A Service Value Constellation for automated vehicles based on technology acceptance indicators

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Abstract

Automated vehicle (AV), in any level of automation system, proved to be a paradigm shift in terms of mobility. AV as a solution tends to improve safety and bring substantial benefits to personal and social perspectives. Although, its mass distribution requires considerable legal and business, changes, and a deep shift in the customers' perceptions, that determine the AV technology acceptance, or not. The government and interested private parties should adequate their offerings to assist the user to co-create value while using an AV, thus redefining the customer experience and create new demands for it. The acceptance level reflects the driver's perceived value of this type of vehicle, resulting from their experience as a service. This paper aims to identify acceptance indicators and attitudes towards AV. Moreover, the indicators guided the development of a service concept and service value constellation proposition to adjust value offerings to the new mobility paradigm and to maximize technology acceptance. The study took place in Portugal and included a questionnaire that assessed users' perception on AV. The results suggest that AV create new opportunities for value creation, extending the frontiers of the service ecosystem.

Keywords: Automated vehicle; acceptance indicators; paradigm shift; perceived value; customer acceptability.

1. Introduction

Nowadays, urban mobility management is gaining ground in academic, business, and political discussions (Campisi et al., 2022; Fagnant & Kockelman, 2015; Grindsted et al., 2022). The preference for cars in daily routines could generate negative effects that directly impact life quality and compromise the economic competitiveness of urban mobility (Fagnant & Kockelman, 2015; Grindsted et al., 2022). It is known that the time consumed on daily trips, car accidents, and the pollution generated by gas emissions are well-defined concerns in urban management (Fagnant & Kockelman, 2015; Grindsted et al., 2022). Thus, it has been a great challenge to manage the mobility functionality that considers all road design and infrastructure that involves urban spaces (Grindsted et al., 2022). Still, guaranteeing the driver's safety during their journey is the main topic of mobility plans (Fagnant & Kockelman, 2015).

Several studies investigate new transportation modes to tackle those concerns and bring new understanding and demands for urban mobility (Grindsted et al., 2022). Automated vehicles (AV) emerge as a potentially effective solution to improve safety and create new mobility paradigms (Grindsted et al., 2022). The "traditional" urban mobility might be gradually losing space to shared and on-demand mobility options (Maeng & Cho, 2022). Still, the customer choice for such options depends on its operational model, the service configuration, and fleet specification (Vosooghi et al., 2019).

This study aims at contributing to the deployment of AV-based mobility services, by designing the service concept and service value constellation, considering the customers' value perception of said services. Possible value offerings were identified based on acceptance indicators that resulted from an acceptance questionnaire performed in Portugal.

This paper is divided into a literature review about AV and its contextualization followed by the methodology conducted that points out Factor Analysis (FA) and Structural Equation Model (SEM) methodology used to address the latent variables of the Portuguese acceptance over AV. The results from those models fed the design of a service concept, to transform the statistical findings into customer offerings. In the end, the results discovered throughout this paper ware convert to a proposal service concept to promote the acceptance of the AVs in Portugal. A conclusion within the later propositions and further studies completes this paper.

2. Literature review

According to Leonard et al. (2020), Automated vehicles (AVs) have the potential to transform the transportation industry and revolutionize employment. Fagnant and Kockelman (2015) suggest that the benefits of AVs include reduced traffic congestion, improved safety, and increased mobility for individuals with disabilities. However, there are also challenges to overcome, including legal and ethical concerns, cybersecurity risks, and changes to the workforce.

Faisal et al. (2019) argue that policymakers must address these challenges through effective planning and regulation to fully realize the potential benefits of AVs. Additionally, Litman (2020) notes that AVs could have significant implications for urban planning, as they could lead to reduced parking demand and changes in land use. To address those challenges, stakeholders need to be included in the discussion.

On that topic, Feys et al. (2020) highlight the importance of considering stakeholders' perspectives when planning for AVs, particularly in the context of public transportation.

Despite of the evolution of policy, technology is being developed and several major companies, including BMW (BMW Group and others, 2016), Ford (Ford Motor Company Media Center, 2016) and Daimler (Daimler, 2017) have announced plans to develop fully autonomous vehicles for commercial use.

