Fleet and traffic management systems
for conducting future cooperative mobility

D2.4 Specification and initial version of the enhanced governance models

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1 EXECUTIVE SUMMARY

Expanding on the primary objective of the CONDUCTOR project, focusing on the design, integration, and demonstration of advanced traffic and fleet management solutions for the efficient and optimal transportation of both passengers and goods, this deliverable focuses on the pivotal role of governance and regulation in the adoption of CCAM services. Based on Task 2.6, this deliverable introduces the considerations required for the development of enhanced governance models, tailored to modern transportation needs. It underlines areas of intervention, with emphasis on cooperative, connected and autonomous vehicles, shared/on-demand mobility, MaaS platforms, and infrastructure management. Through stakeholder consultations and existing standards, as well as through the review of literature, the deliverable offers an impact assessment and proposes the development of governance models that align with the current landscape of research, national- and EU regulations, and industry best practices.

To address the prevailing gaps in governance and regulatory frameworks for CCAM services, as well as traffic and fleet management, this deliverable outlines a comprehensive approach with several objectives. Existing advantages and barriers of CCAM services are extensively reviewed, with a specific emphasis on determining the EU's strategic approaches to these issues. Additionally, we examine the regulatory architecture already in place within Europe. Drawing insights from these reviews and stakeholder consultations, passenger safety, road infrastructure, data privacy, legislative frameworks and affordability are pinpointed as specific domains necessitating targeted interventions. Central to our analysis is the execution of a stated preference survey which aims to analyse the main barriers preventing CAV adoption. Synthesizing the outcomes of this survey, the predominant factors shaping European citizens' perspectives are presented, thereby shaping informed strategies to amplify CAV adoption while addressing inherent challenges.

The findings were then considered within the perspective of a transport authority, namely the Athens Urban Transport Organisation (OASA), who in parallel also assessed the following objective: The formulation towards governance models for public-private collaboration models of traffic and fleet management.

A game-theoretic-based regulatory model was constructed, examining how public and private entities collaborate and compete in traffic management, highlighting the multi-objective balance between cooperative efforts and individualistic strategies rooted in real-world scenarios. The model was validated on the well-established Braess network. Upon inspection of the trade-off between objective values, and in consideration of different toll values, it was demonstrated that in the case of the collaboration between information service providers and authorities, an intricate balance necessitates governance, particularly in consideration of dynamic traffic scenarios. This highlights the need for the harmonisation of the diverse interests of multiple parties. Capturing two players in the upper level of the bi-level formulation within the test example, the model serves as a foundation for the in-practice real-world situation of coordinating between multiple parties of interest.

Lastly, an analysis regarding the interrelations between governance, policies and business models was conducted, concluding the specifications and considerations required behind an initial version of an enhanced governance model. It was found that the relationship between governance, business models, and policies is intricate and constantly evolving. Strong governance underpins robust business models and effective policies. With rapid change, stakeholder alignment needs, and the push for sustainability and social responsibility, this landscape increases in inherent complexity. Success is based on adaptability, stakeholder engagement, and a proactive approach to governance, strategy, and policymaking.

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

2 INTRODUCTION

2.1 Background

The development of Connected and Autonomous Vehicles (CAVs) with vehicle-to-everything (V2X) communication technologies has catalysed 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 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.

The current requirements for frequent and driverless travel, combined with the evolution of technology, have led to the development of higher 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 Society of Automotive Engineers (SAE) has categorized automation into six progressive levels based on their degree of 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]. The attractiveness of automated driving is supported by its plethora of benefits, including enhanced safety [4], reduced driver stress [5] increased parking availability, improved living conditions [6], and additional support for lowering carbon emissions [7]. Challenges however remain, particularly prevalent in terms of data privacy concerns [8], ambiguous liability [5], and economic shifts, including job reallocations and potential ridesharing surges [7]. The debate is centred on crafting and/or revising legislation [9], but the overarching objectives remain to ensure consumer protection and promote innovation [10], necessitating international legal adaptations [9].

The H2020-funded GECKO project [11] set out to tackle and further the debate by guiding authorities in the development of the appropriate regulatory frameworks and governance models for the transition to a new era of cooperative, sustainable, and interconnected mobility across all modes, grounded in evidence-based research. The empirical findings of this project built a foundation of existing standards that CONDUCTOR intends to further research. The developments will be fostered by investigating effective cooperation and governance models for operating CCAM services, designed as part of a real-world developed and tested fleet and traffic management systems. This deliverable sets out to provide and detail the specifications and considerations required to present an initial version of enhanced governance models given existing literature and stakeholder consultations, fulfilling a multitude of management levels including strategic, tactical, and operational, as well as communication and engagement. The means to achieve this are outlined in the following section.

2.2 Objectives

To extend beyond the current landscape of governance and regulatory frameworks and bridge the existing research and regulatory deficit, the following objectives have been outlined:

- Review the existing advantages and barriers of CCAM services and determine how the EU intends to resolve them.
- Review the regulatory frameworks already implemented in Europe.
- Define areas of intervention as a result of the review and stakeholder consultations.
- Conduct an impact assessment by investigating through a stated preference survey important aspects related to the barriers to using CAVs.
- Analyse the results of the impact assessment and identify the key factors influencing the European citizens' opinions, resulting in a well-educated selection of targeted actions and strategies that can increase the uptake of CAVs throughout Europe, mitigating its barriers.
- Formulate possible governance and public-private collaboration models for traffic and fleet management considering existing standards, national and EU regulations, and best practices.
- Evaluation of findings from the perspective of a transport authority.
- Analysis of the link between governance, policies, and business models.

In the subsequent chapters of this deliverable, the stated objectives are addressed through a comprehensive review of existing research and case studies, laying the foundation for modelling a suitable framework. First, a literature review on the governance and regulation of CCAM services was conducted, inspiring the design and execution of an impact assessment through the use of a stated preference experiment, of which its results were analysed, outlining key areas of intervention. Developments on collaborative traffic and fleet management governance and regulation were then evaluated to construct a game-theory-based regulatory formulation. The model examined how public and private entities collaborate and compete in traffic management, highlighting the multi-objective balance between cooperative efforts and individualistic strategies rooted in real-world scenarios. The findings and recommendations of the two individual chapters on CCAM and traffic and fleet management were both reviewed from the perspective of a public transport authority. The deliverable lastly concludes with an analysis linking governance, policies, and business models.

3 GOVERNANCE AND REGULATION OF CCAM SERVICES

3.1 Literature Review

To determine and identify the necessary areas of intervention for the support of CCAM adoption, the regulatory frameworks implemented throughout Europe have been reviewed, as well as the existing advantages and barriers of the services, determining how the EU intends to resolve them.

Highly automated driving promises multiple benefits. Notably, it enhances safety by efficiently countering spontaneous in-person driver decisions [4]. Driver stress is reduced since the vehicle's software takes full responsibility for the transportation [5]. Moreover, the frequent commute and reduction of dead time increases the availability of parking spaces, improving living conditions [6]. Additionally, as concluded by the University of Kentucky's SWOT analysis of their "Self Driving Car" project, automation supports the adoption of electric vehicle technology, reducing carbon emissions [7].

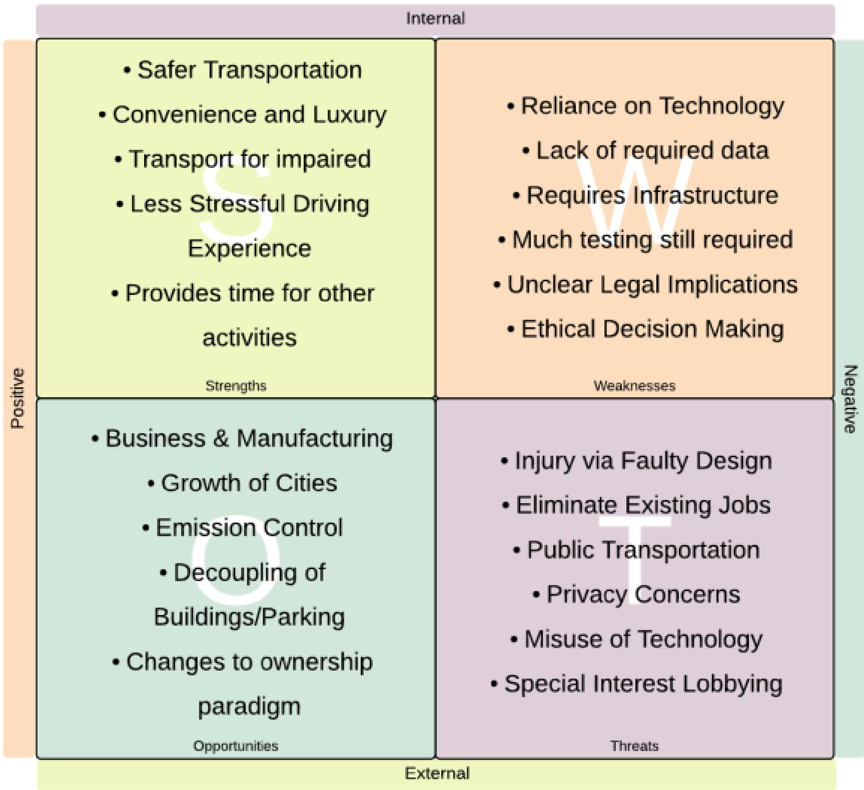

Figure 1 SWOT analysis for Autonomous Motor Vehicles [7]

