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Resistance towards autonomous vehicles (AVs)

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ABSTRACT

The resistance towards automated vehicles (AVs) is little understood. The main objective of this study is to examine the resistance towards AVs, identifying the factors explaining resistance. Comments submitted by residents of California to the California Public Utilities Commission (CPUC) on the fared deployment of AVs were analyzed. In total, we identified four main themes, and twenty-nine sub-themes. We developed a conceptual framework for resistance that explains resistance by individual and vehicle characteristics, the direct and indirect consequences of use, reactions of others, and external events. AVs were considered incompetent, and unpredictable, violating traffic rules, blocking traffic, not explicitly engaging in communicating with other road users, and causing conflict situations. Respondents questioned the effectiveness of AVs in meeting today's transportation-related challenges, and feared the indirect negative consequences of the deployment of AVs for traffic safety, flow efficiency, transition towards sustainable mobility, environmental efficiency, privacy, economy, social equity, livability of cities, and humanity. Respondents perceived a low responsibility of stakeholders involved in the manufacture, deployment, and regulation of AVs given a lack of accountability, and legal liability. Moreover, they reported a limited involvement of local residents and community in the decision-making processes behind AV deployment and an unjust distribution of costs and benefits. The scientific dialogue on acceptance of AVs needs to shift towards resistance as the 'other' essential element of acceptance to ensure that we live up to our promise of transitioning towards more sustainable mobility that is inclusive, equitable, fair, just, affordable, and available to all.

1. Introduction

The California Public Utilities Commission (CPUC) approved the fared deployment of SAE Level 4 autonomous vehicles (AVs) (SAE International., 2021) in San Francisco (SF) (Cpuc, 2023). AVs face resistance from other road users, stopping these vehicles by placing objects on them (e.g., cones) or stepping in front of them to test their capabilities and interfere with their operation (Thubron, 2023).

The scientific literature investigating automated vehicle acceptance (AVA) has been skewed towards acceptance, applying technology acceptance models to identify the factors influencing acceptance. The models that were developed for the assessment of AVA, such as the multi-level model on automated vehicle acceptance (MAVA) (Nordhoff et al., 2019), consider resistance only as a side phenomenon without explaining it theoretically. In MacInnis et al. (2023), it is argued that the traditional technology acceptance models (e.g., Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB)) "might explain resistance to buying EVs" (electric vehicles) (p. 2). These scholars define resistance as "willingness" or "the mirror image of willingness". In the study of Chen and Granitz (2012), which investigated adoption, rejection, and convergence of book digitalization, it is posited that "in technology adoption models, adoption or rejection remains the outcome". The present study, however, argues that we need a different theoretical framing for resistance as traditional acceptance models were designed to explain acceptance (commonly by the behavioral intention to use and actual usage of the technology) and not resistance.

The resistance towards AVs is still little understood, but is growing in importance, as documented by recent studies (Ju and Kim, 2022; MacInnis et al., 2023). Resistance is linked to an object or content that is being resisted (e.g., introduction of new technology) (Jermier et al., 1994; Lapointe and Rivard, 2005). It is defined as a psychological reaction or usage behavior, capturing disuse or lack of or no use, low level of use, harmful use (Martinko et al., 1996), or misuse (Marakas and Hornik, 1996). It can be passive (e.g., excuses, delay tactics), active (e.g., voicing opposite points of view, asking others to intervene, forming coalitions), or aggressive (e.g., strikes, boycotts, sabotage) (Lapointe and

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Rivard, 2005). Borrowing ideas from (Marakas and Hornik, 1996), this paper posits that acceptance and resistance can be placed on one continuum, with acceptance as measure for use at one end of the continuum, and resistance as measure for disuse at the other end of the continuum, as presented in Fig. 1. Herein, acceptance is defined as use as intended by system designers.

Here we argue that resistance should not be seen as dysfunctional behavior representing an obstacle or barrier to overcome, or that needs to be investigated to improve the uptake and use of AVs (Milakis and Müller, 2021; Van Wynsberghe and Guimarães Pereira, 2022). Instead, it should be considered as functional orientation that can occur as the result of legitimate concerns associated with a change (Marakas and Hornik, 1996). It should be approached with curiosity rather than stigmatization, being assigned an equal weight in the debate about AVs than acceptance. Neither phenomenon is more important than the other; we need to investigate both ends of the spectrum to the same extent to ensure that the development, design, and deployment of AVs reflect the diverse needs, views, and concerns of all socially relevant individuals and groups in and around AVs. The design of AVs should be a process being open to producing different outcomes representing the results of negotiations among socially relevant groups within different sociocultural and political environments until the design no longer creates problems to any group (Klein and Kleinman, 2002; Milakis and Müller, 2021).

