# Technology Acceptance Modelling for Investigating the Uptake of Electric, Connected, Autonomous, and Shared Mobility Technologies

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Abstract: This paper introduces QETAM (Quantitative Effect and Technology Acceptance Modelling), the first quantitative user acceptance model for evaluating the impact and adoption of Electric, Connected, Autonomous, and Shared (ECAS) mobility technologies. Developed in Python, QETAM leverages data collected through specifically designed questionnaires to assess key adoption factors, including technological reliability, user attitudes, infrastructure, and environmental considerations. The model accounts for the interconnected nature of ECAS technologies, emphasizing synergies between electric propulsion, connectivity, autonomy, and shared mobility services. Utilizing advanced statistical techniques, it analyzes large-scale datasets to provide a data-driven understanding of user behavior. Beyond academic contributions, QETAM offers practical insights for policymakers and industry stakeholders, supporting the transition toward sustainable and user-centric mobility solutions.



## 1 INTRODUCTION

In the contemporary landscape of urban mobility, the integration of electric, connected, autonomous, and shared (ECAS) mobility technologies marks a paradigm shift, offering transformative potential in addressing environmental concerns, enhancing connectivity, and revolutionizing transportation systems (Society of Automotive Engineers, 2014). The rapidly evolving technologies in this field aim to create numerous benefits for both society and individuals including improved traffic safety, higher fuel economy, and reduced emissions. Therefore, as we stand at the crossroads of technological innovation and sustainable urban development, understanding such technologies' intricate dynamics, risks, and acceptance patterns becomes imperative. In other words, the intention of consumers to adopt ECAS mobility technologies is critical for forecasting adoption rates and aiding policymakers and implementers (Becker et al., 2020) (Karathanasopoulou et al., 2022).

Up to today, researchers have extensively examined the factors influencing end users' behavioral intention to use and adopt new technologies. While prominent models like the Technology Acceptance Model (TAM) (Davis., 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) have provided frameworks for understanding user adoption, recent studies emphasize the importance of user trust and psychological factors. In the particular domain of mobility, the issue of the public acceptance of ECAS mobility solutions is attracting scholarly attention such that extensive discussions have been conducted on the factors that influence the acceptance of ECAS vehicles, while the biggest obstacle to the popularization of such technologies is related less to the technical aspect and more to the low psychological acceptance of the public (Yuen et al., 2021).

While numerous studies have explored user acceptance in the context of highly automated vehicles, the majority of these investigations have predominantly relied on theoretical models to assess the factors influencing the behavioral intention to use such vehicles. In our proposed model, we seek to integrate both theoretical and practical perspectives, providing a comprehensive framework to not only identify obstacles but also to offer guidance for future advancements within this domain. In particular, we



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propose a comprehensive model that systematically analyzes the multifaceted effects and acceptance nuances surrounding ECAS mobility solutions.(Wang et al., 2025) here's a breakdown of the specific challenges you've outlined:

1. Lack of Specificity for ECAS: Traditional models might not capture the unique features and concerns surrounding electric, connected, autonomous, and shared mobility solutions.
2. Difficulties with Dynamic Nature: Rapid advancements and the evolving nature of ECAS technologies can make it challenging for existing models to provide accurate long-term predictions.
3. Inadequate Trust Focus: Existing models may not fully address the intricacies of how users develop trust in autonomous systems, which is crucial for widespread acceptance.
4. Missing Regulatory Considerations: The legal and regulatory landscape surrounding autonomous driving significantly influences user acceptance, and current models may not sufficiently consider these factors.
5. Gaps in Safety Perception: Safety concerns are paramount. Existing models may not fully capture how users perceive the safety and reliability of autonomous vehicles.
6. Cultural Variations Omitted: Technology acceptance is influenced by cultural factors, and existing models may not adequately consider this diversity in user attitudes.
7. Ethical Concerns Unaccounted for: Ethical concerns around decision-making algorithms in autonomous vehicles pose challenges to user acceptance, and current models often don't address these ethical dimensions.