The integration of autonomous vehicles within society, however, presents challenges, particularly due to the ambiguity within concerns over infrastructure, legal framework, and ethics. This notably includes the risk of personal data leaks [8], the need for effective decision-making unique to each case, and the immutability of the AV's algorithms, necessary to prevent malicious reprogramming, such as cyber-attacks [6]. Globally there is also a lack of specific legislation in the event of a collision, necessary for regulating liability to either the operator or manufacturer where appropriate [5].

Economic challenges are also posed, encompassing high purchasing and maintenance costs, and personnel redistribution, with certain jobs declining or being fully eliminated while others flourish. All of which may lead to the uptake of ridesharing and pay-as-you-go transportation models [7].

Generally, there exists an ongoing debate on whether to create new technology-specific legislation or to revise existing laws [9]. Regardless, the following two goals remain: consumer protection and innovation promotion [10]. Inevitably, incorporating new technology within legal frameworks entails a series of international developments and changes [9].

At the same time as technology has developed rapidly in recent years, the EU aims to establish common rules. However, this poses many challenges in terms of the legislative framework. Some countries such as Denmark, the US, and South Korea have made attempts to formulate a legal framework for highly automated driving, primarily focusing however on ethical codes and conduct guidelines [12].

The European Commission has announced plans to establish a unified platform across the EU, involving relevant public and private stakeholders to coordinate autonomous vehicle testing on open roads, [13] covering means of maritime and air transport as well. This initiative emphasizes the requirement for a code of conduct on data protection, as well as responsibility in the event of an accident [14].

Regarding ethical issues, since the EU guideline on AI is currently under development, there is no precise positioning except that the autonomous vehicle should respect human dignity and freedom of choice [3]. Balancing data protection, with the vehicle's need for information for effective operations, poses a specific challenge, divided into three sub-areas: autonomy, information, and surveillance privacy interests [8].

Accident liability for conventional vehicles typically lies entirely on the driver [15], except for cases involving a vehicle defect, where action can be taken against the manufacturer, provided the driver was unaware of the defect that caused the accident [16]. In highly automated vehicles, which in contrast do not require constant driver control, the dynamics in liability changes, with responsibility shifting to the software, more specifically, the vehicle manufacturer, software engineer, or road designer, if deemed to play a significant role in the AVs' movement [15]. An important question arises about whether automation falls under the existing legal framework, as it is unclear whether vehicle software is considered a service or a product.

For road safety, European harmonization of traffic rules and infrastructure innovation is considered crucial as unmanned vehicles will share the same roads as CVs, cyclists, and pedestrians [3]. In 2016, the European Commission (EC) introduced a European Strategy for Cooperative Intelligent Transport Systems (C-ITS) to align investments and regulations across the European Union (EU). C-ITS allow road users and traffic management to effectively coordinate and share information [1].

In Greece according to Law 4266/2014 (Law 4266/2014 - Government Gazette 4266/A/10-6-2014 - AUTOMOBILES, 2014) "every moving vehicle [...] must have a driver", requiring "the necessary physical and mental capacity [...] appropriate physical and mental condition" (par. 3) [17]. These present obstacles to the adoption of AVs in the country. However, the Ministry of Infrastructure and Transport has voted in Law 4313/2014 (Government Gazette 261/A/17-12-2014) where "the urban bus is allowed to move along a road without the presence of a driver", only valid for research trials [18]. This exception requires approval from the local city council and traffic authority. The route and duration of the experimental AV operation should be specified and determined through a traffic study, according to Article 52 of Law 2696/1999 (A' 57) [18]. Thus, from the 1st of September 2015 to the 29th of February 2016, a pilot route of a driverless autonomous bus was carried out on the streets of the city of Trikala, through the European project CityMobil2 [19].

In Germany, there are plans for daily trips using automated six-seat SUVs in the cities of Darmstadt and Offenbach. The AVs will be electric and equipped with special cameras and sensors. The transport planning and coordination will be handled by the German Railways' subsidiaries Loki and Clevershuttle [20]. Legislative obstacles however persist, due to the absence of proper European legal frameworks for autonomous driving. The German Ministry of Transport emphasizes the need for a framework that should "allow the typical operation of autonomous, driverless motor vehicles on public roads, geographically limited to a defined environment" [21].

In the Netherlands, the Future Bus made its first journey on Dutch public roads in 2016. As per Dutch traffic rules, a backup driver was present inside the AV, with intervention only required in case of oncoming traffic [22]. This mode of passenger transportation is anticipated to become a standard means of public transport in the country [23]. The Netherlands is also focusing on automating commercial and delivery vehicles, aiming for greater economic benefits [24].

Lastly, the UK has funded pilot projects since 2015. In 2021, the first autonomous bus was introduced in Cambridge, running on public roads near the University. Again, the need for government action persists due to the lack of relevant regulations, ensuring the seamless integration of AVs into citizens' daily lives [25]. Regarding insurance and compensation, legislation enacted in 2018 mandates compulsory insurance for AVs. This insurance covers third parties' compensation as well as for the insured party, typically the driver [9]. In cases where the vehicle is uninsured, the owner assumes responsibility [26].

3.2 Impact Assessment and Outcomes

3.2.1 Areas of Intervention

To formulate the appropriate governance models and policy instruments necessary to support CCAM services and their adoption throughout Europe, relevant areas of intervention were defined, in alignment with the conclusions drawn from the literature review. The emerged five key factors affecting Connected and Autonomous Vehicles (CAVs) acceptance are as follows:

- Passenger safety
- Road infrastructure
- Data privacy protection
- Legislative framework
- AV Affordability

To assess European citizens' views on adopting highly automated vehicles in their daily lives in relation to the outlined areas of intervention, we conducted a Stated Preference (SP) survey experiment [27], gathering 191 participants [28] at this point in time. The survey was developed collaboratively with CONDUCTOR partners across Europe and was created and distributed online in four different languages: English, Greek, Spanish, and German. The areas of intervention were assessed through respondents of the survey across European countries, including the following ten countries: Belgium, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, Slovenia, Spain, and the UK.

The questionnaire of the SP survey 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 existing infrastructure, safety, trust in driving scenarios, economic considerations, and data privacy awareness.

In the following sections, the contents and findings of the described impact assessment are further detailed.

3.2.2 Impact Assessment

The SP survey assessed the areas of intervention through the research of the following five key parameters: affordability, passenger safety, data privacy protection, road infrastructure, and legislative framework for Connected and Autonomous Vehicles. Respondents indicated their preference for autonomous vehicles when one parameter was negative and the other four were positive. Four distinct questions, with "Yes" or "No" answers, were posed to each respondent, with no constraints on their responses.

Below, we present the socio-demographic profile and key findings on respondent mobility behaviour. The data underlies the understanding of factors impacting autonomous vehicle acceptance and sample-specific patterns. Notably, the online survey features diverse respondent categories (Table 1): approximately 57% are employees, 29% are university students, and 9% are self-employed. Gender was split between 52% female, 47% male, and 2% diverse.

The age distribution is concentrated within the below 36 age bracket, where overall around 86% of respondents consist of either university students or employees; fewer participants were over 46.

Table 1: Sociodemographic information

Sociodemographic	Responses, N=171					
Gender	**Male**	**Female**	**Diverse**			
	47%	52%	2%			
Age	**18-25**	**26-35**	**36-45**	**46-55**	**56-65**	**>65**
	27%	38%	13%	14%	6%	1%
Professional status	**University student**	**Employee**	**Self-employed**	**Unemployed**	**Retired**	
	29%	57%	9%	3%	2%	
Monthly Income	**<1000€**	**1000-1500€**	**1500-2500€**	**2500-3500€**	**3500-5000€**	**>5000€**
	40%	24%	18%	10%	6%	3%

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 neighbourhoods shows dissatisfaction, with 13% finding it completely inadequate and 33% rather inadequate. Concerning trip purposes, 45% primarily travel for work, 19% for entertainment, 13% for education, and another 11% for family duties. Their main transport modes include 34% using public transport, 31% driving a car, and 6% travelling as passengers. Additionally, 19% walk and 5% cycle.