In comparison to conventional vehicles, AVs have higher sensing capabilities, and are situationally aware, being able to adapt and communicate with their environment (Winfield, 2012), creating privacy and security (e.g., hacking) issues (Bloom et al., 2017; Chen et al., 2023). Existing research studies also revealed concerns related to safety, trust (Chen et al., 2023), affordability, unemployment, and financial insecurity (Agrawal et al., 2023). In (MacInnis et al., 2023), the resistance towards EVs was associated with instrumental considerations (e.g., 'Maintaining EVs is more costly than maintaining gasoline-powered cars'), non-instrumental considerations (e.g., 'EV batteries are likely to catch on fire'), and normative considerations (e.g., 'Global warming will not be a serious national problem'). (Oreg, 2003) developed the resistance to change scale, which consisted of four main factors, including routine seeking (e.g., 'I generally consider changes to be a negative thing'), short-term thinking (e.g., 'Changing plans seems like a real hassle'), emotional reaction (e.g., 'If I were to be informed that there's going to be a significant change, I would probably be stressed'), and cognitive rigidity (e.g., 'I often change my mind'). Furthermore, it has been proposed that community or local acceptance is a key determinant for societal acceptability. Resistance would be low if the conditions for distributional justice (i.e., sharing of costs and benefits), and procedural justice (i.e., equal opportunities of all relevant stakeholders for participation in the decision-making process) are met (Wüstenhagen et al., 2007). Furthermore, the perception of threats was considered a necessary condition for resistance to occur. It is defined as expression of overwhelming emotional pain or the perception of dangerous situations (Marakas and Hornik, 1996). The perception of threats, a change in the power dynamics between groups with unequal gains, inequity issues, stress and fear, efficacy or outcome expectations contributed to the occurrence of resistance. Finally, resistance is linked with personal characteristics of individuals or groups of individuals (e.g., age, gender, socio-economic status).

1.1. The present study

Resistance towards AVs can have severe negative consequences, preventing the implementation or use of the system, and thereby undermining the realization of transport-related objectives. An enhanced understanding of the resistance towards AVs contributes to exploiting the benefits of AVs (Shariff et al., 2021). The main objective of this study is to examine the resistance towards AVs, identifying the factors explaining resistance. Comments submitted by Californian residents to the CPUC on the fared deployment of AVs were analyzed using qualitative and quantitative text analysis techniques. Finally, this paper offers a conceptual framework, which synthesizes the results of the data analysis.

2. Methodology

2.1. Data analysis

The data was analyzed in four steps.

First, to inform the development of the main themes and sub-themes, a content analysis was conducted. These themes were derived inductively from the data by applying common text analysis methods, such as writing notes, searching for keywords, and jumping between text passages. The development of themes was based on repetitions, similarities, and differences between the key words and phrases. Themes were then compared with constructs from the literature (e.g., Kusano et al., 2023; Lapointe and Rivard, 2005; Lehtonen et al., 2022). This step supports construct operationalization in future studies. The development of the themes was an iterative and emergent process, with the researcher revisiting themes developed at an earlier stage to adjust them at a later stage, based on the knowledge obtained from comparing the themes with the literature, and the coding process itself. This part of the analysis was conducted in Atlas.ti (Version 22.0.2). Using prompts, ChatGPT was applied for the development of the main themes and sub-themes. For the development of the main themes, we asked ChatGPT to do the following: *"The comments below were obtained from respondents who submitted comments on the fared expansion of automated vehicles in San Francisco. If you read the comments below, what are the common themes that you see in the data? Provide a summary of the themes."* For the development of the sub-themes, we used the following prompt: *"If you read the following comment below, what is the common theme that you see in this comment? Provide a summary of the theme, and propose a name for this theme."* When ChatGPT assigned a different name or label to a sub-theme, the researcher provided ChatGPT with the following prompt: *"I see that you came up with a different name for this sub-theme, which is totally justified. Do you think that this quote could also represent the sub-theme ["enter name of sub-theme"]?"* The researcher compared the developed codes with the results generated by ChatGPT, and based on that, refined the coding scheme. As the objective of this study is to identify the factors explaining the resistance towards AVs, we will not present data that does not address this objective, such as the benefits associated with AV deployment.

Second, the occurrence of these sub-themes was manually counted, and illustrative quotes were selected to portray the meaning of each sub-theme. These quotes may represent sentences mentioned at different points in time during the interview.