In light of the above, the contribution of this paper lies exactly in addressing these gaps and challenges, by proposing a novel technology acceptance model, building on previous research efforts, and enhancing them by adding the ability to accurately predict and understand the factors influencing the acceptance of autonomous driving technology, more quantitatively.

This paper is structured as follows: The next section (II) delves into an exploration of the related work that has been conducted within the field of ECAS vehicle acceptance and the methodologies employed in previous research. Section IIII describes the proposed model, the hypotheses, the research methodology and the profile of the participants. Details of the survey results on general attributes, factors associated with intent to use ECAS vehicles, and data analysis with hypotheses testing are reported in Section IV. The most important implications of the present study which showcase the benefits of the proposed model, are discussed in Section V. Last, concluding remarks are drawn in Section VI, along with an outlook on future work.

# 2 RELATED WORK

## 2.1 Technology Acceptance Models

The Technology Acceptance Model (TAM), introduced by Davis (Davis., 1989), has been a cornerstone in understanding user acceptance of information systems and technologies. **TAM** focuses on two core beliefs: Perceived Usefulness (PU) - the degree to which users believe technology will enhance their job performance, and Perceived Ease of Use (PEU) - the perceived effort required to learn and use the technology. While TAM has been widely applied, it may not fully capture the nuances of user acceptance for Electric, Connected, Autonomous, and Shared (ECAS) mobility solutions. For instance, TAM's focus on general-purpose technologies might not account for the unique features and concerns surrounding ECAS, such as trust in autonomous systems or cultural variations in user attitudes (Alfadda and Mahdi, 2021). As evidenced by the studies exploring user reactions to Zoom for language learning (Alfadda and Mahdi, 2021) and healthcare IT adoption (Kamal et al., 2020), the Technology Acceptance Model (TAM) has been a versatile tool for understanding user acceptance across various domains. However, limitations have been identified, such as infrequent measurement of variables and a potential lack of detailed theoretical explanation for the constructs used in the model (Kamal et al., 2020). Furthermore, the TAM-TOE model, which integrates TAM with the Technology-Organization-Environment framework, offers a broader perspective by considering social, environmental, and technological factors influencing technology adoption, as seen in the research by Sheshadri Chatterjee et al. (Chatterjee et al., 2021). While valuable, TAM-TOE might still lack the specific focus needed to fully understand user acceptance of Electric, Connected, Autonomous, and Shared (ECAS) mobility solutions. Building upon these insights and addressing the limitations of existing models, this research proposes a novel user acceptance model specifically tailored to the complexities of ECAS technologies (Ferran et al., 2024). The proposed model offers a more comprehensive framework to not only identify the factors influencing user acceptance but also to provide a quantitative understanding of these factors.(Chatterjee et al., 2021). Indeed, TAM shows several similarities with the Unified Theory of Acceptance and Use of Technology (UTAUT), having the same primary constructs (perceived ease of use and perceived usefulness), as the latter was created based on TAM and seven other theoretical frameworks. Nevertheless, UTAUT examines the acceptance of technology, determined by the effects of performance expectancy, effort expectancy, social influence, and facilitating conditions. TAM and UTAUT has been used in different fields to assess user acceptance of specific technologies. For instance, it has been applied to identify the main factors that determine students. acceptance of MOOCs in higher education in Saudi Arabia (Altalhi et al., 2021). Also, UTAUT with core constructs such as social influence, enabling conditions, etc. has been used by researchers Novianti Puspitasari et al. (2019) to identify variables that influence users to use the Integrated Licensing Services Information System (Puspitasari et al., 2019).

## 2.2 Failure Mode and Effect Analysis

An important factor that can negatively affect the successful execution or performance of a process or a project is risk, which can manifest itself as uncertainties. For this reason, effective risk management is vital, as it helps mitigate potential challenges.

