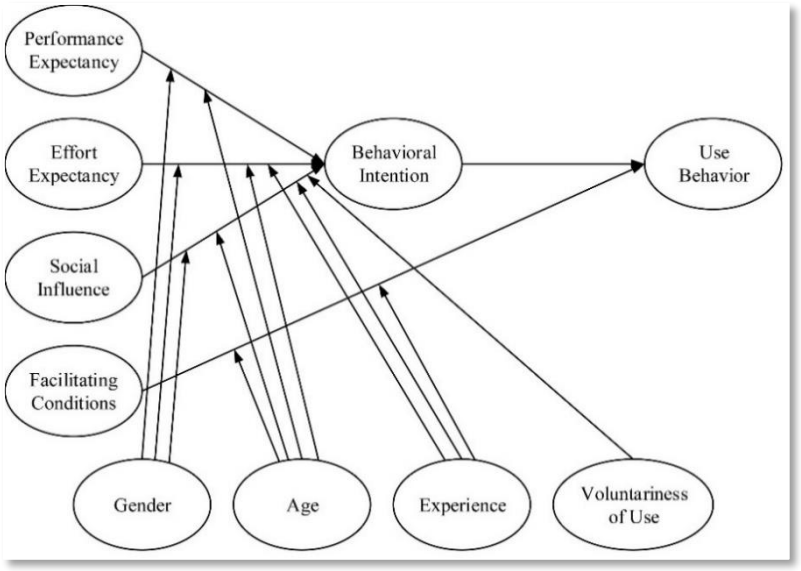

Figure 1. The unified theory of acceptance and use of technology (UTAUT) model

Acceptance in Relation to the Future of Transport

In the area of mobility, traditional problems in connection with the potential of technological advancements lead to consider the study of the motivations of travellers as a fundamental part to solve transport issues. Such decision-making analysis opens another door to prepare final users to a smooth transition from conventional cars to self-driving vehicles. An identical situation from the perspective of public transport towards automated busses. While the deployment of AVs considers the use of artificial intelligence, cameras, and radars to analyse external conditions, internal aspects are associated to AVs user's acceptance which require the study of gestures, emotions, and physical actions aimed to exceed their expectations. In other words, the whole adoption of such systems depends in part of the assessment of the acceptance of the future AVs owners and passengers. In such context, different projects continue under development studying how to improve the adoption of the Connected and Automated Vehicles (CAV) by the final users.

SUaaVe project considers the public acceptance of CAV as a problem that expect to change through a Human-Driven Design (HDD) approach. In a view of users contributing actively to concept definition, technology development and as testing participant, and not only the centre of the process. As explained on the website, "SUaaVE will focus on the human side, working to improve more "intangible" aspects as safety perception, attitudes and, in general, emotional appraisal of CAV." (suaave.eu, n.d).

Concentrated fundamentally in the benefits that safety, trust, and acceptance of AVs, Trustonomy Project considers the integration of technical and non-technical challenges in a perspective of experts and ordinary citizens working closely together (h2020-trustonomy.eu, n.d.).

The "Guide2Autonomy" (G2A) is the main goal of PAsCAL project. Particularly interested in the investigation of the needs of the future "drivers", this evaluates different transport modes and mobility services to establish a set of guidelines and recommendations for a user-friendly evolution of CAV (Enhance driver behavior and Public Acceptance of Connected and Autonomous vehicLes | PAsCAL, n.d.).

From a gender perspective, the Diamond project addresses the study of data to achieve inclusiveness for women in transport and work. In this case are evaluated specific measures "to meet the needs and expectations of women as users of different modes of transport…" (Diamond project, 2021).

Acceptance in Drive2TheFuture Project

Regarding the integration of automation into the European transport system, the Drive2theFuture project also focuses on the acceptance of automated vehicles by the transport users. Even though technology is gradually progressing, a main point to be determined is whether humans are ready to abandon their old habits (e.g., the driving task and/or even the car ownership – in combination with car sharing/pooling applications) and board on a vehicle with no driver. Throughout the Drive2theFuture project, the issue of transport users' acceptance is being addressed in a multi-parametric way; by means of sentiment analysis on social media, the involvement of different types of users in its pilot testing; with emphasis on vulnerable user groups and through a wide consumer survey.