2.1. Automation levels

The Society of Automotive Engineers (SAE) defines Automated vehicle as: "a motor vehicle driving automation system that perform part or all dynamic driving tasks (DDT) on a sustained basis" (SAE International, 2021). In other words, they are mobile robots that share automation fundamentals likewise aerial drones, industrial robots, and other forms of the technology (Leonard et al., 2020). The SAE taxonomy describes the level of driving automation systems by low levels [0-2] of automation that are limited to performing driving support and those higher levels [3-5] of automation that indeed perform automated driving features (SAE International, 2021).

The very first level considered by the SAE taxonomy, level 0 (zero), stands for fully manual systems supported by driving features (Leonard et al., 2020). The first automation principles begin on level 1 (one) driving automation system to perform driver assistance activities while occurring the driving activity (Leonard et al., 2020). A partial driving automation stands for level 2 (two) driving automation system whereas the system automates both lateral and longitudinal vehicle motion at the same time (SAE International, 2021). Level 3 (three) driving automation system is prepared to perform conditional driving automation (SAE International, 2021). A high driving automation category is placed on Level 4 (four) driving automation system (SAE International, 2021). Nevertheless, the full driving automation is placed within the level 5 (five) category of the driving automation system with the ability to automate all DDT activities and fallback DDT situations without any driver expectation to intervene (SAE International, 2021).

2.2. Automated vehicle as a service

Besides the driving automation system classification, the business models that could arrive with AVs might threaten the way current car manufacturers operate sales (Dans, 2021). Driven by shared economy models and advances in information technology, the market has expanded its transportation range and challenged the ownership model (Shaheen et al., 2015), sharing business switches from the convention vehicle, purchasing system, and ownership paradigm to sharing goods culture (Maeng & Cho, 2022). New businesses have been created and changed the way how people could plan and execute a trip (Shaheen et al., 2015). For instance, AVs could be operated as a shared mobility service, with on-demand or reservation-based approaches (Narayanan et al., 2020; Shaheen et al., 2015). Shared Automated Vehicle (SAV) services could be independent or integrated, connecting with public transportation systems (Narayanan et al., 2020).

Finally, AVs could also be used as freight service providers (Halliday, 2021; Leonard et al., 2020). There are various modes of operation for AV freight, including autopilot mode, human-human platooning, and human-AV platooning (Viscelli, 2018). Some companies are exploring the potential of AVs in the "middle mile" solution and already shown their interest in such technology (Halliday, 2021).

3. Materials and methods

3.1. The survey

To evaluate the acceptance indicators of the Portuguese population regarding the AVs, this paper used the data gathering from an online questionnaire applied in Portugal. The questionnaire, composed by seven main sections, received 501 responses in June and July of 2020.

The first section corresponds to the sociodemographic characterization of the respondents, including: (a) the representativeness of the sample; and (b) the influence of these factors on the predisposition for the AVs acceptability. The following section consists of the questions about transportation habits. The questions assess the type of transport used, the distance usually travelled, the number of hours spent traveling, and the existence of physical restrictions that could interfere the mobility. In the same way, the third section of the questionnaire concerns driving habits. The respondents should indicate how often they drive, and whether driving is part of their professional activity. The types of roads used and the most frequent reason for using the vehicle are also answered.

The fourth questionnaire section, on the one hand, assesses the respondent's degree of knowledge about AVs: if the respondent heard and/or experimented with any vehicle with any level of ADS. Sections five and six, on the other hand, refer to perceived benefits and concerns about the technology, respectively. Among these sections, the respondents were evaluating these aspects using a 5-point Likert scale: strongly disagree, disagree, neither disagree nor agree, agree, and strongly agree, in all proposed circumstances.

The seventh section, refers to the perspectives on the use of AVs in regard to what kind of trips would be performed in AVs, in what circumstances the respondents would use AVs, and what tasks could be, ideally, performed while traveling in an AV. Nevertheless, the questionnaire also contemplates what car manufactures should consider when designing AVs and if the participant has the intention to use AVs in the future.

3.2. Respondents' sociodemographic characteristics

The sociodemographic characteristics of the 501 participants that contributed to this survey are represented in Table 1. Among the survey respondents, 51% were females while 49% were males. Regarding the age, the sample had the highest distribution of respondents aged from18 to 27 years old (26%), followed by 38 to 47 years old (22%), and 28 to 37 years old (20%). The remaining 32% accounted for respondents aged more than 48 years old. Regarding education levels, respondents were mainly people with high education degrees (29%, 26%, 28%).

Considering that the survey was based in Porto, and the majority of the answers came from the Porto region, with some participations in other districts (Figure 1). Accordingly, the respondents live in predominantly urban areas (70%), followed by medium urban areas (22%) and predominantly rural areas (8%).