The Failure Mode and Effects Analysis (FMEA) (Sharma and Srivastava, 2018) can be characterized as a risk management tool and is an engineering method that helps to identify weak points during the concept and design phase of all kinds of products (hardware, software) and processes. It is mainly a qualitative analysis, which shows how reliable the designed system is (Liu et al., 2013). FMEA can be also used to implement the analysis of component failure modes, their resultant effects, and secondary influences on both local component function and the performance of the whole system (Carlson., 2012). Essentially, the purpose of FMEA is to take steps to eliminate or reduce failures, starting with those that have the highest priority, and more specifically those that cause the most serious consequences, or that occur frequently and can be identified most easily.

By combining FMEA with the TAM model, which is a theoretical approach, we leverage the strengths of both models to obtain quantitative results and to provide a more comprehensive and robust framework for evaluating the acceptance and impact of emerging ECAS mobility technologies.

## 2.3 Studies on Technology Acceptance of ECAS Mobility Solutions

User acceptance is paramount for the success of any new technology. It serves a two-fold purpose, firstly allowing developers to monitor potential acceptance during the priori development phase ("a priori") and by providing valuable feedback to the industry that can influence product development. This is crucial for Electric, Connected, Autonomous, and Shared (ECAS) mobility solutions. While public perception of autonomous vehicles is gradually becoming more positive, a deeper understanding of user acceptance is essential for widespread adoption. Social and psychological factors significantly influence how societies respond to new technologies. Research has identified several key factors impacting public acceptance of ECAS technologies, including: Perceived Risk**:** **1**. Concerns about safety and potential for accidents with autonomous vehicles. **2.** Trust: The level of trust users has in the technology's ability to function safely and reliably. **3.** Perceived Benefit: The perceived advantages and improvements to transportation that ECAS solutions offer.

Existing models like the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Car Technology Acceptance Model (CTAM) by Osswald et al. (Osswald et al., 2012; Sithanant et al., 2023) have provided valuable insights into user acceptance. CTAM, for example, incorporates UTAUT's framework along with additional constructs like safety to understand user attitudes towards driving information technology systems. However, Madigan et al. (Madigan et al., 2016) highlight that CTAM's investigation did not extend to behavioral intentions towards using such systems. Further research (mention a recent study if possible) emphasizes the need for models that specifically address the unique features and concerns surrounding ECAS technologies. Recent studies have focused on enhancing existing models (TAM and UTAUT) to account for the specific attributes of automated driving, but there is still a gap in understanding user perceptions of usefulness and trust in these novel technologies (Panagiotopoulos et al., 2018). This paper proposes a novel user acceptance model specifically tailored to ECAS technologies to address these limitations. Our model leverages the strengths of existing models and incorporates Failure Mode and Effect Analysis (FMEA) to identify potential "acceptance failures" that could hinder user adoption. By combining these approaches, our model offers a more comprehensive framework for evaluating user acceptance of ECAS solutions.

While the original TAM, as proposed by Davis et al. in 1989, has been widely used to understand user acceptance of various technologies, including information systems, health informatics, and educational platforms, has also several limitations, as discussed previously. Adding three new factors, “Perceived Trust (PT)”, “Social Influence (SI)”, and “Facilitating Conditions (FC)” to the original TAM, addresses some of the limitations and enriches the framework with a more nuanced understanding of factors affecting user acceptance of ESAC technologies. The integration of TAM with FMEA bridges the gap between technology reliability and user acceptance, recognizing that these elements are interrelated. This integration allows us to not only assess the acceptance of ECAS technologies but also identify and prioritize potential system design failures, leading to more informed decision-making and risk mitigation strategies.

Leveraging these foundations, the following section delves into our user acceptance model for highly automated vehicle (HAV) technologies. We'll explore the model's structure, the Python code behind its implementation, the questionnaire design used for data collection, the obtained results, and finally, the conclusions drawn from this initial evaluation.

# 3 CONCEPTUAL MODELING

## 3.1 Overview

The speed at which consumers embrace advancing technologies is influenced by factors like technology availability, convenience, consumer needs, and trust. Various theories and models, as proposed so far (as indicated in the previous section), aim to elucidate consumers’ inclination toward adopting new technologies. Examining the intention of consumers to use ECAS mobility solutions is crucial, given that this emerging technology is gradually penetrating the global market.