Additionally, respondents were questioned about their knowledge and perception of autonomous vehicles. 46% claimed ignorance, while just 6% had excellent knowledge. 57% of respondents were found to not have driven a vehicle with automation elements. Concerning the safety of autonomous vehicles, responses skewed towards agreement that, in general, driving an AV is safer than a conventional vehicle. Furthermore, 46% were willing to use driverless public transport, while 42% expressed potential interest.

Table 2: Mobility behaviour information of the respondents

Mobility behaviour	Responses, N=171					
Preference	**1= totally dissatisfied**	**2**	**3**	**4**	**5=totally satisfied**	
Satisfaction with transport modes	4%	19%	41%	29%	7%	
Adequacy of PT service	13%	33%	27%	20%	7%	
Main transport mode	**Vehicle as driver**	**Vehicle as passenger**	**Public urban transport**	**Motorcycle**	**Bicycle**	**On foot**
	31%	6%	34%	4%	5%	19%
Main trip purpose	**Work**	**Education**	**Entertainment**	**Leisure trip**	**Shopping**	**Family duties**
	45%	13%	19%	4%	7%	11%

Moreover, respondents were asked about their trust in autonomous vehicle operation in city centres and on highways (Table 3). Highways garnered more trust compared to city centres. Economic affordability is a key factor, with 47% saying it must be accessible to all, and 23% saying it should be. Two other factors considered for AV preference were data privacy and user familiarity. Additionally, 74% knew of autonomous public transport already being used in European countries.

Table 3: Preference for Autonomous Vehicles

Autonomous vehicle	Responses, N=171				
Preference	**1= absolutely not**	**2**	**3**	**4**	**5= absolutely yes**
Driving in a city centre	10%	30%	29%	25%	6%

Driving on a highway	12%	17%	29%	35%	6%
Economically accessible to all	6%	6%	18%	23%	47%
Data privacy issues	17%	14%	30%	26%	13%
Ignorance of AVs	23%	16%	30%	23%	9%

As mentioned earlier, the stated preference experiment assessed five factors influencing autonomous vehicle adoption: AV affordability, passenger safety, data privacy protection, road infrastructure, and legislative framework for CAVs. Each factor was presented with a scenario of one unfavourable aspect, and four remaining favourable aspects. The results are summarized in Table 4, below.

Table 4: Preference for 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	-	52%	55%	62%	51%
The legislative framework is insufficient, but	64%	-	56%	53%	61%
There is no road infrastructure, but	75%	67%	-	60%	70%
The car industry does not guarantee for the safety of its passengers, but	83%	79%	80%	-	82%
The protection of data privacy is not ensured, but	52%	54%	53%	54%	-

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

The above table reveals passenger safety as the primary factor influencing a European citizen's preference for choosing autonomous vehicles. Over 79% would not choose one unless it is guaranteed as safe by the car industry. 83% would similarly choose against an AV, even if it were economically affordable. Road infrastructure is the second most important factor, with preferences ranging from 60% (with passenger safety guaranteed) to 75% (with affordability). Adequate legislation is crucial, with 64% avoiding AVs, even with reasonable prices, and 61% being cautious despite data privacy protection guarantees. Furthermore, 56% would abstain from selecting an AV even when road infrastructure is deemed sufficient, and 53% would do so even if passenger safety is assured. On the other hand, data privacy protection varies: 54% prefer AVs for safety, even at the expense of data privacy. However, 54% resist even in the case of sufficient legislative framework. Economic accessibility matters least; 62% would choose AVs if they are considered safe, 55% with good infrastructure, and 52% with strong legislation. Nonetheless, 51% would not choose AVs, despite the assurance of data protection.

3.2.3 Outcomes

To uncover the benefits and challenges of implementing connected and autonomous vehicles and explore the EU's mitigation strategies, we examined legislative frameworks and regulations, with a focus on European cases. Five key factors affecting CAV acceptance emerged: passenger safety, road infrastructure, data privacy protection, legislation, and affordability.

To assess the governance models' impact on CAV integration and understand adoption factors, we conducted stated preference surveys focusing on the five CAV utilization barriers. We then analysed the survey results, emphasizing sample socio-demographics, daily mobility behaviour, 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 the literature review and SP survey findings on CAV regulatory frameworks and influencing factors, we suggest the following future 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.

In light of the investigation, the aforementioned binary logit model, based on the calculated coefficients of a utility function used to capture the influencing factors of the surveyed user preferences, will be used to support the development of a governance model. The logit model will as a result calculate the probability of CAV uptake and acceptance.

3.3 Considerations within the perspective of a transport authority (OASA)

CCAM services can be integrated within the public transport system to provide an efficient mode of transportation by offering high-quality service, safety of passengers, and reduced operating costs for Public Transport Operators [29]. In Europe, two large EU-funded demonstration projects, namely SHOW [30] and ULTIMO [31], support the deployment of shared and connected automation in urban transport to promote sustainable mobility.

SHOW, in particular, addresses real-life demonstrations of automated mobility in 20 European cities in terms of automated mixed passenger/cargo mobility under complex and environmental conditions, with added value services for cooperative and connected mobility [32]. To achieve this, a fleet of more than 70 SAE L4/L5 AVs of all types (where L4 corresponds to High Driving Automation and L5 to Full Driving Automation, according to the 6 levels of vehicle autonomy defined by the Society of Automotive Engineers – SAE), was deployed for both passenger and cargo transport in dedicated lanes and mixed traffic [30]. The ULTIMO project meanwhile is more specifically oriented on enhancing public transport by deploying an economically viable large-scale, on-demand, and passenger-oriented automated vehicle service. This is showcased through a fleet of automated shuttles with intelligent services for improving urban-rural mobility, a feeder service line fully integrated with other traffic in a suburban environment and an on-demand electric service to passengers connecting different facilities within a certain estate that mainly includes various hospital units [31].

The factor of safety is a key element in the adoption of autonomous vehicles. It is of paramount importance that technologies are extensively tested before implementing CCAM in the urban environment, as the safety of passengers is the most important consideration for operators and authorities responsible for planning and providing public transport services.

Following the findings of the literature review, the legal framework of CCAM adoption poses another challenge in its implementation by authorities and public transport operators. At present in Greece, the deployment of a highly automated service can be considered for research trials only, and the lack of a legislative framework constitutes a major obstacle in adopting automated vehicles and integrating them within the public transport service.

CCAM can be a viable alternative to car ownership and run complementary to the “conventional” public transport service on various occasions within the urban and peri-urban environment. However, the cost of funding such projects can pose as an impediment to public transport authorities. Although operating costs can be reduced in the long term by the efficient and optimised utilisation of the automated fleet, the capital cost of the investment might be prohibitive at this stage.

4 GOVERNANCE FOR TRAFFIC AND FLEET MANAGEMENT

4.1 Towards governance models for collaborative traffic and fleet management

4.1.1 Background

Advances in information and communication technologies, along with new business entrants, have changed the state of practice in traffic and fleet management. Traditionally, public road authorities mainly used roadside sensors, such as inductive loop detectors, to obtain information about the state of traffic. More recently, private parties in particular (for e.g., Google, TomTom, Waze) have started to collect real-time information using GPS technologies (see, e.g. [33]). Oftentimes, these private parties also offer information services to their users (including both road users as well as logistics service providers), either through a description of the network state or in terms of advice on the best possible route or mode alternative, based on individual and or trip characteristics. Where public parties generally used roadside systems, such as Variable Message Signs, to manage traffic on the road, the services provided by private parties have, at least theoretically, supplemented the pool of measures available to improve traffic flow and network performance.

New opportunities, and even new business models, emerge within the field through the variety of services and information collection systems [34]. This may require some form of cooperation and/or coordination, to prevent deployed management measures having unintended or even counterproductive effects, as they are often decided upon independently from other players. The level of cooperation can vary from sharing information about intentions to a joint effort with pooled resources, including data, aligned objectives, and the orchestrated or harmonized deployment of services. In the European SOCRATES2.0 project, these levels of cooperation were summarised in three collaboration models: exchange data, shared view, and coordinated approach [34].