The purpose of this ***Voice of Customers' survey*** that has been developed and disseminated within the project is to collect, analyse and present transport users' opinions about the AVs of all different levels and purposes (e.g., for public transport vehicles, private cars, drones for urban deliveries, air transport vehicles for passenger inter-city flights, cargo ships, rescue boats, passenger ships, passenger and freight trains, etc.), while also provide a comprehensive estimation of their willingness to use them under different circumstances, respecting a good balance of gender, geographical coverage, transport modes and user clusters. For this to be achieved and to attract responses of as many user groups as possible, the developed survey has been translated in 18 different European languages; This to facilitate to the respondents to provide the responses in their mother language or any other language of their preference.

From the analysis of the replies, no remarkable differences have been identified among the different transport modes, with the respondents being mostly neutral in the case of air and maritime transport, while expressing a more positive opinion towards the automation in rail and road transport. However, a point that needs to be noted is the fact that the preference of most of the respondents regarding the automation levels of all modes, focused on the lower and/or middle levels, where cooperation between the vehicle and the driver still exists. These results can be considered as indicative of the lack of awareness of most users or even of their misinformation, often leading to their misconception of automation. This points out the imperative need for initiatives and projects that can support, but also intensify, the necessary efforts for public awareness and acceptance in the areas of automated transport.

Risks Related to AVs Acceptance

In the Drive2theFuture project, besides exploring and recognising factors affecting users' acceptance of autonomous vehicles, it is among the aims to examine the risks related to AVs user acceptance and the key features and factors that will be taken under consideration. Emphasis is also given on the analysis of these risks, and on the suggestion of specific recommendations for their elimination. The risk assessment within the Drive2TheFuture project is based upon an extended FMEA methodology, adapted according to the needs and the nature of the project, since it allows us to identify relevant risks and to cluster them in categories, capturing all the dimensions of their probable impact. Using extended FMEA methodology allows us to identify risks that are related to behavioural, legal, operational, and technical issues related either directly to the project's outcomes, as well as indirectly to its stakeholders, while also prioritise them according to their severity, occurrence probability, detectability, and recoverability.

The FMEA (Failure Mode and Effects Analysis) procedure is a tool that has been applied in many ways for many purposes. It can contribute to improve design for products and processes, resulting in higher reliability, better quality, increased safety, enhanced customer satisfaction and reduced costs. In Drive2TheFuture the extended FMEA that has been developed at ADVISORS project is being used (Bekiaris et al., 2005) and a thorough assessment of risks and barriers regarding the acceptance of the users using this methodology takes place in two phases: *a priori* on expected risks and *a posteriori,* based also on the analysis of social media and project evaluations. This assessment is expected to assist on the adoption of Drive2theFuture outcomes, towards the enhancement of the acceptance of the AVs functions.

Within the a priori risk analysis that has already been completed in the project, 50 risks were identified in total, from which 14 were defined as behavioural, 8 legal, 18 as operational and 10 as technical. All identified risks have been ranked either as of moderate or as of severe significance. The risks that have arisen from this analysis are mostly related to the following issues:

- Overreliance on technology and/or wrong use of AVs technology by the users.
- Impact on traffic density, pollution, and safety, mainly in big cities.
- Need for the adaptation of legislation.

- Data protection and data ownership issues.
- Employment and re/upskilling need and resources.
- Operational changes in TMC and logistics chains.
- Cost of relevant services.
- Issues of integration with/interaction to emergency services.
- Weather conditions.
- Communication failures and sensors malfunctions.
- Cybersecurity attacks.
- Impact on the use of Public Transport.

The Acceptance Risk Assessment will continue throughout the project and is expected to confirm or contradict the already identified risks, but also identify new ones coming from the sentiment analysis of social media activity and the realisation of the different pilot phases.