Third, we conducted a simple frequency analysis to count the most common words. To achieve this, the text was preprocessed and cleaned. Words (or tokens) with ≤ 2 and ≥ 30 letters, digits, hashtags, or hyperlinks, were removed. Then we transformed words to lowercase, and

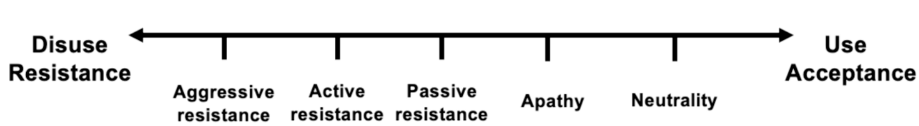

Fig. 1. Resistance-acceptance continuum, based on (Lapointe and Rivard, 2005)

removed duplicates, stop words and words that did not add any substantial meaning to the sentences were removed. Any other noise was also removed, such as characters, digits, hashtags, or hyperlinks. We also applied spellchecking in order to correct for misspelled words. The sentences were tokenized, which means that each sentence was separated into a smaller unit of sentences so that it could be more easily processed by the algorithm. This part of this analysis was conducted in Python.

Fourth, the results of the content analysis were synthesized in a conceptual framework. The development of the framework was based on the themes (i.e., main, sub-themes) developed in the present study, and informed by the model to explain resistance to the implementation of information technology by (Lapointe and Rivard, 2005). This model specifies relationships between initial conditions, technology features, perceived threats, and resistance, as briefly explained in Section 1. To build this framework, we applied the grounded theory approach (Glaser et al., 1968; Jabareen, 2009). The development of this framework was considered completed until a framework could be identified that made sense (Jabareen, 2009). In this framework, the main and sub-themes developed in the study represent the independent variables explaining resistance towards AVs, while resistance itself represents the dependent variable.

3. Results

3.1. Respondents

In total, 329 comments from 321 respondents were analysed. Six respondents submitted more than one comment. One comment was double-posted by the same respondent, and therefore omitted from the analysis, resulting in 328 comments that remained for further analysis. Respondents provided their name, residential location, and zip code. Based on the name that respondents attached to their comment, we determined that 45 % of respondents were female, and 53 % were male, and the gender of the remaining respondents could not be determined due to unclear or ambiguous initials provided. 86 % of respondents resided in San Francisco, California (CA), followed by 4 % of respondents residing in Oakland, CA. The remaining 10 % of respondents resided in other cities in CA, such as Los Angeles, Sacramento, San Rafael, San Leandro, or Sausalito. Table A1 in the appendix provides a complete overview of respondents' personal information. We deleted names to protect their confidentiality.

Fig. 2 provides the results of the frequency analysis of the 75 most common terms that were used by respondents.

Both the researcher and ChatGPT independently coded the data. The results of the individual coding processes were merged, and the final result is presented in Table 1. In total, we identified four main themes, and twenty-nine sub-themes, representing the factors explaining the resistance towards AVs. The four themes are individual characteristics

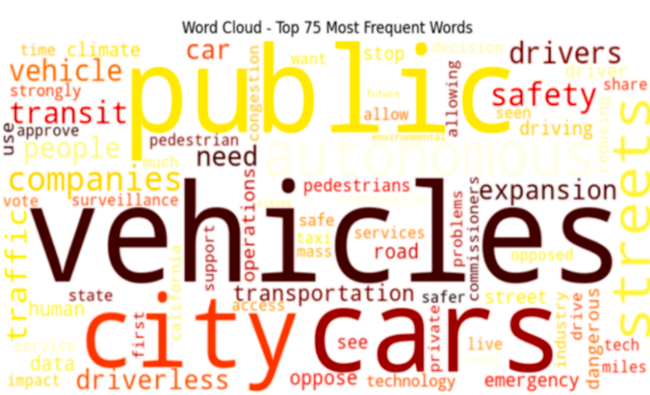

Fig. 2. Word cloud, 75 most common words.

Table 1
Factors contributing to resistance towards AVs (main theme, sub-theme, meaning, keywords, n = total number of mentions of sub-themes).