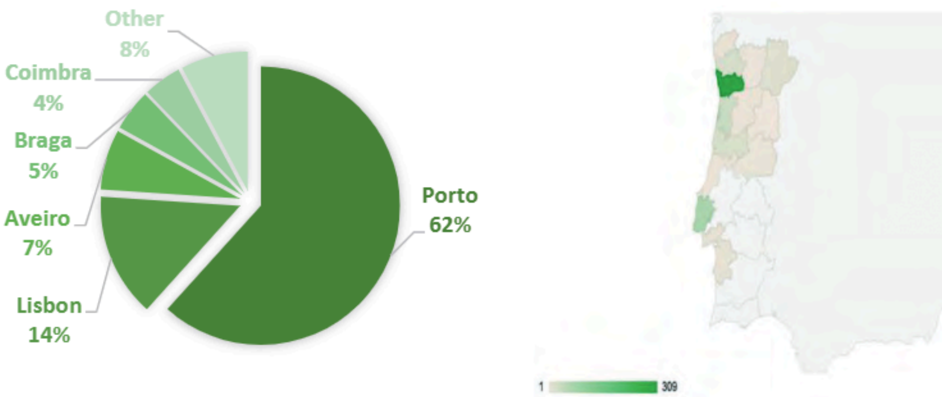

Figure 1. Region distribution

3.3. From data to value propositions

The data retrieved from acceptance related questions gave valuable inputs regarding customers expectations about automated vehicles. Those inputs were converted into value propositions that might increase AV acceptance.

To identify potential value propositions, we performed a Factor Analysis (FA) and developed a Structural Equation Model (SEM). The results from those analysis supported the design of the Service Concept and corresponding Service Value Constellation map. The value constellation helps service providers to further develop new services that respond to the new mobility paradigm.

First, the exploratory FA was conducted on *SPSS Statistics* to group variables into the most significant factors. The main goal was to identify the latent variables and their observed variables from the questionnaire. Then, latent variables were consolidated in a SEM, in which the latent variables were correlated with each other. The model's purpose was to hypothesize the main factors that affect the AV acceptability in Portugal. To conclude, those factors were analysed and transformed into potential value propositions. Results are described in the next section.

Table 1. Respondents' sociodemographic characteristics

Characteristics [Questionnaire ref.]	Answers' categories	Frequency (n=501)	Proportion (%)
Gender [1.1]	Female	254	51%
	Male	247	49%
Age [1.2]	18-27	130 99	26%
	28-37	112	20%
	38-47	79	22%
	48-57		16%
	58-67	65	13%
	>= 68	16	3%
Education [1.3]	1st cycle of basic education	0	0%
	2nd cycle of basic education	1	0,2%
	3rd cycle of basic education	7	1%
	Secondary education	100	20%
	Graduate degree	145	29%
	Master	129	26%
	Doctorate	119	24%

Employment situation [1.4]	Employee	336	67%
	Self-employment	33 5	7%
	Unemployed	17	1%
	Retired	99	3%
	Student	11	20%
	Other		2%
Economic income (considering National Minimum Wage for 2020 - €635) [1.6]	Less than the NMW	9	2%
	Between 1 to 2 NMW	145	29%
	Between 3 to 4 NMW	189	38%
	5 or more NMW	106	21%
	Rather not answer	52	10%
Typology of the residential area [1.8]	Predominantly urban area	352	70%
	Medium urban area	110	22%
	Predominantly rural area	39	8%
Physical restriction that affects your mobility [2.6]	Yes	11	2%
	No	485	97%
	Not answered	5	1%
Have a driving license [3.1]	Yes	472 29	94% 6%
	No		
Have a car [3.2]	Yes	429	86%
	No	72	14%

4. Data analysis and results

Latent variables resulting from the exploratory FA, with factor loadings greater than 0.5, and their representative observed variables are presented Table 2.