Affective, Persuasive and Trusted HMI to Increase the Acceptance of AVs

The different user groups which are affected by the increasing level of transport automation have the same means of communication with the automated technology, the Human-Machine Interface (HMI). The HMI is often referred to as a "window" in human-machine communication, as it informs users about the current state of the machine and grants access to mutual intentions (Carsten and Martens, 2019). Even though automation shall ease the tasks for the human user, new challenges arise when using automated systems, as defined in Bainbridge's (1983) ironies of automation. Therefore, Drive2theFuture investigates the design of optimal HMIs for AVs to set the ground for user acceptance. One of the core questions the project aims to address in this regard is how the HMI can be adapted to support final user's educated decision when and for what to adopt AVs in their daily lives (Mathis et al., 2020).

Approach

In the HMI framework of Drive2theFuture, the optimal interaction concepts for AVs are defined by combining expertise from the different transport modes and by setting a focus on affective, persuasive, trusted and personalized interfaces. Based on a benchmarking with more than 30 examples from all transport modes, user clusters and automation levels, different good practices in existing HMI concepts were identified to be applied cross-modally. In addition, practical recommendations for the design of persuasive, trusted and affective HMIs were derived from prior research. These recommendations provide the basis for HMI development and optimization in the project's vehicles subject to iterative testing with end-users and experts. The derived optimal HMI elements for different modes will be used to develop an HMI toolkit in Virtual Reality (VR), allowing rapid prototyping and evaluation of new HMI concepts regarding user acceptance.

HMI Development for All Transport Modes

The performed benchmarking has shown that many in-vehicle and operator HMI concepts over different

transport modes share the good practice to display the current system mode to the user. Therefore, Drive2theFuture's HMI concepts investigate how the vehicle's automated mode shall be communicated to different user groups to ensure transparency and increase users' awareness (e.g., Muthumani et al., 2020). Most differences in good practices were identified in the input devices used to interact with the vehicle in low levels of automation or after the request for manual operation, where each transport mode has its own established good practices (e.g., steering wheel, joystick, control yoke). Practical recommendations for the design of persuasive, trusted and affective HMIs were then derived from prior research and categorized regarding user group and HMI type. In cross-modal expert sessions, the recommendations were discussed to find examples for different transport modes and selected ones were applied to HMIs for automated functions developed in the project's pilot vehicles and demonstrations.

Table 1 shows two exemplary recommendations, which were applied, among others, for the development of an HMI concept in VR for driving a highly automated car on the highway. The HMI concept illustrates how to simplify a step-by-step process for the user and explicitly guiding him through the process of using an automated function, e.g., by pop-up notifications in the instrument cluster upon activation of automated driving. This notification gives information on the available interaction options for the user during this driving mode. To enhance trust, the HMI always communicates the current activated vehicle mode (in this case, "autopilot", "assist" or "manual") by textual feedback in the menu bar on the dashboard, whereby the activated mode is highlighted by a coloured signifier.

Table 1: Exemplary recommendations derived for an affective, persuasive and trusted HMI

User group	**HMI type**	**Practical recommendation**	**Examples for different modes**
Operator Passenger VRU	In-vehicle Remote External	The HMI assists the users in guiding them through a process or experience (Oinas-Kukkonen & Harjumaa, 2009)	1. Road (car): Show next task or user action that is necessary, e.g., put hands on steering wheel for take-over. 2. Aviation (drone) The HMI guides the operator through the process of authorization request
Operator Passenger VRU	In-vehicle remote, External	The HMI is transparent about the system status by providing a continuous feedback. (Beggiato et al., 2015; Ekman et al., 2018; Miglani, Diels, & Terken, 2016)	1. All modes: Icon or LED indicating automation or system status. 2. Aviation (drone): The HMI offers updated information about the key parameters that determine the system status (e.g., signal quality, battery status, altitude, speed, etc.)