Main theme, #	Sub-theme, #	Meaning	*n*
Individual characteristics (1)	Vulnerability in traffic (1)	Lack of protection of vulnerable road users against speed and mass of motorized road users, leading to involvement in severe injuries and road traffic causalities (European, 2021; Torfs and Meesmann, 2019)	31
	Use of sustainable travel modes (i.e., transit, active walking modes) (2)	Use of sustainable transport modes (i.e., transit, active walking modes)	17
	Anecdotes and negative personal experience (3)	Anecdotes (e.g., "I / we have heard") and personal experiences involving negative interactions with AVs	13
	Concern for environment (4)	Concern for environment	48
	Negative attitude (5)	Negative attitude towards cars, AVs, and AI, and fared deployment of AVs	87
	Fear of unknown (6)	Fear of unknown, i.e., see sub-theme 'indirect consequences of system use' (Joshi, 2005)	34
	Feeling unsafe (7)	Low perceived safety and feelings of discomfort when interacting with AVs	7
	Lack of control (8)	Inability to control vehicle operation given driverless operation of AV (Nordhoff et al., manuscript submitted for publication	3
Vehicle characteristics (2)	Incompetent (9)	AVs being considered incompetent and incapable to navigate complexity of urban environments, assessing and responding to objects and events accurately	26
	Unpredictable (10)	Erratic, unhuman, and unexpected vehicle behavior (Ioannou, 1998), such as AV stopping suddenly	16
	Low effectiveness (11)	AVs not addressing transport-related problems (May et al., 2020) given redundancy of transport options, and incompetent, unpredictable, and unwanted vehicle behavior	20
	Inaccessible (12)	Inaccessible vehicle design not accomodating to needs of individuals with impairments and disabilities, or in need of assistance with carrying luggage, pertaining to entire travel journey (Dicianno et al., 2021), including ordering of vehicle via smartphone app, entering and exiting vehicle, getting buckled on, and receiving assistance with carrying items to apartment	32
	Unwanted actions		
	Violating traffic rules (13)	Violating traffic rules, e.g., running red light or stop sign, or parking in bus lane	13

(continued on next page)

Table 1 (*continued*)

Main theme, #	Sub-theme, #	Meaning	*n*
	Causing conflict situations (14)	Causing evasive maneuvers by other road users, an unsafe proximity with other road users, or collisions (Kusano et al., 2023)	24
	Not explicitly communicating with road users (15)	Lack of explicit communication (e.g., eye contact, hand gestures, verbal communication) with road users due to absence of human driver, contributing to uncertainty as to whether AV successfully detects and responds to road users	14
	Blocking traffic (16)	Blocking other road users, including first responders, being stuck or confused, incapable of moving around objects	78
Indirect consequences of use (3)	Public safety (17)	Negative impact on public safety, with AVs being perceived as risky, unsafe, or dangerous, and causing crashes (Liljamo et al., 2018) due to unwanted vehicle actions, unpredictable and incompetent vehicle behavior	80
	Traffic flow efficiency (18)	Negative impact on traffic flow efficiency, associated with increase in congestion and lower road capacity (larger number of vehicles on road) (May et al., 2020), with AVs disrupting traffic	42
	Transition towards sustainable mobility system (19)	Negative impact on multi-modal mobility system, including both transit and active walking modes (May et al., 2020)	62
	Environmental efficiency (20)	Negative environmental impact, with AVs running unoccupied, contributing to increase in single vehicle miles travelled (VMT), congestion, noise, emissions, and car dependency, undermining transition towards sustainable mobility system (May et al., 2020; Milakis and Müller, 2021)	56
	Privacy (21)	Negative impact on road users' personal privacy due to continuous collection of data about surrounding environments and road users by AV sensors without consent (Bloom et al., 2017), engendering civil rights of e.g., people seeking abortions, if data is shared with law enforcement agencies	31
	Economy (22)	Negative impact on economy, replacing human labor in transportation industry (e.g., taxi and ride-hailing industry) by artificial intelligence (AI) (Federspiel et al., 2023)	25
	Social equity (23)	Negative impact on social equity, contributing to further marginalization of already disadvantaged communities associated with undermining transition towards sustainable transport modes (May et al., 2020; Milakis et al., 2018)	8
	Liveability of cities (24)	Negative impact on city planning, including allocation of public space and resources, promoting car-centric infrastructure over alternative transportation modes	12
	Humanity (25)	AVs as embodiment of artificial intelligence (AI) representing threat to human existence (Federspiel et al., 2023)	4
Governance and regulation (4)	Responsibility and liability (26)	Low responsibility of stakeholders involved in manufacture, deployment, and regulation of AVs, involving principles of accountability (i.e., explain wrongdoing of AVs), and legal liability (i.e., responsibility to financially compensate for wrongdoing of AVs) (Papadimitriou et al., 2022)	46
	Procedural injustice (27)	Limited involvement of local residents and community in decision-making processes of AV deployment, with respondents mentioning lack of informed consent, and sharing of AV testing and development data, recognition of unjust procedures, and bias of decision-makers being influenced by industry interests, leading to deprioritizing of public good (Reitz et al., 2022; Vuichard et al., 2022)	96
	Distributive injustice (28)	Unequal distribution of costs and benefits, with respondents mentioning lack of financial compensation for being unwanted test subjects in 'public experiment' involving testing AVs on public roads, and AV operators profiting from deployment (Reitz et al., 2022)	40
	Lack regulatory framework and safety standards (29)	Lack of regulatory framework and safety standards for indirect consequences of AV deployment, involving limits on AV fleet size	45

(8), vehicle characteristics (8), indirect consequences of system use (9), and governance and regulation (4). Each sub-theme was represented by quotes, as shown in the subsequent section. In total, we identified 1065 quotes, of which 370 quotes represented individual characteristics, 202 represented vehicle characteristics, 254 quotes represented indirect consequences of use, and 192 quotes represented the main theme 'governance and regulation'. 47 miscellaneous quotes could not be assigned to any sub-theme, and were thus omitted from the analysis.