Table 2. Latent and observed variables resulting from factor analysis

Latent variables	Observed variables [Questionnaire reference]
Intention to use AV [ITU]	ITU1 – AV are appealing [4.3]
	ITU2 – I consider using AV in the future [11]
	ITU – I would prefer AV to one without automation, in the future. [12]
	ITU – Comfortable for me that my family use in the future [13]
	ITU – I would use automated bus in the future [14]
Perceived Safety Risks [PSR]	PSR1 – Driver and passenger safety [6.1]
	PSR2 – Pedestrian safety [6.2]
Performance Expectation [PE]	PE1 – Lower fuel consumption [5.5]
	PE2 – Reduction of polluting gases [5.6]
AV Experience [EXP]	EXP1 – Experience with automated trains and subways [4.2.1]
	EXP2 – I have no experience with using any AV [4.2.3]

Overall, all the factor loadings l and CR values presented in the factor analysis were greater than the recommended values. This suggests that all the observed variables have considerable reliability and explanation for their latent variables (Yuen et al., 2020). Therefore, the Intention to use AV (ITU) is the representative factor of the AV be considered an appealing concept measurement (Questionnaire ref: 4.3) as well as the observed variables that consider use AV in the feature: personal consideration to use AV (Questionnaire ref: 11), preferences for automated vehicles (Questionnaire ref: 12), comfortable with family using AV (Questionnaire ref: 13) and considering use automated buses in the feature (Questionnaire ref: 14).

In the same way, in one hand, the driver and passenger safety (Questionnaire ref: 6.1) as well as the pedestrian safety (Questionnaire ref: 6.2) are represented by the latent variable Perceived Safety Risks (PSR) and point out some cautions for considering AV as transportation mode. The perceived benefits, on the other hand, are represented by the Performance Expectation (PE) latent variable that is the representative factor of the lower fuel consumption (Questionnaire ref: 5.5) and reduction of pollution gases (Questionnaire ref: 5.6) observed variables.

The AV Experience (EXP) also take place in this study to identify the acceptance indicators of AV in Portugal. The variable was considered in the form of latent variable with the correlation between both experience with automated trains and subways (Questionnaire ref: 4.2.1) and no prior experience with the technology (Questionnaire ref: 4.2.2) observed variables.

Afterwards, the variables (observed and latent) were correlated in a SEM diagram to identify the model fit as well as the standardized regression weights estimates between the measures. As the Intention to use AV (ITU) is the main latent variable desired to identify its correlations in this study, the construction of the model considered not only the observed variables identified into the factor analysis, but also all other latent variables as main builders of the construct. The outcome of the model confirmed the results of the FA, since all the R^2 values are greater than 0.5, demonstrating that the latent variable variance is explained and significant by their observed variables.

The latent variables demonstrated relative relationship to certain new technology adoption themes when the subject is about intention to use AV. There is a clear necessity to transmit safety and reliability while customer co-creating value using AV. The Driver and passenger safety (PSR1) and the Pedestrian safety (PSR2) demonstrated that the customer needs to trust the system while performing the activity and so, if something went wrong on their journey, leave everyone involved covered by insurance and regulation policies.

In the same way, experiences with other automated vehicles (EXP1 and EXP2) demonstrated a positive correlation to customers use AV. The possibility of integrating other transportation modes proved to help in the acceptability of the AV, as it allows customers to co-create value exploring new routes (train and buses) and thus expand its usability limit.

However, customers still do not have a clearly understand about AV. The consideration of using AV (ITU2) and its preference over a non-AV (ITU3) in the future, as well as the classification of AV being an appealing concept (ITU1), demonstrate a possible misunderstood of the AV´s technology. Customers create their expectations about the technology, and informative service should promote AV acceptability. Still, as the variables Lower fuel consumption (PE1) and Reduction of polluting gases (PE2) highly demonstrate a connection to the use of AV, the customer still relates AV to Electric vehicles (EV).

4.1. Value Constellation Experience to use AV

In order to consolidate these findings into a proposal service concept, Figure 2 illustrates a value constellation experience (VCE) representing high-level activities for a customer using AV.

Figure 2. Value Constellation Experience to use AV.

In this perspective, the high-level activities are the following:

- Obtaining information about AV, which may be done through AV service provider.
- Hiring an insurance, which may be contracted from an insurance agency.
- Accessing MaaS, which may be done via multiple actors such as MaaS Operators, Mobility Service Provider, other users and System managers/planners (Sellstedt & Sjöling, 2019).
- Using AV, which may involve sharing vehicles with other customers.

The VCE reveals that the customer co-creation value while using AV is not limit to the AV services providers. Insurance agencies also have an important role in the customer experience modelling while performing their contract formation activities or informing customers about their insurance offerings, for instance.

