Impact assessment of governance models on the integration of connected and autonomous vehicles

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Abstract. The development of Connected and Autonomous Vehicles (CAVs), with vehicle-to-everything (V2X) communication technologies, has catalyzed the digital transformation of the vehicle and infrastructure automation industry. These advancements aim, among others, to benefit users by reducing traffic congestion and emissions, enhancing safety, providing comfortable travel, and saving fuel costs. Society's approval of the aforementioned implementations, as well as the expected impact of Connected, Cooperative, and Automated Mobility (CCAM) on traffic performance, are still, however, areas with limited exploration. Although many studies have investigated the influence of CAVs on traffic congestion, there exists a lack of governance policies and regulations related to the uptake of CCAM. To fill this gap, we review the regulatory frameworks already implemented in Europe and we investigate through a stated preference survey important aspects related to the barriers of using CAVs. Finally, we analyze the results of the surveys resulting in a well-educated selection of targeted actions that can increase the uptake of CAVs throughout Europe.

Keywords: Connected Autonomous Vehicles (CAVs), Governance, Policy, CCAM, vehicle-to-everything (V2X).

1 Introduction and Background

The current requirements for frequent and driverless travel, combined with the evolution of technology, have led to the development of vehicle automation on a European level. The European Union (EU) estimates that the replacement of Conventional Vehicles (CVs) by Autonomous Vehicles (AVs) will occur within the following decades. Conversely, issues concerning the legal framework and road infrastructure have yet to be resolved [1].

The objective of this study is to review the existing advantages and barriers of adopting this new technology and to determine how the EU intends to resolve them. Finally, using a stated choice survey, we analyze and conclude the key factors influencing the European citizen's opinions and explore strategies to enhance automation adoption, mitigating its barriers.

The Society of Automotive Engineers (SAE) has categorized automated vehicles into six progressive levels based on their degree of automation feasibility: Level 0: No

automation; Level 1: Hands-on - Driver assistance; Level 2: Hands-off - Partial automation; Level 3: Eyes off - Conditional automation; Level 4: Mind off - High automation; and Level 5: Steering wheel optional - Full automation [2], [3].

Autonomous driving offers numerous advantages, including improved safety by countering impulsive driver decisions [4], reduced driver stress with vehicle software handling transportation [5], increased parking availability, and better living conditions due to reduced commuting [6]. Furthermore, it promotes electric vehicle adoption, lowering carbon emissions [7]. Integrating autonomous vehicles brings challenges like ambiguity over infrastructure, legal framework, and ethics, including concerns about personal data leaks [8]. There is a need for tailored decision-making and unchangeable AV algorithms to prevent cyberattacks [6]. Global collision legislation gaps make determining liability for operators or manufacturers challenging [5]. Economic hurdles include high costs, job shifts, and the potential rise of ridesharing and pay-as-you-go transport models [7].

In Europe, the ongoing debate revolves around creating new tech-specific laws or revising existing ones [9]. Key goals are consumer protection and promoting innovation [10]. Integrating tech into legal frameworks necessitates international changes [9]. Despite rapid tech advancement, the EU aims to establish common rules, posing legislative challenges. Countries like Denmark, the US, and South Korea have created legal frameworks for automated driving, focusing on ethics and guidelines [11].

The European Commission plans an EU-wide platform for testing autonomous vehicles in various transport modes, emphasizing data protection and accident responsibility [12] [13]. Regarding ethics, the EU AI guideline is under development, emphasizing respecting human dignity and freedom of choice [3]. Balancing data protection with operational needs poses challenges in autonomy, information, and surveillance privacy [8]. In traditional vehicles, drivers are primarily liable for accidents, except for cases involving defects where manufacturers can be held accountable if drivers are unaware of the defect [14] [15]. Highly automated vehicles shift liability to software, involving manufacturers, software engineers, or road designers if they significantly influence vehicle movement [14]. There is ambiguity about whether automation fits within existing legal frameworks, and whether vehicle software is considered a service or product.

To enhance road safety, Europe needs harmonized traffic rules and innovative infrastructure, given unmanned vehicles sharing roads with others [3]. The European Commission introduced a 2016 Strategy for Cooperative Intelligent Transport Systems (C-ITS) to align EU investments and regulations, enabling effective information sharing among road users and traffic management [1].