Results of Initial User Tests and Expert Sessions

Initial user tests, as performed in the Drive2theFuture pilots (Sjörs-Dahlman et al., 2020), support the benefit of applying the derived recommendations to the different transport modes and different types of HMIs (in-vehicle, external and remote HMIs). For automated buses, it was shown that an in-vehicle HMI which informs the passengers about the activated automation mode of the vehicle, e.g. by a LED stripe in the windscreen, enhances their user experience and leads for users to a more predictable experience. Several user tests also investigated the suitability of external HMI to help pedestrians or cyclists to understand an AVs actions and awareness of the surroundings. The obtained results for different external displays using icons and text messages show that external HMI can support other road users in a safe interaction with AVs and aid people's comprehensibility of these vehicles, thus also contributing to more user acceptance of AVs in road traffic.

Furthermore, an expert session with Traffic Management operators was conducted to investigate operators' HMI needs for the introduction of automated busses into traffic. Results show that an icon or LED stripe on the operator dashboard regarding the status of the bus would be preferable. Given that the remote operation of autonomous busses was possible in case of automation failure in the future, the interviewees stated that a joystick or controller would be preferable over a steering wheel. The participants agreed that this would be easier to operate for remote operation. As a recurring need crucial for user acceptance, interviews during user tests have shown that users expect training and information on new HMI elements for automated functions to interpret and use them correctly, which is also one of the goals in Drive2theFuture.

Conclusions

- Considering the voice customers survey, the analysis of the replies on the different transport modes questionnaires and the expressed acceptance of their respective AVs, we can assume that there are no remarkable differences among the modes. Reviewing the overall opinion of the respondents about the AVs of the different modes, we may note slight differences, with the respondents being mostly neutral in the case of air and maritime transport, while expressing a more positive opinion for the rail and road transport. However, it needs to be noted here that the preference of most of the respondents regarding the automation levels of all modes, focuses on the lower and/or middle levels of automation, where cooperation between the vehicle and the driver/ operator still exists.

- The results regarding users' concerns and fears that also fit the above conclusions, are almost identical for all modes, focusing mainly on the issues of cybersecurity and safety, while rating much lower the risks related to employment. This fact is also inter-connected to the fact that for all modes, the majority of the respondents stated that they would accept AVs, as soon as they have close to zero accidents or at least much fewer accidents (i.e., reduction of 50% or more),

in comparison to the conventional ones. Another concern that has also been emphasized throughout the modes is the one of environmental sustainability. In relation to the interaction of the AVs with other users (either road users and/or non-automated vehicles), again most of the respondent's state that they would prefer automated vehicles to be somehow marked (e.g., by the use of Variable Message Signs (VMS)), in order to be clearly distinguished. Finally, regarding the impact on employment and employability, most of the respondents of all modes believe that automation will cause job losses in the transport sector. However, at the same time there is a quite big rate of respondents also expressing the opposite opinion, that automation will also bring new jobs, concluding to a rather balanced situation.

- Regarding the analysis of risks, the *a priori* phase of the risk assessment has been finalised, 50 risks have been identified so far, with most of them (36%) focusing on operational issues. More specifically, emphasis has been given by the experts to re/upskilling needs and resources, while also to operational changes in Traffic Management Centres (TMC) and logistics chains and the cost of such services. Behavioural risks follow (28%), mainly concerning the overreliance on technology and/or wrong use of AVs technology by the users. The technical risks (20%) focus mainly to communication failures and sensors malfunctions, as well as the fear of cybersecurity attacks, while the legal issues (16%) deal mostly –as expected – with the need for the adaptation of legislation and data protection and data ownership.

- In order to demonstrate the project's optimized HMI concepts and provide a tool to investigate user acceptance of new HMI concepts in the future, a VR based HMI toolkit is developed in the further course of the project. VR offers the advantage that users can interact with AVs without risks and can familiarize themselves with the technology in an immersive environment. For HMI researchers and developers, the toolkit will allow for easy prototyping of new HMI solutions for different transport modes by providing different scenarios (e.g., countryside, highway, city), vehicles (e.g., car, bus, ship), user groups (e.g., driver, operator, pedestrian) and a library of HMI elements (e.g., steering devices, displays, icons). Using the envisioned Drive2theFuture HMI toolkit, HMI concepts can be tested easily regarding their user acceptance and be improved iteratively with end-users before market entry. In addition, the VR-based toolkit can also be used to provide training options for new HMI concepts to future users of automated transport.

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