To investigate this, the Technology Acceptance Model (TAM) has provided valuable insights into factors influencing user adoption of new technologies. Concomitantly, Failure Mode and Effect Analysis (FMEA) offers a systematic approach to identify and assess potential challenges that may arise during user interaction. This study builds upon these established methodologies to create a comprehensive user acceptance model based on the key indicators of TAM and the computational method of FMEA.

## 3.2 Framework Description

In our approach, we leverage a combination of 2 methods, by exploiting the quantitative nature of (FMEA) with the modeled social analysis advantages of the Technology Acceptance Model (TAM) to assess the User Acceptance of HAV In this context, it is essential to meticulously identify and measure the key parameters outlined in the TAM. This integrated methodology enables a comprehensive evaluation of potential failure modes while concurrently gauging user acceptance factors, ensuring a robust and holistic assessment of the new technologies' viability and user satisfaction. More specifically the main components of the derived FMEA-based acceptance model QETAM (Quantitative Effect and Technology Acceptance Modelling) are structured as follows:

- **Perceived Trust (PT) -** Measure of a person’s trust in a particular technology
- **Perceived Usefulness (PU) -** Measure of the usefulness of a particular technology
- **Perceived Ease to Use (PEU) -** Measure of the usability of a particular technology.
- **Social Influence (SI) -** The degree to which someone is influenced by social norms and their social environment.
- **Facilitating Conditions (FC) -** The degree to which an individual believes that an organizational and technological infrastructure exists and also the degree to which they have the appropriate knowledge and resources to use the system.

The main research hypotheses, upon which the analysis is focused, are the following: **H1**: The overall impact of Perceived Trust (PT), Perceived Usefulness (PU), Perceived Ease to Use (PEU), Social Influence (SI), and Facilitating Conditions (FC) on Behavioral Intention to Use (BIU) **H2**: The Correlation of Perceived Trust (PT) with Perceived Usefulness (PU) and their impact on Behavioral Intention to Use (BIU) **H3**: The Correlation of Perceived Trust (PT) with Perceived Ease to Use (PEU) and their impact on Behavioral Intention to Use (BIU) **H4**: The Correlation of Perceived Trust (PT) with Social Influence (SI) and their impact on Behavioral Intention to Use (BIU) **H5**: The Correlation of Perceived Trust (PT) with Facilitating Conditions (FC) and their impact on Behavioral Intention to Use (BIU).

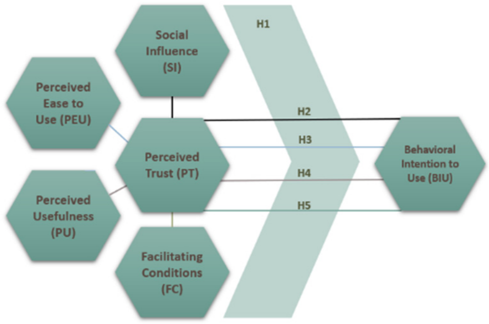


Figure 1: "QETAM Conceptual Modelling".

According to the above, the outcome is the identification of several user Acceptance, based on the aforementioned Behavioral Intention to Use (BIU), For each distinct category within the administered questionnaire, participant responses will be subjected to a ranking procedure. This ranking will utilize a standardized 1-to-10 scale. Following the ranking of responses, a Batch Index Unit (BIU) number will be calculated using Equation 1 Once the BIU number is obtained, it will be used to categorize based on Table 1

$$BIU_i = PU_i \times PEU_i \times PT_i \times SI_i \times FC_i \ (i = 1, 2, \ldots, N) \quad (1)$$

| BIU Number | Behavioural Intention to Use |
|---|---|
| 80.001-100.0000 | Very High |
| 50.001-80.000 | High |
| 20.001-50.000 | Medium |
| 5.001-20.000 | Low |
| 0 - 5.000 | Improbable |