Based on these themes, and using the framework from (Lapointe and Rivard, 2005) as reference model, we developed a conceptual framework explaining resistance by factors pertaining to the individual, the vehicle, the direct and indirect consequences of use, reactions of others, and external events, as presented in Fig. 3. The direct consequences of use are based on direct experiences with the AV, sharing space with them and interacting with them in traffic, while the indirect consequences refer to the longer-term implications or effects that result from a larger-scale deployment of AVs on public roads. The theme 'reaction of others' captures the reactions of stakeholders involved in manufacturing, regulating, and deploying AVs. External events refer to events related to the AV implementation or deployment process. The results will be discussed in the subsequent sections.

3.2. Individual characteristics

This main theme 'individual characteristics' captures several sub-themes. Respondents mentioned their vulnerability in traffic (e.g., *"I am a bicyclist, pedestrian, and voter in San Francisco, and I find these driverless cars terrifying for many reasons"*, R198), and use of sustainable transport modes (e.g., *"As a resident of San Francisco who rides transit and walks everywhere, I strongly oppose the use and expansion of autonomous vehicles here"*, R240).

Anecdotes and personal experiences involving negative encounters with AVs were reported (e.g., *"I have personally witnessed Waymo and Cruise cars back up traffic in situations that normal cars would have been able to navigate with ease"*, R11).

Respondents also expressed a concern for the environment (e.g., *"AVs do not actually solve any problem related to the climate crisis – they just exacerbate the problems by adding more VMT, at a time when the climate is warming seemingly exponentially. AVs are not the answer"*, R231), and a negative attitude towards AVs, and the fared deployment of AVs in SF (e.g., *"I strongly oppose the expansion of AVs in SF"*, R246).

The fear of the unknown was a common theme expressed by respondents (e.g., *"It appears that no environmental study was conducted on the direct and indirect impacts of these vehicles"*, R300). Respondents reported low perceived safety and feelings of discomfort when interacting with AVs (e.g., *"I'm opposed of AV operations in San Francisco because it leaves citizens of the city to feel uncomfortable and unsafe having these vehicles operate on the road"*, R06).

The driverless operation of the AV contributed to a perceived lack of control to influence the vehicle's operation (e.g., *"I have personally witnessed a driverless autonomous vehicle drive directly into the middle of a road construction zone. It is terrifying that there is nothing anyone could do in that situation except hope that the vehicle stops"*, R225).

3.3. Vehicle

The vehicle characteristics include the perceived incompetent, and unpredictable vehicle behavior, with AVs violating traffic rules, blocking traffic, not explicitly engaging in communicating with other road users, and causing conflict situations. Respondents described the vehicle as incompetent, being incapable to meet the complexity in the road environment (e.g., *"Oppose. AVs are unable to handle the real-world conditions of the roads. While company owners and engineers might call these 'edge cases', they are situations that happen every day"*, R233). The unpredictable vehicle behavior was associated with the erratic, and unhuman behavior of the AV, behaving in unexpected ways (e.g., *"These AVs have displayed erratic maneuvers across San Francisco that are not in line with how a human driver would typically behave. This unpredictability poses a significant safety hazard"*, R272).

Other respondents questioned the effectiveness of AVs in meeting today's transportation-related challenges (e.g., *"This will not solve our transportation problems. It's unclear to me what need they even address"*, R236).

Another sub-theme pertained to the inaccessible vehicle design pertaining to the entire travel journey, such as ordering the vehicle via smartphone app, entering the vehicle, getting buckled on, exiting the vehicle, and assisting passengers with carrying items to the apartment (e.g., *"As a senior, I could not use one because there would be no one to assist me into and out of the car and ensure that I was safely buckled in"*, R228). Unwanted actions capture the AV violating traffic rules, blocking other traffic, such as emergency responders (e.g., *"I am strongly against "self-driving" cars. I've witnessed these cars stop in the middle lane of Hyde Street on a green light as ambulances are trying to pass"*, R160).