Recently, several CCAM-based collaboration initiatives with new use cases have emerged. For example, in the Netherlands, local road authorities and traffic navigation providers exchange data. This allows for the use of GPS-based information to possess a better picture of the current and near-future traffic conditions, while the private party can offer a new service to its users. Heavy-duty vehicles or trucks can be detected for signal control purposes without passing over an induction loop. At the same time, the drivers can obtain near-future predictions on the traffic signal status or may even be granted priority over other traffic. Many of the initiatives, however, are ad-hoc collaborations between different transport authorities since sustained collaboration on the level of 'coordinated approach' may be difficult to establish in practice, due to conflicting views and goals between and among public and private parties [35-38]. Road authorities, for instance, are mainly concerned with performance within their region or subnetwork, not the whole network per se [39, 40], while information service providers mainly aim for accurate information for their users. A lack of collaboration may lead to conflicting advice, with for example roadside systems suggesting a path to users that differs from the one advised by a navigation device, or a shift or introduction rather than mitigation of traffic-related issues if traffic from freeways is diverted onto urban roads [35].

In general, the benefit of collaboration cannot always be expressed in terms of a direct improvement in the objective function in the short term (the *win-win* situation) and may also be of a strategic nature, e.g., if new services can be offered [41]. With the transition from the public authority, solely responsible for traffic management, towards a multi-stakeholders' perspective on traffic management, where incidental non-selfish behaviour is key to making collaboration initiatives a success, challenges regarding governance appear: how should the decision-making be organized, and how should the efforts, benefits and costs be distributed to assure that traffic management-related challenges are addressed, while individual parties remain committed? Although such governance models or arrangements are out of reach in this chapter, we address the potential of collaboration initiatives between different types of parties as a first indication of to which degree the individual goals can be protected under collaboration.

4.1.2 Modelling framework

We explore the potential of collaboration initiatives, specifically in the context of traffic management. Therefore, we adopt a game-theoretic framework to capture the strategic interactions between the actors involved in traffic management, including users' route choices as a result of the deployed services. This approach provides us with initial evidence regarding the impact of public-private collaboration on the objective values and goals of each actor. This relates to a multi-level hierarchical structure, with the interactions between public and private service providers represented in the upper level(s), and the response of users in the lower level. We use concepts from cooperative and non-cooperative game theory to model the outcome of the interactions and particularly consider two ends of the spectrum on this matter. The 'ideal' situation may be modelled as a cooperative game where parties collaborate to optimize the objectives of each partner, while the current situation is hypothesized to be closer to a non-cooperative (Nash) game where actors aim to optimize their own objective function. In a real-world setting, there may be a mix of parties cooperating and competing, e.g., with parties cooperating within a coalition but competing against other (groups of) parties outside the coalition [42].

Game-theoretic models have frequently been used to model the interactions between different actors involved in traffic and mobility management [33,37-40,43,44]. In our setting, we consider both competition and cooperation between public and private parties for traffic management using a one-shot game, specifically focusing on (public) road authorities and private information service providers, under the assumption that there is full information about other parties' optimization problems, including the objective function and the parameters, although this does not hold true in practice (so-called game with imperfect information – see [45]).

One of the main challenges in this context is the a priori assessment of benefits. Such an assessment provides an indication of the potential value of joining a partnership. However, even for relatively simplified non-cooperative settings, the 'stable' decisions of the upper-level players, according to a Nash equilibrium, may not exist [46]. In the case that a 'solution' to such a game exists, it is difficult to formulate tractable (dual) optimality conditions [47], similar to the well-known Karush-Kuhn-Tucker conditions for nonlinear programs in the presence of a constraint qualification. Authors therefore often resort to heuristic methods to find good or stable outcomes of such games. The quality of these methods is difficult to assess without the conditions of optimality, which would also pave the way for exact numerical algorithms. In the remainder of this chapter, we sketch the complexity of decision-making in traffic management within a context with multiple service providers.

4.1.3 Problem formulation and notations

We capture the interactions between public and private parties, and road users, in a hierarchical game. In this game, (public) road authorities and (private) information or mobility service providers are the 'leaders' or upper-level players, while the road users are represented by a lower-level player (see [48] for more information). The upper-level players have a temporal advantage over the follower in the sense that they decide first, resulting in the route choices of the road users (within a static traffic assignment context) occurring in response to the measures deployed by the leaders. Yet, the upper-level players anticipate, and can even perfectly predict in this case, the response of the follower, i.e., they play a so-called Stackelberg game. In our setting, we assume that there is no hierarchical dependence among the upper-level players, although in practice it may very well be the case that one party has a certain degree of power over another player. Each actor wishes to optimize its own objective(s). For example, road authorities are typically interested in (sub)network performance within their own jurisdictional boundaries [39,40], expressed using objective functions related to economic efficiency, GHG emissions, air pollution, safety etc. An authority can deploy various measures (e.g., traffic information through variable message signs, change in signal timings), but direct- and personalized communication with road users in a dynamic manner is assumed to occur through private information service providers. Such private parties typically have objectives related to business performance, e.g., maximize revenues [33], but also wish to provide a high level of service to their users, i.e., route users onto fast and comfortable paths [34]. Road users are indeed often interested in their own travel time but may also be willing to act 'socially' [49], i.e., take system-beneficial detours as long as the additional travel time remains within bounds (further discussed in CONDUCTOR Deliverable 3.2 "Specification and initial version of techniques for dynamic optimization and network load-balancing"). In our setting, a certain degree of coordination with road authorities is required to find these socially desired routes. Under the social behaviour of a portion of the travellers, cooperation between information providers and public parties can be of strategic interest for all actors. Information providers can offer a new service (e.g., eco-friendly routes) and thereby further tailor the routing service to the needs of the users [50].

We model the strategic interactions between the actors involved in traffic management using a multi-leader single-follower game. The game has K upper-level players, and we assume for the sake of simplicity that each upper-level player $i \in \{1,2,\ldots,K\}$ has only a single objective g^i to minimize. The actor can therefore use a strategy y^i from its set of *admissible strategies* $Y^i \subseteq R^{m^i}$ (see also [47]) e.g., related to the minimum and maximum allowed tolls. The objective value of each actor g^i depends on the actor's strategy y^i, but also on the decisions of all the other players, denoted by $y^{-i} := (y^1, y^2, \ldots, y^{i-1}, y^i, \ldots, y^K\}$ and the *response* of the road users, expressed by a static traffic assignment, denoted by a pair of vectors (f, x) (to be introduced below).

The response of the road users, conditional on the decisions of all upper-level actors denoted by $\bar{y}$, is modelled according to a bounded rational user equilibrium flow distribution [51]. In our context, this intuitively means that (some of) the road users are willing to take a small detour of at most ε (say, minutes) compared to the fastest path due to the benefit of collaboration between the upper-level actors. We assume that such behaviour can only be induced when the traffic navigation application (of the private party) advises them to do so. This could mean, for example, that they take an 'eco-friendly route', as is also offered by modern traffic navigation devices. We assume that public parties can only set tolls on their network as a measure to control traffic.

A directed graph $G = (V, E)$ is given, where V is the set of nodes and E is the set of edges. Additionally, a set of origin-destination (OD) pairs $\mathcal{K} \subseteq V \times V$ is provided with static demands $d_k > 0$, $k \in \mathcal{K}$. Each OD pair k is connected through a set of simple directed paths, P_k. The set P of all paths in the network is captured as the union of the path sets per commodity: $P = \bigcup_{k\in\mathcal{K}} P_k$. The set of feasible traffic flows F for given demand vector d consists of all the pairs of vectors $(f, x) \in \mathbb{R}^{|P|} \times \mathbb{R}^{|E|} = (f_p, p \in P; x_e, e \in E)$so that $\Lambda f = d, x = \Delta f$, and $f \geq 0$, with Λ the OD-path incidence matrix and Δ the link-path incidence matrix. Each link $e \in E$ in the network has a flow-dependent travel time or cost function $l_e(x)$.