# 4 RESULTS AND DISCUSSION

## 4.1 Implementation

For the quotative approach of the QETAM model, a code was created in the programming language Python. In this code, five categories were created, which are „Perceived Usefulness (PU)", "Perceived Ease to Use (PEU)", "Perceived Trust (PT)", "Social Influence (SI)" and "Facilitating Conditions (FC)". For each category individually, the inappropriate acceptance was found according to the tables x1, x2, x3, x4, and x5. The responses provided indicate that users' overall acceptability for each category was 7.694 for Perceived Usefulness (PU), 7.548/10 for Perceived Ease to Use (PEU), 6.858/10 for Perceived Trust (PT), 7.492/10 for Social Influence (SI) and 7.314/10 for Facilitating Conditions (FC).

Then another piece of code was added that concerned the BIU. The code creates a histogram based on table x6 and takes values from 0 to 100,000. The Total BIU score is calculated as the result of the five BIU parameters for each category found. Furthermore, the code categorizes the results into five categories: Improbable, Low, Medium, High, and Very High. Each category corresponds to a different value range. Then, the histogram displays the total BIU score in a bar, using different colors for each category, with the color representing the category of each value.

Finally, a correlation matrix was created to respond to the assumptions defined above, to find out which combination affects user acceptance positively and negatively. This code analyzes correlations between different lists of data. Initially, it calculates the means of each list's values and then computes the correlation coefficient between one list (PT) and the rest of the lists (PU, PEU, SI, FC). Then, it displays the correlation values in an image, using color to represent the level of correlation, with blue indicating high correlation and lighter shades indicating low correlation

## 4.2 Survey Design

To gain comprehensive insights into user perspectives on autonomous driving technologies, we have designed a targeted survey structured around three key components aimed at assessing user acceptance.Firstly, demographic data including age, gender, education, and work location are collected to explore potential correlations between user characteristics and their acceptance of Electric, Connected, Autonomous, and Shared (ECAS) technologies. This foundational information is crucial for capturing the diverse viewpoints that influence user comfort with autonomous vehicles. Secondly, we evaluate user awareness of highly autonomous vehicles through two general knowledge questions. These questions assess familiarity with classification criteria such as SAE levels and any personal experience users may have had with driving such vehicles. This approach enables us to gauge user awareness, knowledge levels, and direct interaction with autonomous driving technology. The core of our survey comprises 25 meticulously crafted questions, categorized into five key areas aligned with our newly developed acceptance model: Perceived Trust (PT), Perceived Usefulness (PU), Perceived Ease of Use (PEU), Social Influence (SI), and Facilitating Conditions (FC). Each category is designed to probe user perceptions and attitudes towards ECAS mobility solutions through targeted inquiries. For example, questions under Perceived Trust explore user comfort levels with autonomous vehicles handling emergencies or navigating complex road condition.

The demographic part of the survey includes basic information about age, gender, education level, and work location. These serve as critical variables in our analysis, allowing us to explore potential associations between user characteristics and acceptance of ECAS technologies. Understanding demographic factors' influence is integral to capturing the different perspectives that may shape user attitudes toward autonomous vehicles.

In addition, participants were asked if they were familiar with the criteria that classify vehicles as highly autonomous, such as those meeting a Society of Automotive Engineers (SAE) level of more than 3, and if they have personally driven highly autonomous vehicles. Thus, we were able to understand better whether there is an awareness and understanding and personal experience of the specific vehicles from the users.

Finally, the core of our survey consists of 25 questions divided into five 5 categories, namely “Perceived Trust (PT)”, “Perceived Usefulness (PU)”, “Perceived Ease to Use (PEU)”, “Social Influence (SI)”, and “Facilitating Conditions (FC)”. Each category includes five questions tailored to capture nuanced insights into user perceptions and attitudes toward ESAC mobility technologies.