AVs were reported to cause conflict situations with other road users, causing near misses or collisions, resulting in evasive maneuvers by other road users, or an unsafe proximity with other road users (e.g., *"I was taking a walk at night with my partner and an AV did not slow down when we were crossing in front of it. We moved quickly out of the way to avoid getting hit. This threat to safety is unacceptable"*, R248). Due to the absence of a human operator in AVs, respondents also mentioned the lack of explicit communication (e.g., eye contact, hand gestures, verbal communication) between AVs and them as road users, making it difficult for road users to safely and efficiently interact with them (e.g., *"I am a blind individual who works in SF. I am concerned that a poorly controlled autonomous vehicle may collide with me and my guide dog while I cross a street"*, R183).

3.4. Indirect consequences of use

This main theme captured the indirect negative consequences of the deployment of AVs for traffic safety, flow efficiency, transition towards sustainable mobility, environmental efficiency, privacy, economy, social

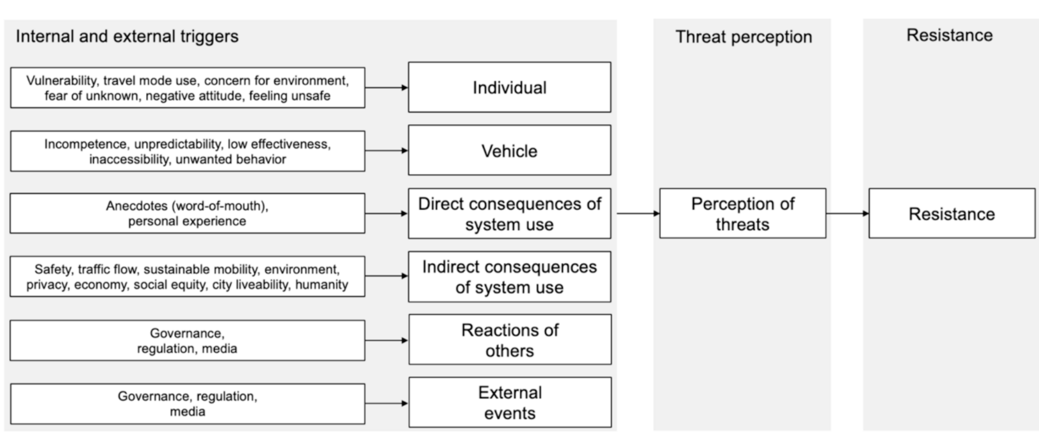

Fig. 3. Conceptual framework for resistance towards AVs.

equity, livability of cities, and humanity. AVs were considered as risky, unsafe, or dangerous. The threat to public safety was associated with the AV's unwanted vehicle actions, and unpredictable and incompetent vehicle behavior, as described in the previous section (e.g., *"Strongly opposed. AVs are a significant threat to my safety. Their odd behavior (sudden, persistent stops) makes other vehicles move more erratically"*, R175).

The deployment of AVs contributed to a perceived negative effect on traffic flow efficiency, with respondents mentioning that AVs contributed to congestion due to a larger number of vehicles on the road disrupting traffic by adverse vehicle behavior (e.g., *"Oppose; Cruise and Waymo AVs are causing havoc in our streets. Multiple times a day they stop randomly and block traffic. Often, they interfere with both transit and emergency services"*, R242).

Another indirect negative consequence of AV deployment that we identified in this study captures the transition towards a more sustainable, multi-modal mobility system, including both transit and active walking modes (e.g., *"I want to see less money invested in self-driving cars and more towards public transit. That needs more support and attention to make it accessible and safer for residents to use"*, R181). Respondents expected a negative impact on environmental efficiency, mentioning that they observed incidences of AVs running unoccupied, contributing to an increase in single vehicle miles travelled (VMT), congestion, noise, emissions, and car dependency, undermining the transition towards more sustainable mobility (e.g., *"Most self-driving cars I see are empty. This is just releasing more emissions into our already damaged environment"*, R160).

AVs continuously collected data about their surrounding environments and road users within these environments without the road users' consent (e.g., *"It makes me very uneasy to have dozens of driverless vehicles equipped with cameras recording and using images. There is no way to escape them if one does not wish to consent to their image being recorded and exploited"*, R188). Consequently, respondents were concerned about the invasion of their privacy, and the engendering of civil rights, of e.g., people seeking abortions, if the data is shared with law enforcement agencies (e.g., *"The Sacramento police department has forwarded surveillance data to states which could prosecute those seeking an abortion. A city-wide, moving network observing and analyzing everything that happens outdoors is something out of a dystopian movie, not a democratic society"*, R273).