In Germany, plans are underway for daily automated six-seat SUV trips in Darmstadt and Offenbach using electric AVs equipped with cameras and sensors, managed by German Railways' Loki and Clevershuttle subsidiaries [16]. However, legislative challenges persist due to the absence of proper European autonomous driving frameworks. The German Ministry of Transport emphasizes the need for a framework allowing typical AV operation in specific areas [17].

In the Netherlands, the Future Bus had its debut on public roads in 2016 with a backup driver for oncoming traffic intervention, expected to become a standard public

transport mode [18] [19]. The Netherlands also prioritizes automating commercial and delivery vehicles for economic gains [20].

Lastly, the UK funded pilot projects since 2015 and introduced its first autonomous bus in Cambridge in 2021, underlining the ongoing need for government intervention due to regulatory gaps [21]. Regarding insurance, legislation from 2018 makes it compulsory for AVs, covering third-party compensation and usually the driver [9]. Vehicle owners bear responsibility for uninsured AVs [22].

2 Data collection, Results and Analysis

To assess European citizens' views on adopting highly automated vehicles in their daily lives, we conducted a Stated Preference (SP) survey [23] including 171 participants [24]. The survey, developed collaboratively with partners across Europe, was translated and distributed in four languages: English, Greek, Spanish, and German.

In addition to the SP survey, the questionnaire gathered sociodemographic data, everyday mobility patterns, and insights into respondents' knowledge and perceptions of autonomous vehicles. Topics covered included satisfaction with transportation options, adequacy of local public transport, primary modes of transport, and trip purposes. Questions related to autonomous vehicles explored safety, trust in driving scenarios, economic considerations, and data privacy awareness. The SP survey assessed five key parameters: affordability, passenger safety, data privacy protection, road infrastructure, and legislative frameworks for Connected and Autonomous Vehicles (CAVs). Respondents indicated their preference for Autonomous Vehicles when one parameter was negative and the other four were positive. Four distinct "Yes" or "No" questions were posed to each respondent, with no constraints on their responses.

Below, we present the socio-demographic profile and key findings on respondent mobility. This data underlies the understanding of factors impacting autonomous vehicle acceptance and sample-specific patterns. Notably, the online survey features diverse respondent categories (**Table 1**): around 60% employees, 25% university students, and 10% self-employed. The gender split: 53% female, 45% male, and 2% diverse. The age distribution is balanced, with 85% of university students or employees; few under 25 or over 56. Respondents represent ten countries: Belgium, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, Slovenia, Spain, and UK.

Table 1. Sociodemographic information

Sociodemographic	Responses, N=171					
Gender	*Male*	*Female*	*Diverse*			
	45%	53%	2%			
Age	*18-25*	*26-35*	*36-45*	*46-55*	*56-65*	*>65*
	22%	40%	14%	16%	7%	1%
Professional status	*University student*	*Employee*	*Self-employed*	*Unemployed*	*Retired*	
	25%	60%	10%	4%	2%	

Monthly Income	*<1000€*	*1000-1500€*	*1500-2500€*	*2500-3500€*	*3500-5000€*	*>5000€*
	36%	26%	18%	11%	6%	2%

Regarding respondent mobility (**Table 2**), satisfaction with available transport modes is mostly high, with a slight shift towards total satisfaction. However, public transport adequacy in their neighborhoods shows dissatisfaction, with 14% finding it completely inadequate and 30% rather inadequate. Concerning travel purposes, 46% primarily travel for work, 17% for entertainment, 12% for education, and 12% for family duties. Their main transport modes include 35% using public transport, 31% driving, and 6% as passengers. Additionally, 20% walk and 5% cycle.

Additionally, respondents were questioned about their knowledge and perception of autonomous driving. 47% claimed ignorance, while just 6% had complete knowledge. Only 58% had not driven an automated vehicle. Concerning autonomous vehicle safety, responses skewed towards agreement that they are safer than conventional ones. Furthermore, 46% were willing to use driverless public transport, while 41% expressed potential interest.