This survey was designed to gain valuable insights into user acceptance of autonomous driving technologies, ultimately strengthening the competitive advantage of the European Union's autonomous vehicle industry and achieving user-driven market adoption. Conducted between September 2023 and January 2024, the survey targeted adult participants. Notably, it employed a two-stage approach: an initial survey and a follow-up survey to be conducted later. This design will enable us to assess the impact of future developments on user perceptions We utilized Google Forms to create the questionnaires, with the resulting data set delivered in an .xls file format. To ensure a representative sample of the general population, we employed a random sampling approach and disseminated the survey electronically through mailing lists, social media platforms, and QR codes distributed at relevant events. In total, we received responses from 128 individuals.

The subsequent figures (Figures 2, 3) illustrate the distribution of various demographic attributes among the respondents who completed the questionnaires.

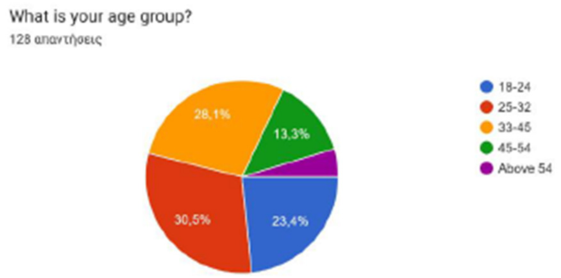


Figure 2: ‘Age groups’.

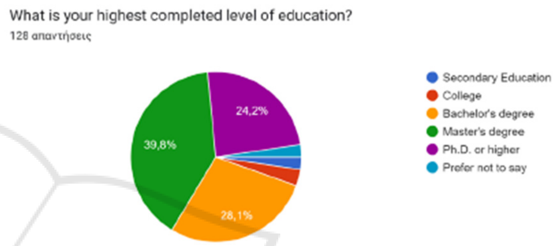


Figure 3: Education.

To understand user understanding of the technology behind autonomous vehicles, we included two questions assessing their fundamental knowledge of highly automated vehicles. Analyzing the responses reveals that while a majority of participants grasp the concept, many lack firsthand experience with the technology. This finding aligns with our expectations, considering the survey targeted European adults and widespread autonomous vehicle deployment might not be as prevalent compared to other regions. This lack of experience could potentially influence user attitudes, such as leading to a more cautious or apprehensive perspective towards autonomous vehicles.

### 4.3 Hypothesis Testing

This study investigates the impact of various factors on individuals' intention to use (BIU) the technologies adopted in Highly Automated Vehicles (HAVs). We leverage an acceptance model that builds upon the well-established Technology Acceptance Model (TAM) Our first hypothesis (H1) examines how user perceptions, such as Perceived Trust (PT), Perceived Usefulness (PU), and Perceived Ease of Use (PEU), along with external factors like Social Influence (SI) and Facilitating Conditions

(FC), contribute to the formation of a behavioral intention to use HAV technology. Prior research has established the positive influence of PU and PEU on BIU. H1 extends this understanding by incorporating the effects of PT, SI, and FC.

Utilizing data from Figure 4, our analysis reveals a Behavioral Intention to Use (BIU) score of 21,823.9963, placing HAV technology within the "medium" category of user acceptance. Interestingly, the question on HAVs knowledge indicates that while 76.6% of participants are aware of HAVs, only 25% have used them. This suggests a potential for significant growth in user acceptance as experience with the technology increases. Our detailed analysis of H1 revealed that each factor (PT, PU, etc.) had a significant positive impact on BIU, with Perceived Trust being the strongest factor influencing user intention to use HAVs.

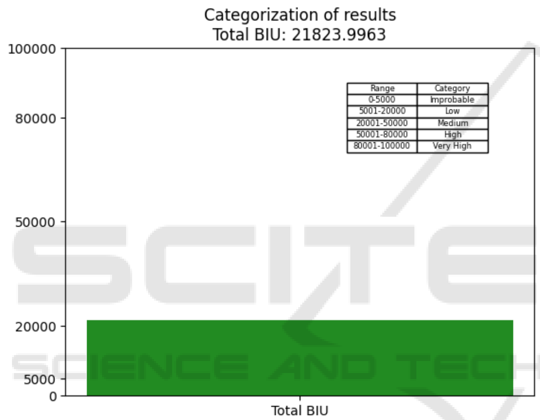


Figure 4: “Behavioral Intention to Use Outcome”.