The MaaS Operators and System managers/planners are actors responsible for delivering and planning the service to their customers. Actions such as ticket validation, customer support and route planning are some of the possible activities provided by these actors (Sellstedt & Sjöling, 2019). Mobility Service Provider might or might not be the AV service provider and so, offering complementary activities to integrate with AV.

4.2. Customer Value Constellation while using AV

After the definition of the VCE and their high-level activities presented among multiple actors, the next step included mapping value offerings that companies might provide to enable customers to cocreate value. Thus, Figure 3 illustrates the customer value constellation, to represent the service concept and value offerings, placing the customer of an AV at the centre of the system.

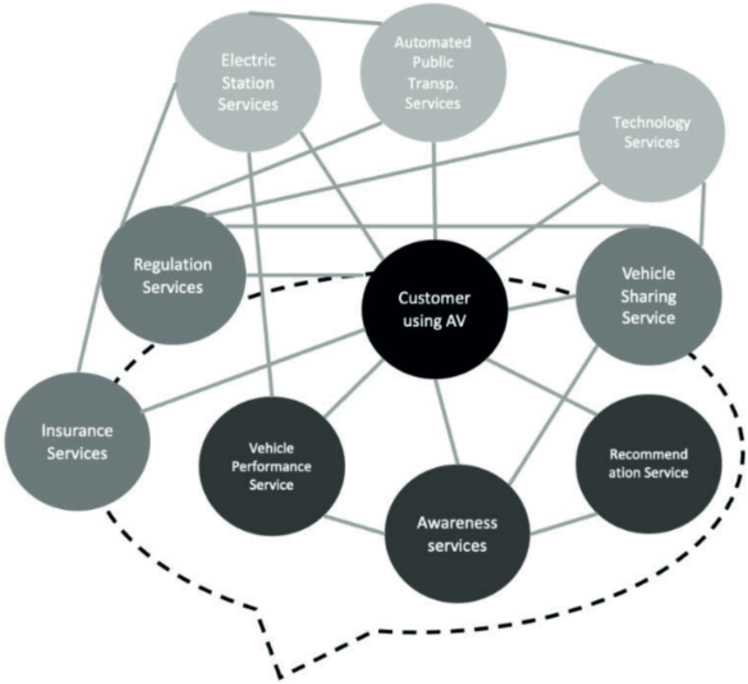

Figure 3. AV´s provider service concept in the customer value constellation

As the *Customer using AV* activity is placed in the centre of the CVC, this diagram reveals the boundaries of the AV providers as well as all the correlated offerings among each other. These offerings are not limited to AV providers but intertwine with other business players. In the next paragraphs we provide a brief explanation on the value offerings for the new services.

Awareness and recommendation services

Awareness and recommendation service offerings might be presented in the AV provider value proposition because companies´ present interest in expanding their business and general education and information about new value offers to increase acceptability. Thus, marketing campaigns are suitable activities that AV providers should consider while promoting the technology and clarifying possible mismatches of public information. Furthermore, AV providers can also prepare educational campaigns enouncing the benefits to the public and point out the convenience and the enjoyment of such a service (Yuen et al., 2020).

Vehicle performance service

As previously mentioned, *performance expectation* has a positive effect on technology acceptability. Perceive the value from the technology and the convenience while using it is crucial for its acceptability (Marangunić & Granić, 2015). An easy to use and understandable vehicle performance service offering might enable the customer to co-create value while interacting with the service. This offering might be also related to real-time information to point out not only consumption indicators but also vehicle wear and tear.

Electrical station service

Another perceived value among AV, and already pointed out by other authors, is the possibility of AV being electric. Once customers tend to link AV with EV (Lobo et al., 2020), this expected value demonstrates that customers who see value in using AV are also concerned with climatic issues. Therefore, the CVC might consider electric station service offers, related to public infrastructure, to foster AV acceptance. The government places a crucial involvement in this offer to facilitate conditions among electric stations and regulations to encourage fuels from less polluting sources.

Insurance service

Hiring an insurance policy experience might be presented in the customer journey to use AV. The Perceived Safety Risks (PSR) over driver and passengers (PSR1) and pedestrians (PSR2) indicate that customers might be passing through the creation of an insurance policy. The value would be cocreated not only in the bureaucratical process of the insurance agencies but also in the insurance plans that would give the perception of the customer being covered and secure while using AV. The perception of responsibilities and situations covered tends to clarify customer information about regulation terms and axialite the co-creation of awareness about the technology (Fagnant & Kockelman, 2015).