Table 2. Mobility behavior information of the respondents

Mobility behavior	Responses, N=171					
	1= totally dissatisfied	*2*	*3*	*4*	*5=totally satisfied*	
Satisfaction with transport modes	4%	19%	40%	29%	8%	
Adequacy of PT service	14%	30%	27%	21%	7%	
Main transport mode	*Vehicle as driver*	*Vehicle as passenger*	*Public urban transport*	*Motorcycle*	*Bicycle*	*On foot*
	31%	6%	35%	4%	5%	20%
Main trip purpose	*Work*	*Education*	*Entertainment*	*Leisure trip*	*Shopping*	*Family duties*
	46%	12%	17%	4%	7%	12%

Moreover, respondents were asked about trust in autonomous vehicle operation in city centers and on highways (**Table 3**). Highways garnered more trust compared to city centers. Economic affordability is key, with 51% saying it must be accessible to all, and 22% saying it should be. Two other factors considered for AV preference were data privacy and user familiarity. Additionally, 76% knew of autonomous public transport in European countries.

Table 3. Preference for Autonomous Vehicles

Autonomous vehicle Preference	Responses, N=171				
	1= absolutely not	*2*	*3*	*4*	*5= absolutely yes*
Driving in a city center	9%	30%	27%	27%	7%

Driving on a highway	11%	19%	28%	35%	7%
Economically accessible to all	5%	5%	16%	22%	51%
Data privacy issues	18%	13%	30%	27%	12%
Ignorance of AVs	15%	15%	30%	22%	9%

As mentioned earlier, the stated preference experiment assessed five factors influencing autonomous vehicle adoption: affordability, safety, data privacy, road infrastructure, and legislative framework for CAVs. For each, a scenario with one unfavorable aspect and four positives was presented. Results are summarized in **Table 4**.

Table 4. Preference on choosing an Autonomous Vehicle considering different factors.

Would you prefer an Autonomous Vehicle when:	the vehicle is financially affordable?	there is an adequate legislative framework?	there is sufficient road infrastructure?	the car industry guarantees for the safety of its passengers?	the protection of data privacy is ensured?
The vehicle is not financially affordable, but	-	**51%**	**55%**	**60%**	**53%**
The legislative framework is insufficient, but	**64%**	-	**55%**	**51%**	**60%**
There is no road infrastructure, but	**76%**	**68%**	-	**61%**	**71%**
The car industry does not guarantee for the safety of its passengers, but	**85%**	**80%**	**81%**	-	**84%**
The protection of data privacy is not ensured, but	**51%**	**53%**	**51%**	**57%**	-

Note: percentages associated with a higher "Yes" proportion are highlighted in green.

The table above reveals safety as the primary factor influencing European citizens' preference for autonomous vehicles. Over 80% would not choose one unless it is guaranteed safe, and 85% would not even if it is economically affordable. Road infrastructure is the second most important factor, with preferences ranging from 61% (with passenger safety guaranteed) to 76% (with affordability). Adequate legislation is crucial, with 64% avoiding AVs, even with reasonable prices, and 60% being cautious despite data privacy guarantees. Data privacy has mixed effects; 55% would abstain even with good road infrastructure, and 51% would do so even if passenger safety is assured. On the other hand, data privacy protection varies: 57% prefer AVs for safety even at the expense of data privacy. However, 53% resist even with sufficient legislation. Economic accessibility matters least; 60% would choose AVs if safe, 55% with good infrastructure, and 51% with strong legislation. Nonetheless, 53% would not choose AVs even with data protection.

3 Conclusions and future research

This paper aims to uncover the benefits and challenges of implementing connected and autonomous vehicles (CAVs) and explore the EU's mitigation strategies. We examined legislative frameworks, with a focus on European cases. Five key factors affecting CAV acceptance emerged: passenger safety, road infrastructure, data privacy, legislation, and affordability. To assess the governance models' impact on CAV integration and understand adoption factors, we conducted preference surveys focusing on the five CAV utilization obstacles. We then analyzed survey results, emphasizing on sample socio-demographics, daily mobility, and attitudes toward these influencing factors. Survey participants prioritize passenger safety as the most crucial aspect when considering autonomous vehicles. Governments should also focus on road infrastructure sufficiency and robust legislative frameworks for accidents or data privacy issues. Economic affordability, while important, is a consideration for most citizens, who believe CAVs should be accessible to everyone.

Based on our literature review and SP survey findings on CAV regulatory frameworks and influencing factors, we suggest the following research directions:

- Develop a binary logit model to quantify each influencing factor's impact on CAV acceptance.
- Enhance sample socio-demographics with vehicle ownership and trip mode data.
- Conduct cross-country or regional comparisons of the results.

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