For modelling purposes, we distinguish public (subset I) and private parties (subset J, with $I \cup J = \{1, \ldots, K\}$). As mentioned, public parties can only set tolls, while private parties aim to route their users onto acceptable paths. We denote the resulting link tolls as $\tau_e = \sum_{i\in I} y_e^i$, and consider a setting with only one navigation provider J, where the strategy $y^J \in \mathbb{R}^{|P|}$ satisfies $0 \leq y^J \leq \varepsilon$ [52]. Then, under natural assumptions regarding the link cost functions, (f, x) is an (ε-) bounded rational user equilibrium (conditional on the link tolls $\bar{\tau}$) if and only if (f, x)solves the following optimization problem $Q(\bar{y})$:

$$\min z_0(x) + \tau^T x + \overline{y^J}^T f \qquad s.t. \quad (f, x) \in F \qquad (1)$$

Note that in $Q(\bar{y})$, the decisions of the upper-level players appear as parameters. If we denote by $S(y)$ the multi-function that maps to each upper-level decision y the solutions (f, x) to $Q(y)$, then under a full information scenario, the optimization problem for each (non-cooperative) actor i becomes:

$$\min_{y^i \in Y^i} g^i(y^i, \bar{y}^{-i}, f, x) \quad s.t. \quad (f, x) \in S(y^i, \bar{y}^{-i}) \qquad (2)$$

A solution $\bar{y}$ to the Nash game between all the leaders playing a Stackelberg game with the follower is such that for each upper-level player i, $\bar{y}^i$ is a solution to the above mathematical program with equilibrium constraints. One should note, however, that such a solution does not necessarily exist [46,47] and that under non-uniqueness of the response (f, x) it is unclear which response the follower may exhibit [53]. In a grand coalition, upper-level players join forces resulting in a multi-objective optimization problem with equilibrium constraint, i.e.,

$$\min_{y^i \in Y^i, i=1,\dots,K} G(y, f, x) = (g^1(y, f, x), \dots, g^K(y, f, x)) \qquad s.t. \quad (f, x) \in S(y) \qquad (3)$$

In this case, Pareto solutions can be considered optimal in the sense that none of the objective values can be improved without hurting at least one other player.

4.1.4 Example

We study the potential of public-private collaboration through an example using the well-known Braess network. Figure 2 shows the network under consideration, where edges are labelled with their associated travel cost functions. We assume that there exist six units of flow travelling from O to D. Travelers can choose route 1 (O, V, D), route 2 (O, W, D) or route 3 (O, V, W, D) to reach their destination. We assume that the travel cost along a route is the sum of the travel costs of the edges that constitute that route. There are heterogeneous actors in this network: a road authority (upper-level player 1) has control over toll τ on the vertical edge, while the routing engine of an information service provider (player 2) routes users onto fast paths. The maximum toll is assumed to be six.

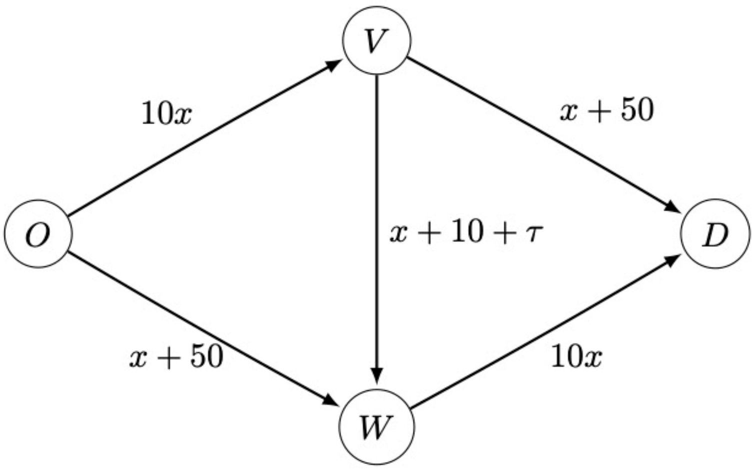

Figure 2 Braess network

The objective of the road authority is to minimize the toll, as well as the average or total travel time, all combined into one objective function $g^1(y, f, x) \coloneqq \sum_{e \in E} x_e \cdot l_e(x_e) + \frac{1}{2}\tau$. The information service provider's routing engine aims to route users onto the shortest path but might be considering offering a system-beneficial route to its users as long as this path is acceptable i.e., the detour is bounded from above by $\epsilon = 7$. However, the weighted total detour, expressed by the objective function $g^2(y, f, x) \coloneqq \sum_{p \in P} y_p^2 f_p$, is aimed to be minimized since travellers might need to be nudged towards this route, and users can only be expected to incidentally take a non-shortest route.

Without collaboration, the stable outcome of the game played at the upper level is considered to be in Nash equilibrium. Independent of the toll imposed by the road authority, the service provider routes its users onto the shortest path, leading to a Wardrop or user equilibrium in the lower level. Without any toll $\tau = 0$, the demand is then equally distributed among the three routes, with an average travel time of 92. In system optimum, the average travel time is 83. However, such a system optimum requires - without cooperation - a toll of at least 13. The resulting Nash equilibrium among the upper-level players leads to a stable outcome, in which the toll will be maximized, i.e., $\bar{\tau} = 6$, with an accompanying authority's objective value of 90.8.

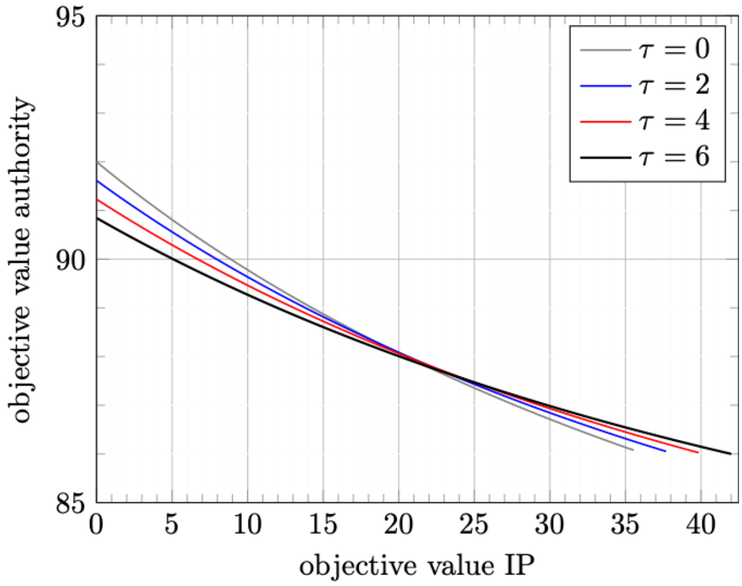

Figure 3 Trade-off objective values

We assume that travellers can be nudged to take a detour for the benefit of the road authority's objective value. This detour should, however, remain within certain bounds when compared to the shortest path. When cooperating, the aim is to minimise the vector of objectives $G(y, f, x) = \left(g^1(y, f, x), g^2(y, f, x)\right)$. This leads to a trade-off between the objective of the information provider and the road authority, illustrated in Figure 3 for different toll values τ. We observe that an increase in the objective value for the information provider (IP) leads to an improvement in the objective value of the authority. However, there is a whole range of Pareto-optimal solutions, i.e., a curve for which the objective value of one actor can only improve at the cost of the objective value of another player. In this case, setting the optimal toll is only possible if the effort of the information providers is known. In this example, only two upper-level players are considered, while in practice a multitude of parties are commonly found to play such a game. In any case, governance is required to balance the interests of the heterogeneous actors and to orchestrate measures, particularly if a similar curve appears in the context of real-time traffic management and decisions need to be taken under time pressure.

4.2 Considerations within the perspective of a transport authority (OASA)

The multimodal transport networks of cities are often operated and managed by various actors which in many cases act separately, intended to optimize their individual operations and achieve their distinct behavioural and business objectives. To add to the case identified in this chapter between road authorities and private information service providers, public transport authorities are also key stakeholders in the urban transport ecosystems, particularly in the consideration for collaboration initiatives to improve fleet management. The latter bear the responsibility for the planning, coordination and management of public transport fleets, but do not necessarily have any jurisdiction in the management of road traffic on the network.

Although road traffic management mainly involves the exchange of information between road authorities and service providers, as identified in paragraph 4.1.1, the collaboration of public transport authorities with private entities (for e.g. Google) can improve the overall performance of the transportation network. Transport agencies provide static data on public transport timetables to the service providers, which in turn offer advice on mode alternatives to their users. Moreover, public authorities like TfL have also identified opportunities for improving overall mobility by exchanging real-time information on bus arrivals and freely releasing data via an API for developers to use in their own software and services [54].

The need for coordination between various stakeholders to provide network and integrated traffic management strategies, taking into account new types of transport (namely automated vehicles), is addressed by the ongoing European Frontier Project [55]. The main objective was to develop an autonomous management system that would constantly involve using data generated for real-time monitoring of the transportation system and knowledge by operators and decision-makers. The developed system has been tested in Oxfordshire, Athens, and Antwerp. The conflicting objectives of stakeholders are addressed by a set of predefined response plans that are willing to be adopted to optimize network performance.

In light of the aforementioned, the modelling framework proposed in section 4.1.2 is a key step in capturing the conflicting objectives between the various public and private entities involved in traffic management and can provide a base for promoting further collaboration and interaction between transport authorities and third parties.