Following our initial hypothesis on the overall impact of user perceptions on BIU, we delve deeper into the interplay between these perceptions, specifically focusing on the role of trust. The next four key hypotheses explore how perceived trust interacts with various user perceptions, ultimately influencing their intention to use the technology (BIU). The 2nd Hypothesis focuses on the relationship between perceived trust (PT) and perceived usefulness (PU), and we aim to understand how trust interacts with perceived value to drive user adoption. The 3rd hypothesis investigates the correlation between perceived trust (PT) and perceived ease of use (PEU) and focuses on exploring how trust interacts with user-friendliness to shape technology acceptance. From the 4th hypothesis which examines the link between perceived trust (PT) and social influence (SI), we will understand how trust interacts with the influence of a user's social circle on their technology adoption. Lastly, the 5th hypothesis examines thoroughly the correlation between perceived trust (PT) and facilitating conditions (FC) where we will explore how trust interacts with the availability of resources and support systems in influencing technology adoption.

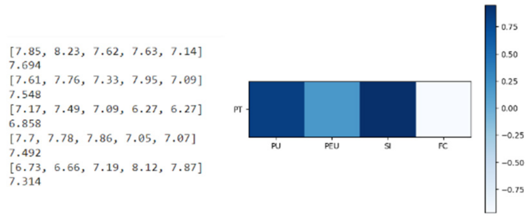


Figure 5: “**Correlation Vector**”.

These hypotheses will help us create a "correlation vector," a tool to identify which factor PU, PEU, or SI, in correlation with PT, affects BIU the most. According to the data presented in Figure 5, the highest impact at the behavioral intention to use a technology is the Perceived trust about social influence. That means for people to trust and accept a technology they have to be introduced and encouraged to use it from their social environment. Furthermore, there is a strong correlation between perceived trust and perceived usefulness. This implies that technology acceptance is significantly influenced by users' opinions on both the usefulness and trustworthiness of the technology. The correlation between perceived trust and perceived ease of use, as well as the impact of facilitating conditions, may be less significant in this case. This is likely because a large portion of the surveyed population lacks experience with highly automated vehicles.

## 5 CONCLUSIONS

In summary, this paper introduces the QETAM model, a novel framework that bridges the gap between transportation engineering, social psychology, and technology acceptance studies. By integrating these diverse fields, QETAM provides a comprehensive understanding of the factors influencing user adoption of Electric, Connected, Autonomous, and Shared (ECAS) mobility technologies. The model's strength lies in its ability to analyze large-scale datasets through advanced statistical techniques, validating its effectiveness and offering valuable academic and practical insights into ECAS mobility. QETAM’s collaborative approach ensures that future mobility solutions prioritize both sustainability and user-friendliness.

Through advanced statistical analysis, QETAM identifies key adoption factors, such as technological reliability, user attitudes, infrastructure support, and environmental considerations. Our findings highlight Perceived Trust (PT) as the most influential factor in Behavioral Intention to Use (BIU), particularly its correlation with Social Influence (SI) and Perceived Usefulness (PU). These results underscore the significant role that social acceptance plays in fostering trust and driving adoption. The BIU score of 21,823.9963 reflects medium acceptance of Highly Automated Vehicles (HAVs), with potential for growth as user familiarity increases.

Throughout the EcoMobility project, we aim to influence future development and remeasure the BIU score at the project's conclusion. Building on these insights, we aim to extend QETAM to explore gender-related differences in technology acceptance. Understanding how gender influences adoption factors will enhance the model's predictive power and contribute to more inclusive and targeted mobility strategies. Additionally, ongoing monitoring of user behavior will support adaptive policymaking and technological advancements in ECAS mobility.

By continually refining QETAM, this research contributes to informed decision-making, supporting the transition to sustainable, connected, and user-friendly urban transportation systems.

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