Another sub-theme addressed the expected negative impact on the economy, replacing human labor in the transportation industry by artificial intelligence (AI) (e.g., *"Cruise and Waymo are a disaster for workers and safety. This is a labor and safety issue that we all need to be concerned about as AI makes more and more of us dispensable"*, R159).

Respondents feared a negative impact on social equity (e.g., *"I am concerned about their impact on public transportation, the decrease of services which disproportionally impacts already marginalized populations"*, R03), and the livability of cities (e.g., *"I am opposed to this. This forces us to build cities car sized instead of people sized, making it inherently unwalkable"*, R237).

Respondents expected a negative impact of AVs on humanity, considering AVs as a threat to human existence. This sub-theme also includes the comments of respondents who mentioned the lack interaction with humans (e.g., *"We humans need to preserve and foster social interaction. The use of robot taxis goes against natural human instincts and is an attack on the human spirit. Our leaders must defend the human spirit. The world needs more humanism"*, R28).

3.5. Governance

This sub-theme 'responsibility and liability' addressed the perceived low responsibility of stakeholders involved in the manufacture, deployment, and regulation of AVs given a lack of accountability, and legal liability. Accountability refers to the principle to explain wrong behavior of AVs (e.g., *"A driverless car will just hit me and keep going and there's nothing anyone can do, including holding the company accountable"*, R176). Legal liability refers to the responsibility to financially compensate for the behavior of AVs (e.g., *"Who will bear the responsibility, when a driverless vehicle breaks the law or causes injury or death to someone in our city?"*, R164).

The sub-theme 'procedural justice' includes aspects pertaining to a limited involvement of local residents and community in the decision-making processes to deploy AVs on public roads, including the lack of informed consent (e.g., *"These vehicles are being foisted on the people of SF without their consent. I hope the CPUC will enact more local participation and democratic engagement"*, R154). Respondents mentioned the lack of data sharing by the AV companies (e.g., *"I demand that AV companies share unredacted incident data. The lack of transparency is alarming"*, R268), and unjust procedures addressing the unequal treatment of AVs in comparison to conventional vehicles (e.g., *"There is no punishment for an AV killing someone. An innocent civilian death is just accepted with no real consequences. When someone has an accident, there are consequences. None of those exist for an AV"*, R280). Furthermore, key local decision makers would be biased, being influenced by AV manufacturers (e.g., *"The fact that John Reynolds was part of this decision demonstrates corruption and influence peddling of the highest order"*, R246).

This sub-theme 'distributive justice' addressed the perceived unjust distribution of costs and benefits (e.g., *"They are yet another technological pipe dream that will make few companies rich while using real life San Franciscans as guinea pigs"*, R19), and a lack of financial compensation for being unwanted test subjects in an experiment on public roads (e.g., *"San Franciscans were literally put into harm's way to do so. Those San Franciscans will receive zero compensation – those profits will stay with the car companies"*, R241).

4. Discussion

The main objective of the present was to examine the resistance of Californian residents towards the fared deployment of AVs in SF. Informed by the results of the data analysis and previous literature, a conceptual framework was proposed, which has the main objective to explain resistance towards AVs. This framework represents the themes that we identified in the current study, proposing relationships between these themes. The independent variables in our framework are individual and vehicle characteristics as well as the direct and indirect consequences of use, reaction of others, and external events.

Individual characteristics included the vulnerability of road users in traffic, use of sustainable travel modes, concern for the environment, negative attitude towards AVs / AI and the fared deployment of AVs, and perceived safety when interacting with AVs in traffic. In a previous study (Nordhoff et al., submitted for publication), the vulnerability of road users was associated with perceived safety risks, and the uncertainty about the ability of the AV to recognize and respond to road users. Use of sustainable travel modes and concern for the environment might be indicative for pro-environmental attitudes and behavior, which may explain why those individuals resist AVs, with AVs not being perceived as environmentally-friendly transport. In (Ju and Kim, 2022), concern for the environment indirectly influenced resistance towards EVs.

We also identified vehicle characteristics explaining respondents' resistance towards AVs. The behavior of AVs was considered unpredictable, erratic, unexpected, and unhuman-like, with AVs violating traffic rules, and causing conflict situations with other road users. In the study of (Schwall et al., 2020), contact events between AVs and other road users did not result in severe or life-threatening injuries, with the AVs being capable of avoiding collisions. Collisions in which AVs were involved mostly resulted from the interactions with human drivers. The public may have unrealistic expectations about the safety of AVs, expecting higher safety from an AV than from a human-controlled vehicle (Shariff et al., 2021). The discussion of what constitutes acceptable safety as embodied by questions, such as 'How safe is safe enough?', 'Safe enough for what?', or 'Safe enough for whom?' is ongoing (Cohen et al., 2020; Liu et al., 2019; Shariff et al., 2021; Stilgoe, 2021). The expected positive safety benefits are more likely to be achieved with an increase in the level of automation, cooperation, and penetration rate (Milakis et al., 2015).