5 GOVERNANCE, POLICIES AND BUSINESS MODELS

5.1 Background

In exploring the domain of Cooperative, Connected, and Automated Mobility (CCAM), it becomes apparent that there is a complex interplay between governance, business models, and policies/regulations. This chapter seeks to investigate this relationship, acknowledging that while the interconnection of these elements is widely recognized, the extent and nature of their impact on one another, as well as on the CCAM landscape, are not yet fully understood, and our current grasp of them is still developing. The rapid evolution of CCAM technologies and their potential to transform transportation systems worldwide presents a compelling case for examining how governance frameworks, business models, and regulatory policies interact. This investigation is particularly pertinent as it may reveal insights into how these elements can better align to support the responsible development and deployment of CCAM technologies.

The fast-paced advancements in CCAM technology often move ahead of the existing governance and policy structures, presenting a unique challenge: how can governance and policy not only catch up but also effectively guide the development of sustainable business models in this sector? Conversely, how do emerging business models in CCAM influence and shape governance and policy decisions? These questions are critical in navigating the nascent yet rapidly evolving CCAM field. CONDUCTOR partners aim to contribute to the ongoing discourse by piecing together evidence from various sources, recognizing the tentative nature of conclusions in a field marked by continual innovation and change.

With an exploratory mindset, we want to shed light on the interdependencies between governance, business models, and policies in the CCAM context, guided by the understanding that these insights are part of a larger, evolving discussion. The goal is not to provide definitive answers, but to offer a nuanced perspective that can inform further research and policy development in this dynamic and increasingly relevant field.

Definitions

Policies-Regulations: Policies are the set of formal guidelines and rules that govern the actions and decisions within an organization or sector [56,57]. They provide a structured approach to addressing and managing key issues, ensuring consistency and compliance with overarching goals and values. In the CCAM sector, policies play a crucial role in defining the regulatory landscape for automated and connected mobility solutions. They address concerns such as safety standards, data privacy, interoperability, and environmental impact, guiding the development and implementation of CCAM technologies in alignment with societal and ethical norms.

Governance: Governance is the framework of rules, practices, and processes by which an organization or sector is directed and controlled. It encompasses the mechanisms through which various stakeholders articulate their interests, exercise their legal rights, meet their obligations, and mediate their differences. In the context of Cooperative, Connected, and Automated Mobility (CCAM), governance takes on a specific role in shaping how these technologies are developed, managed, and regulated. It involves not only the traditional aspects of regulatory compliance and oversight but also the stewardship of innovation, collaboration across different sectors, and the integration of emerging technologies with existing transportation systems [58].

The GECKO project defined three main categories of governance [57]:

- Hierarchical governance: top-down approach “traditionally” used on a national level, relying on binding rules or procurements.
- Market governance: policy instruments can be used to influence economic variables (competition, pricing, taxes, subsidies) to achieve policy goals. Example: environmental policies to incentivize the use of alternative fuels.
- Network governance: relatively new. Relies on collaboration between relevant stakeholders for the decision-making.

***Business models*:** Business models describe the method by which an organization or sector seeks to create and capture value. This includes strategies for revenue generation, value proposition, customer engagement, and competitive positioning. Within the CCAM sector, business models are particularly dynamic, reflecting the innovative nature of the technology. They encompass a range of approaches from service-based models, like mobility-as-a-service, to product-oriented strategies, focusing on the commercialization of new technologies [59]. Effective business models in CCAM must navigate the complex interplay of rapidly evolving technologies, changing consumer preferences, and a shifting regulatory landscape, all while striving to achieve profitability and sustainability.

5.2 Analysis of the link between governance, policies, and business models

5.2.1 Commonalities between governance, business models, and policies/regulations

The common attributes between governance, business models, and policies in the CCAM context are:

- Strategic alignment: All three elements are geared towards achieving strategic objectives within an organization or sector. They work in unison to ensure that the organization's goals are met efficiently and effectively.
- Adaptability and responsiveness: Governance structures, business models, and policies/regulations need to be adaptable and responsive to changes in the external environment, including technological advancements, market dynamics, and societal expectations.
- Stakeholder engagement: Each element involves engagement with various stakeholders. Governance structures define how stakeholders interact, policies/regulations set the guidelines for these interactions, and business models determine the value proposition offered to these stakeholders.
- Regulatory compliance: Compliance is a key concern across governance, business models, and policies/regulations. Each must align with legal and ethical standards to ensure lawful and responsible operations.
- Risk management: Managing risk is a central aspect of governance, business models, and policy formulation. These elements collectively contribute to identifying, assessing, and mitigating risks in organizational and sectoral operations.

5.2.2 Differences between governance, business models, and policies/regulations

The diverging aspects between governance, business models, and policies in the CCAM context are:

- Scope and focus: Governance encompasses the overall framework and principles guiding an organization or sector, while business models are focused on the operational and commercial aspects. Policies/regulations are more specific, detailing the rules and guidelines for particular areas of operation.
- Purpose and function: The primary purpose of governance is to establish control and oversight mechanisms, whereas business models are designed to create, deliver, and capture value. Policies/regulations aim to provide clear, actionable directives for specific operational aspects.
- Flexibility and rigidity: Governance structures and business models tend to be more flexible, allowing for adaptation to changing circumstances. In contrast, policies/regulations are often more rigid, providing a stable and predictable framework for operations.
- Creation and implementation: Governance structures are typically created by top management or a governing body with a broad view of the organization or sector. Business models are developed by strategic and operational teams focusing on market opportunities. Policies/regulations are often the result of both internal decision-making and external influences, such as legal requirements.
- Impact and reach: The impact of governance is broad, affecting the entire organization or sector. Business models have a direct impact on the organization's commercial success. Policies/regulations mainly affect operational processes and compliance measures.

5.2.3 Coordination between governance, business models, and policies/regulations

The interrelation between governance, business models, and policies in the CCAM context needs a holistic approach to navigate its complexities. The main pillar of collaboration includes:

Understanding the interplay

The relationship between governance, policies/regulations, and business models is intricate and multifaceted. Governance acts as the structural backbone, guiding and influencing policies and business models within various sectors. For instance, Camilleri and Falk's [60] work on governance highlights the importance of these structures in dictating the direction and control of sectoral activities, including in areas like CCAM.

Governance as the guiding framework

Governance provides the strategic framework that shapes both policies and business models [61, 56]. It encompasses the mechanisms through which stakeholders articulate their interests and exercise their rights, pivotal in sectors undergoing rapid transformation. The complexities of governance in dynamic sectors like CCAM demand a nuanced understanding of how strategic decisions are made and implemented.

Policies: The bridge between governance and business models

Policies, defined as formal guidelines governing actions and decisions, are vital in translating the strategic objectives of governance into practice. They set the parameters for business operations, ensuring regulatory compliance and consistency in decision-making. The SHOW project's exploration of business and operating models in CCAM offers insights into how policy frameworks directly influence and shape business strategies and operational decisions.

Business models: adaptation and response to governance and policies

In response to the established governance and policy frameworks, business models in sectors like CCAM must adapt and evolve. This adaptation is essential for aligning with governance directives and meeting policy requirements. The relationship between corporate governance structures and business practices, as explored in various studies, sheds light on how governance models influence organizational strategies and operations.

A dynamic and cyclical relationship

This interplay is dynamic, with policies informing governance models, which in turn shape the development of policy instruments. This cycle is evident in the implementation of advanced systems like CCAM, where governance, policy, and business model considerations are intertwined, as indicated in the Horizon Europe project HORIZON-CL5-2024-D6-01-09.

The dynamic relationship between governance, policies/regulations, and business models underscores the importance of a holistic approach in sectors like CCAM. Understanding this interplay is crucial for navigating the complexities and guiding strategic developments towards achieving sustainable and efficient outcomes.

5.2.4 Challenges

The exploration of governance, business models, and policies/regulations reveals a landscape rife with challenges, each distinct yet interrelated in the context of organizational and sectoral dynamics.

5.2.4.1 Challenges in Governance

Use Case 1 made evident the challenges that governance faces in adapting to rapid technological development, including:

- **Adapting to rapid change**: One of the foremost challenges in governance is keeping pace with rapid technological advancements and shifting market dynamics [62]. Governance structures must be flexible enough to adapt to these changes while maintaining stability and continuity. This is particularly evident in Use Case 1 (UC1), where cities like Almelo, Athens, and Madrid are implementing advanced intelligent traffic control systems and AI-assisted traffic management strategies, demanding a governance structure that can swiftly adapt to these technological innovations.
- **Balancing diverse stakeholder interests**: Governance involves reconciling the often-competing interests of various stakeholders, including investors, employees, customers, and regulatory bodies [63]. Achieving this balance while ensuring ethical and equitable outcomes is a complex task. In UC1, especially in Madrid's focus on managing events and incidents on the M-30 ring road, effective governance is required to balance the needs of everyday commuters, freight operators, and emergency services.