Regulation services

In coherence with that, the government places a crucial role in AV value co-creation (Fagnant & Kockelman, 2015). The possibility of transporting passengers with no driving licensing or below the considerate major age leads the CVC to consider regulation services offered in the AV´s co-creation value system. It is essential to legislative follow the AV development and embrace federal funding for

AVs research, develop federal guidelines for certification, and determine appropriate standards for liability, security, and data privacy about the technology (Fagnant & Kockelman, 2015). The customer might be co-creating value with several regulated services and so, perceiving the legal aspects of each of them, assist services comprehensions and limitations.

Vehicle sharing service

Sharing services offerings are fully correlated with vehicles (Kohda & Masuda, 2013) Customers are constantly co-creating value while using sharing vehicles. This co-creation of SAV is not limited to operators but withing other customers that are sharing the same journey (Yuen et al., 2020). The booking systems as well as the rating and payments systems assist customers to co-create value in different journey phases. An iterative, ease-to-use and secure integration software relies on customer co-creation value while using SAV.

Technology services

Technology services offerings, in the same way, tend to correlate with AV value co-creation in different ways. From this perspective, the customer might be co-creating value while leading with ADAS technology, to possible configuration setup and/or interpretation.Although,this service offering also refers to networks,telecommunications, and electronics experiences (Taherdoost et al., 2015). Technological companies might be investing in infrastructure and research to follow AV development.

Therefore, enabling customers to use supportive systems while co-creating value.

Automated public transportation services

Nevertheless, integrating different AV modals (ITU5) and the experience with them (EXP) reveal another predominant offering to customers co-creating value while using AV. Automated public transportation services offering placed in the CVC to complement AV. Customers might be cocreating value while using automated trains or buses on long journeys and so, use AV at last-mile distances to access particular destinations. Therefore, investing in local and national infrastructure and public-private partnerships will also facilitate the AV co-creation into urban mobility systems (Leonard et al., 2020).

5. Conclusion

This paper aimed to contribute to AV studies with emphasis on identifying new service opportunities for transport-related service providers to be developed as a way increase the acceptance level for such a technology, in Portugal. The data analysis was based on a questionnaire-based survey conducted in 2020. With a total of 501 participants, the questionnaire covered topics about transportation habits, driving routines, and technology knowledge among others.

To reduce a large number of questions responses (observed variables), an exploratory FA was performed, considering a minimum factor loading of 0.5 to have representative constructs (latent variables) placed in the proposal conceptual model of AV acceptance. Then, a CFA took place to highlight the acceptance indicators for such analysis, determine the factor loading of measured variables, and confirm the relationship between observed variables and their relative constructs.

The findings assumed four latent variables – Intention to use AV (ITU), Perceived Safety Risks (PSR), Performance Expectation (PE), and AV Experience (EXP) – representing the individual's expectations, concerns, and intentions to use AV (RQ1). These variables were then related to each other via ITU and placed into a SEM. The results indicated that the AV acceptance in Portugal depends on intention to use the technology in the future and a better understanding of it. The participants also reveal certain concerns about the driver, passenger, and pedestrian safety that should be assisted before technology implementation. Likewise, regarding performance expectations, the participants look forward to reducing fuel consumption and polluting gases while using an AV. This represents a misunderstanding of AV knowledge due to these PEs relating strongly to EV. Even though there is a tending perspective that the vehicles would become electric in the feature, those two technologies represent different goals. Nevertheless, individuals with some previous experience with any automated vehicle service also demonstrate positive relation to AV acceptance.

To consolidate the previous findings into a feasible service design, the present dissertation created a possible service concept that highlighted offerings that different players should consider to user co-create value and augment the changes for its acceptability while using AV. The suggested offerings in the CVC might cover awareness and recommendation services, vehicle performance service linked to electric station services; regulation and insurance services, vehicle sharing service with other public automated transportation services and related technology services.

The proposed service concept also suggest that the AV acceptance will not pass only from car manufacturers or services providers, but also from the government initiatives and other related services, such as insurance agencies and electrical supply stations. Therefore, to enable customers to co-create value while using AV, the country authorities and other private parties need to prepare and adapt their offerings to be in coherence with the technology. There is also the necessity for a clear definition of the responsibilities and duties of each interested party to augment the chances for technology usability.

The proposed service concept facilitates the development of new services that foster the acceptability of automated vehicle technology. In this sense, this work developed an innovative combination of human factors and service design in the context of AV research.

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