Respondents reported that AVs blocked other traffic, including emergency vehicles, stopping for unexpected reasons, and contributing to an increase in congestion. If AVs impair the operation of emergency vehicles, it can have severe life-and death implications for the drivers of these emergency vehicles, and other road users. In the study of (Liu et al., 2023); 82 % of first responders did not receive AV-related safety training, 41 % of respondents had little knowledge about AVs, and 44 % did not trust AVs. Experiencing traffic disruptions and delays through AVs might be a strong reason for road users to resist AVs.

Respondents feared the indirect, negative consequences of AV deployment on traffic safety, flow efficiency, environmental efficiency, social equity, economy, livability of cities, and humanity. The "fear of the unknown" is a common reason for individuals to resist technology (Joshi, 2005). Without a full-scale implementation of AVs integrated into our current transport system, it may not be possible to estimate the impact of AVs on these dimensions (May et al., 2020). It is expected that vehicle automation will have a positive impact on safety, travel time, highway and intersection capacity, fuel efficiency, and emissions, and a negative effect on vehicle miles travelled (Milakis and Müller, 2021). However, most of the studies assessing the (safety) impacts were conducted in simulated environments rather than in naturalistic driving conditions (Tafidis et al., 2022).

The not-in-my-backyard-theory incorporates a proximity hypothesis, which postulates that the closer residents are to the unwanted technology, the more likely their opposition towards the technology (Dear, 1992). The not-in-my-backyard-theory may also apply with regards to the AVs' implications on respondents' privacy, and the wider societal implications, contributing to respondents' resistance towards AVs. AVs constantly captured audio and video data of road users, encompassing demographic information (e.g., driver's license, real-time location, travel behavior), and non-verbal communication (e.g., body movements) (Khan et al., 2023). Privacy concerns were a delimiting factor for the acceptance and use of AVs (Zmud et al., 2016). (Bloom et al., 2017) revealed that respondents' discomfort was highest for the most privacy invasive scenarios involving AVs (vehicle tracking), and lowest for the least privacy invasive scenarios (image capture). To alleviate concerns, locals could be educated about the potential benefits of the large-scale data collection and analysis (e.g., finding of Silver Alert citizens) (Bloom et al., 2017), and be given the possibility to 'opt out' of the analysis of their data. Respondents also mentioned the lack of democratic participation and engagement in providing informed consent for trialing AVs on public roads, manifesting a perceived sense of procedural injustice. Respondents also mentioned the unequal distribution of benefits and risks, reporting a lack of financial compensation for participating in an unwanted experiment involving the trial of AVs on public roads, and an increase in net wealth of the AV companies. Future research should examine to what extent more engagement and participation (e.g., war gaming methodology, citizen juries) can alleviate these concerns, and promote understanding and knowledge through negotiation and compromise (Birhane et al., 2022; Fraade-Blanar and Weast, 2023). The fear of negative effects on the economy could be addressed by implementing processes, procedures, cultures, and values ensuring ethical behavior in supporting workers in the transition (Winfield and Jirotka, 2018).

Unresolved accountability and legal liability issues and a lack of transparency in terms of data sharing were other reasons explaining resistance. Clarifying the responsibilities and roles of stakeholders involved in the deployment of AVs, especially in the case of accidents, having legislation in place, and promoting transparency about the data collection by AVs mayring, and incidences involving AVs could mitigate the occurrence of resistance (Liu et al., 2020).

4.1. Limitations and implications for future research

First, the data represents the subjective perceptions of respondents. Thus, we could not objectively verify to what extent the subjective perceptions of respondents reflect respondents' actual experience.

Second, comments represent the main source of data in this study. Future research should apply method triangulation, including the collection of observations, self-reported data from both interviews or focus groups, and behavioral and physiological data collected from sensors deployed on respondents.

Third, the comments that were subjected to the present analysis were publicly available, meaning that later comments may have been influenced by previous comments. Future research is needed to assess the extent to which the themes identified in this study can be generalized to other (bystander) groups and local communities.

Fourth, the availability of respondents' socio-demographic information was limited. Building on the study findings of (MacInnis et al., 2023) who showed that resistance towards EV was associated with respondents' political orientation, age, and education, we recommend future research to gather more information about the impact of respondents' personal characteristics on the resistance towards AVs.

CRediT authorship contribution statement

S. Nordhoff: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trip.2024.101117.

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