- **Ensuring transparency and accountability**: In an era where information is abundant and public scrutiny is high, maintaining transparency and accountability in governance processes is both crucial and challenging. This aspect is critical in UC1, where public well-being and safety are paramount, and the deployment of intelligent traffic systems demands transparency in data usage and decision-making processes.

5.2.4.2 Challenges in business models

Business models need to be flexible and adaptable to the market and innovation trends to overcome posing challenges. For this to be achieved, they need to account for:

- **Aligning with market and technological trends**: Business models must constantly evolve to stay aligned with changing consumer preferences and technological innovations. This need for continual adaptation can pose significant challenges, especially in rapidly evolving sectors like CCAM. For example, in UC1 and UC2, adapting business models to incorporate AI in traffic management and demand-responsive transport requires continuous innovation and market alignment.
- **Sustainability and social responsibility**: Integrating sustainability and social responsibility into business models is increasingly important but can be challenging, particularly in balancing profitability with ethical considerations. The Almelo Use Case focus on reducing emissions and improving traffic flow aligns with these sustainability goals.
- **Navigating regulatory landscapes**: Business models often need to be flexible to accommodate changing policies and regulations, which can be a significant challenge, especially in heavily regulated industries. This is a pertinent challenge in UC1, where traffic management solutions must comply with varied and evolving regulatory frameworks in different cities.

5.2.4.3 Challenges in policies/regulations

Developing consistent and applicable policies is challenging. To overcome these problems, they need to consider the following:

- **Keeping pace with innovation**: Policymaking often lags behind technological advancements, creating gaps that can lead to regulatory uncertainties and hinder innovation [64].
- **Global consistency vs. local relevance**: Developing policies that are globally consistent yet locally relevant is a significant challenge, especially in sectors with international reach. This might be particularly relevant in the Slovenian-Italian region from UC2, where cross-border cooperative routing strategies require harmonization of policies across national boundaries.
- **Predicting long-term impacts**: Formulating policies that effectively anticipate and mitigate the long-term impacts of new technologies or market shifts is challenging, given the inherent uncertainties in predicting future trends. In UC1, policies must be forward-looking to accommodate future developments in traffic management and autonomous vehicle integration.

5.3 Concluding Remarks

The interplay between governance, business models, and policies/regulations presents a dynamic but challenging environment. In the context of CCAM, governance, business models, and policies share **common attributes** such as strategic alignment, adaptability, stakeholder engagement, regulatory compliance, and risk management. These elements work together to achieve strategic objectives, adapt to external changes, and ensure efficient and effective stakeholder engagement, where compliance with legal and ethical standards is a key concern.

Nevertheless, they also **differ** in scope, purpose, flexibility, creation, and implementation. Governance is the overall framework, while business models focus on operational and commercial aspects. Policies/regulations provide specific rules for specific areas of operation. Governance structures are more flexible, while business models are designed to create, deliver, and capture value. Governance impacts the entire organization or sector, while business models directly impact commercial success.

The **coordination** between them is complex and multifaceted. Governance acts as the structural backbone, guiding and influencing policies and business models within various sectors. Regulations are the strategic framework that shapes these policies and business models, ensuring regulatory compliance and consistency in decision-making. Business models must adapt and evolve in response to these frameworks, aligning with governance directives and meeting policy requirements. The interplay is dynamic, with policies informing governance models and shaping policy instruments.

Regarding **challenges**, governance must keep pace with technological advancements and shifting market dynamics, while business models must be flexible and adaptable to market and innovation trends. Balancing diverse stakeholder interests is crucial, as is maintaining transparency and accountability. Consistent and applicable policies are also challenging, as they must maintain their pace with innovation, balance global consistency with local relevance, and predict long-term impacts. In summary, the challenges faced by organizations in these areas include adapting to rapid technological advancements, balancing diverse stakeholder interests, ensuring transparency and accountability, and navigating regulatory landscapes.

The key lies in fostering adaptability, promoting stakeholder engagement, and ensuring a forward-looking approach to governance, business strategy, and policymaking.

6 CONCLUSIONS

Centred around the core objective of detailing the specifications behind initial versions of enhanced governance models for the advanced optimization of traffic and fleet management solutions, this deliverable comprehensively consulted existing literature and standards of the current landscape. The urgent necessity and key role of governance and regulation in CCAM services have been emphasized throughout.

Building on the insights from Task 2.6, this deliverable has outlined the necessary requirements for the development of an advanced governance framework, tailored to contemporary transportation demands throughout the multiple chapters. A central focus was addressing the governance gaps in CCAM, and traffic and fleet management, all of which were reviewed from the perspective of a transport authority. First, as a result of thorough stakeholder consultations and existing literature, we extensively reviewed the advantages, barriers, and the EU's strategic stance on CCAM services. The resulting insights from this review led to the identification of key intervention areas, for which a comprehensive impact assessment has been presented through a stated preference survey, highlighting crucial areas for intervention. The resulting analysis concluded the need for a binary logit model, primed for supporting the development of governance, capable of capturing and considering the valuable insights of European citizens' perspectives on CAV adoption, guiding strategies to enhance acceptance.

The second chapter delved into the complexity of public-private collaborations in traffic management. Using a game-theory-based model, the intricate balance between cooperation and individualistic strategies was considered. This was exemplified on the Braess network, emphasizing the critical need for harmonizing interests in various traffic contexts. The multi-player model was formulated for two players in the demonstrations, both of which were represented in the upper level of the bi-level formulation. Whilst the example was tested for two parties, the presented model serves as an expandable foundation for the real-world application of coordinating between multiple parties of interest, especially under the consideration of prospective real-time traffic management.

Within the exploration of the domain of CCAM regulation, the complex interplay between governance, business and policy models becomes increasingly apparent. Thus, an analysis was undertaken by defining key terms within the context of current standards, allowing for the outline of commonalities and differences between the three. The relationship was concluded to be largely dynamic and cyclical, and key challenges were highlighted within each respective field. Governance requires the ensuring of transparency and accountability, balancing stakeholder interests, along with adapting to rapid change. Business models are required to evolve alongside market and technological trends and must navigate the regulatory landscape and bear both sustainable and social responsibilities. Policies and regulations are required to maintain their pace alongside innovation and strike a balance between both global consistency and local relevance, predicting long-term impact. In consideration of the resulting analysis, effective governance is posed as capable of providing the foundation for robust business models and sound policies.

All three chapters established a comprehensive and expansive groundwork, combining specifications and the presentation of the initial version and future work of an enhanced governance model. This deliverable concludes with the summarised undertakings and considerations for the governance of CCAM and traffic and fleet management deployment and innovations, paramount within the scope of CONDUCTOR and its use cases.

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A. APPENDIX: SURVEY ON AUTONOMOUS VEHICLES – GOVERNANCE MODELS AND REGULATIONS

The survey was created in coordination with the CONDUCTOR project's partners across Europe and was distributed in English, Greek, Spanish, and German to companies and institutions involved in EU Horizon projects. The links to the respective surveys are listed below as follows:

English survey:
https://docs.google.com/forms/d/e/1FAIpQLSdSy_fh4OybbnzFms62Uk78MWJU6oMII719tGK2PLfXud50yA/viewform?usp=sf_link

Greek survey:
https://docs.google.com/forms/d/e/1FAIpQLSdSjmV6Fcl_hCp8z96VgGyVRmdznJOpzNZswP-lzFNFgqTZRQ/viewform?usp=sf_link

German survey: https://docs.google.com/forms/d/e/1FAIpQLSdhiZ48bQQ2h8LTXbq8X-OQZBJNXTGhEd8UjJwgdIpeBVfCxg/viewform?usp=sf_link

Spanish survey:
https://docs.google.com/forms/d/e/1FAIpQLSdC83DTotaQMpmE0joNxBnB6tHvMOTcDjiVNfJOBJd8-fFE1g/viewform?usp=sf_link

The English version of the survey is attached below as an additional point of reference.

Survey on Autonomous Vehicles - Governance models and Regulations

* Indicates required question

Fleet and traffic management systems for conducting future cooperative mobility

About the project

This survey is being conducted as part of the CONDUCTOR project, funded by the European Union's Horizon Europe research and innovation programme (Project 101077049).

The CONDUCTOR project's main goal is to **design, integrate and demonstrate advanced, high-level traffic and fleet management that will allow efficient and globally optimal transport of passengers and goods, while ensuring seamless multi-modality and interoperability.** Using innovative dynamic balancing and priority-based management of vehicles (automated and conventional) CONDUCTOR will build upon state-of-the-art fleet and traffic management solutions in the CCAM ecosystem and develop next generation simulation models and tools enabled by machine learning and data fusion, enhancing the capabilities of transport authorities and operators, allowing them to become "conductors" of future mobility networks. **We will upgrade existing technologies to place autonomous vehicles at the centre of future cities, allowing heightened safety and flexible, responsive, centralized control able to conduct traffic and fleets at a high level.** These innovations will lead to less urban traffic and congestion, lowered pollution, and a higher quality of life. Project innovations will be integrated into a common open platform and validated in three Use Cases (UC), testing the interoperability of traffic management systems and integration of different transportation means for both people and goods. UC1 integrates traffic management with inter-modality, UC2 tests demand-response transport, and UC3 urban logistics. In each use case and its demonstrations, simulations will be validated through real life data.

About the survey

This is a survey about the barriers related to the acceptance of connected and autonomous vehicles. The survey is conducted by the National Technical University of Athens (NTUA) and it is part of the CONDUCTOR EU project.

The survey includes 25 questions and it will take approximately 10 minutes to complete.

About your participation

The following survey is public, and is sent to specific individuals identified as potential interested users of Connected and Autonomous Vehicles (CAVs). Please, feel free to distribute this survey to your colleagues, etc. Your participation in this study is fully voluntary and all the collected data will be anonymized and treated confidentially.
The research outputs resulting from this work will only include collated data, without the possibility for anyone to identify individual answers. The survey does not require you to provide any information that could identify you personally (e.g., your name, address, email) except from your country of residence. If, whilst completing the survey, you wish to withdraw, please just close the browser without submitting your answers.

By proceeding with this survey you confirm that you are at least 18 years old, have read and understood the above information, agree to participate in this research study and agree that your responses will be included in our analysis and any research publications resulting from it.

If you have any questions or would like to hear about the results of the survey and/or their usage in the CONDUCTOR project, please contact Emmanouil Nisyrios at emnisyrios@mail.ntua.gr.

Thank you for your participation in this survey.
The CONDUCTOR Project Team

Definition of Autonomous Vehicle

According to Dr. Lance B. Eliot (2017), a vehicle is called autonomous when it can be steered automatically without the need of a driver. This is achieved through the ability to analyze the data it receives from the environment, resulting in prediction and/or decision making.

1. **1. Do you use technological products in your daily life?** *

Mark only one oval.

- ◯ Yes
- ◯ No

2. **2. How satisfied are you with your modes of transportation? Rate from 1 (totally dissatisfied) to 5 (totally satisfied).** *

Mark only one oval.

Totally dissatisfied

1 ◯

2 ◯

3 ◯

4 ◯

5 ◯

Totally satisfied

3. **3. Do you consider the Public Transport services in your neighborhood adequate? Rate from 1 (completely inadequate) to 5 (completely adequate).** *

Mark only one oval.

Completely inadequate

1 ◯

2 ◯

3 ◯

4 ◯

5 ◯

Completely adequate

4. **4. Which is the main *transport mode* in your everyday life? Select at most 2 options.** *

Tick all that apply.

- [ ] Vehicle as driver
- [ ] Vehicle as passenger
- [ ] Public urban transport
- [ ] Motorcycle
- [ ] Bicycle
- [ ] On foot
- [ ] Other: ______________________

5. **5. Which is the main *trip purpose* of your transportation in everyday life? Select at most 2 options.** *

Tick all that apply.

- [ ] Work
- [ ] Education
- [ ] Entertainment
- [ ] Leisure trip
- [ ] Shopping
- [ ] Family duties
- [ ] Other: ______________________

Definition of Autonomous Vehicle

According to Dr. Lance B. Eliot (2017), a vehicle is called autonomous when it can be steered automatically without the need of a driver. This is achieved through the ability to analyze the data it receives from the environment, resulting in prediction and/or decision making.

6. **6. Rate your knowledge about Autonomous Vehicles from 1 (complete ignorance) to 5 (excellent knowledge).** *

Mark only one oval.

Complete ignorance

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Excellent knowledge

7. **7. Have you or a relative of yours ever driven a car with automation elements?** *

Mark only one oval.

⬭ Yes

⬭ No

8. **8. Driving an Autonomous Vehicle is *safer* than a conventional one. Rate from 1 (totally disagree) to 5 (totally agree).** *

Mark only one oval.

Totally disagree

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Totally agree

9. **9. Would you use Public Transport means (Bus, Metro, Tram, etc.) *without* a driver?** *

Mark only one oval.

- Yes
- No
- Maybe

10. **10. Do you trust an Autonomous Vehicle to drive at a *city center*? Rate from 1 (absolutely not) to 5 (absolutely yes).** *

Mark only one oval.

Absolutely Not

1
2
3
4
5

Absolutely Yes

11. **11. Do you trust an Autonomous Vehicle to drive in a *highway*? Rate from 1 (absolutely not) to 5 (absolutely yes).** *

Mark only one oval.

Absolutely Not

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Absolutely Yes

12. **12. Do you believe that an Autonomous Vehicle should be *economically accessible* to all citizens? Rate from 1 (absolutely not) to 5 (absolutely yes).** *

Mark only one oval.

Absolutely Not

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Absolutely Yes

13. **13. Does *ignorance* prevent you from choosing an Autonomous Vehicle for your transportation? Rate from 1 (absolutely not) to 5 (absolutely yes).** *

Mark only one oval.

	Absolutely Not
1	⬭
2	⬭
3	⬭
4	⬭
5	⬭
	Absolutely Yes

14. **14. Will *data privacy issues* affect your preference for an Autonomous Vehicle? Rate from 1 (absolutely not) to 5 (absolutely yes).** *

Mark only one oval.

	Absolutely Not
1	⬭
2	⬭
3	⬭
4	⬭
5	⬭
	Absolutely Yes

15. **15.** Did you know that Autonomous Public Transport modes are already/currently being used in European countries? *

Mark only one oval.

- Yes
- No

Definition of Autonomous Vehicle

According to Dr. Lance B. Eliot (2017), a vehicle is called autonomous when it can be steered automatically without the need of a driver. This is achieved through the ability to analyze the data it receives from the environment, resulting in prediction and/or decision making.

Would you prefer an Autonomous Vehicle when:

16. **16. The vehicle is *not financially affordable*, but** *

Mark only one oval per row.

	Yes	No
the protection of data privacy is ensured		
the car industry guarantees for the safety of its passengers		
there is sufficient road infrastructure		
there is an adequate legislative framework		

17. **17. The legislative framework is *insufficient*, but** *

Mark only one oval per row.

	Yes	No
the vehicle is financially affordable	◯	◯
the car industry guarantees for the safety of its passengers	◯	◯
the protection of data privacy is ensured	◯	◯
there is sufficient road infrastructure	◯	◯

18. **18. There is *no road infrastructure*, but** *

Mark only one oval per row.

	Yes	No
the vehicle is financially affordable	◯	◯
the car industry guarantees for the safety of its passengers	◯	◯
the protection of data privacy is ensured	◯	◯
there is an adequate legislative framework	◯	◯

19. **19. The car industry *does not guarantee for the safety* of its passengers, but** *

Mark only one oval per row.

	Yes	No
the vehicle is financially affordable	◯	◯
there is sufficient road infrastructure	◯	◯
the protection of data privacy is ensured	◯	◯
there is an adequate legislative framework	◯	◯

20. **20. The protection of data privacy is *not ensured*, but** *

Mark only one oval per row.

	Yes	No
the vehicle is financially affordable	◯	◯
there is sufficient road infrastructure	◯	◯
the car industry guarantees for the safety of its passengers	◯	◯
there is an adequate legislative framework	◯	◯

Socio-Demographic Information

B. ABBREVIATIONS AND DEFINITIONS

AI	Artificial Intelligence
AV	Autonomous Vehicles
CAV	Connected and Autonomous Vehicles
CCAM	Cooperative, Connected and Automated Mobility
C-ITS	Cooperative Intelligent Transport Systems
CV	Conventional Vehicles
IP	Information Provider
MaaS	Mobility as a Service
SP	Stated Preference
SAE	Society of Automotive Engineers
V2X	Vehicle-to-everything