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DRIVING TOWARDS THE FUTURE: THE IMPACT OF CONNECTED AND AUTONOMOUS VEHICLES ON TRANSPORT PLANNING

Keywords

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Abstract

This paper focuses on the potential impact of emerging vehicle technologies, particularly connected and autonomous vehicles (CAVs), on various aspects of transport planning, including active travel, road infrastructure, parking and public transport. CAVs are the future of transportation, and they are designed to make roads safer, reduce traffic congestion and improve mobility service. The paper examines the implementation of Level 4 and 5 autonomous vehicles in public transport across the UK, summarising the initial findings, benefits and challenges during the early stages of deployment. A holistic approach is taken to evaluate CAVs' future impact on highway design, parking management, transport modelling, changes in travel behaviour and safety. The analysis highlights how CAVs affect highway design, parking management, and transport modelling, illustrating the significance of these factors in the overall planning process. Considering available data, this paper highlights critical issues that need to be addressed to maximise the benefits of this innovative technology, such as developing transport models that predict traffic patterns and travel behaviour in a real traffic environment. In addition, it is essential to examine the role of CAVs in reshaping road infrastructure, such as lane allocation, traffic signs, communication markers, signal timings, and parking facilities, optimising street space utilisation while maintaining accessibility for all users. Ultimately, the paper seeks to provide a comprehensive understanding of how CAVs could transform various aspects of transport planning, offering insights that could help decision-making processes and promoting sustainable growth.

1. INTRODUCTION

Connected and Autonomous Vehicles (CAVs) refer to advanced vehicles that leverage artificial intelligence (AI), sensors, and other technological advancements to operate with little or no human assistance. The term "Connected" refers to the vehicle's ability to communicate with other devices, infrastructure, and other vehicles through networks, while the term "Autonomous" corresponds to the vehicle's capacity to navigate and drive itself [1]. CAVs have the potential to advance much-needed changes within the transportation industry, offering solutions to current and future transport planning challenges, disrupting both local and strategic planning processes. This could have a lasting impact on active travel, highway infrastructure, parking, and public transport. Decision-makers, transport planners, architects, engineers, and other professionals are actively seeking a comprehensive understanding of how CAVs will impact future travel demands and infrastructure.

This paper aims to address the integration of emerging vehicle technology within the realm of transport planning. The primary focus is on the substantial changes needed for conventional infrastructure to adapt. The secondary focus highlights the requirement for legislative and policy adjustments to accommodate new technologies. By reviewing and analysing the initial findings of case studies undertaken in the UK, the objective is to understand the impacts of future changes on the transport landscape.

2. UNDERSTANDING THE EMERGENCE OF CAVS

The benefits of CAVs are presented in five major perspectives: road safety, highway capacity, mobility, environment and economy. In the realm of transport planning, they have the potential to positively impact the reduction of traffic congestion and travel times, improving traffic flow, increase public transport accessibility, and enhancing road safety [2]. The introduction of CAVs could reshape how people travel, utilising services such as ridesharing and demand-responsive services, offering advanced flexibility and personalisation, bridging the gap in first/last-mile connectivity. Their deployment enables the implementation of intelligent transportation systems, leveraging advanced communication technologies to optimise traffic management and coordination [3]. CAVs integration is in its early stages and faces three core issues: high initial costs associated with expensive technologies, the need for significant infrastructure upgrades to accommodate current autonomous technology, and concerns regarding cybersecurity and data privacy, which impact safety [4].

2.1. Levels of Driving Automation

According to the Society of Automotive Engineering, emerging vehicle technology is categorised into five levels of autonomy. Each level represents a different degree of driver assistance, ranging from Level 0 (no automation) to Level 5 (full automation). The driving automation level begins at driver assistance features (Levels 1-2), partial automation (Level 3), then high (Level 4), and finally fully autonomous vehicles (at Level 5) [5].

2.2. Autonomous Vehicles Deployment in Public Transport

The UK has emerged as a pioneer in autonomous mobility, being the first country in Europe to allow hands-free driving technology with Level 2 autonomy on public roads. The country has also witnessed significant milestones, with the introduction of the world's first autonomous electric bus service for public use in Didcot, Oxfordshire, in March 2023, and a few months later, in May 2023, Edinburgh introduced autonomous bus service in operations on public roads. Both services operate with Level 4 autonomous buses. The transport industry has already seen the successful implementation of Autonomous Train Operation (ATO) technology, which significantly improved commuting, making it faster, safer, and more efficient. Autonomous trains have been in operation since the 1980s. The Docklands Light Railway (DLR) and London Underground have been utilising ATO for over a decade.

3. LEGISLATION, EVIDENCE AND PROJECT REVIEWS

The government has emerged as a significant partner in the drive towards transport automation by engaging in various activities, such as aligning policies and regulations and funding trials. This transformative journey includes significant changes required in areas such as regulation, technology, infrastructure, and consumer behaviour.

3.1. Regulatory and Policy Frameworks

Transition models are essentially political statements, that are provisional, only partially inclusive, and often unstable over time. The political implications of rushed decision-making and intervention strategies are valid concerns of determining when and how to make effective decisions. This poses a risk for the optimal timing of CAVs integration, which will certainly require the development of new regulatory and policy frameworks that address issues such as safety, data privacy, and liability [6]. The UK Government supported the growth and deployment of CAVs, by establishing The Centre for Connected and Autonomous Vehicles in 2015. The same year the government released two “Pathway to Driverless Cars” reports: one outlining an action plan and technology overview, and another delving into regulatory frameworks [7]. They were the foundation for introducing The Automated and Electric Vehicles Act in 2018, enabling testing of self-driving vehicles on public roads. The government's policy paper, "Connected and Automated Mobility 2025: Realising the Benefits of Self-driving Vehicles in the UK," outlines plans and addresses legislative reviews, emphasising the significance of data-based evidence in policymaking.

3.2. Research: Evidence Base Decision

The UK Law Commission has been publishing various consultation papers as part of a three-year review aimed at preparing driving laws for self-driving vehicles. This process ensures informed decision-making processes and the development of legislation that aligns with advancements in autonomous technology. The research results contribute to the proposal and introduction of a new regulatory framework, taking into account how self-driving cars impact traffic, public perception, data generation, and market forecasts.

Research on the Impacts of Connected and Autonomous Vehicles (CAVs) on Traffic Flow (2016) – ATKINS

This study uses VISSIM microsimulation to analyse driving behaviours, lane changes, acceleration profiles, and CAV penetration levels on both the strategic road network (comprising motorways and other major routes designated for strategic traffic) and the urban road network (comprising streets and roads with speed limits typically not exceeding 80km/h (50mph)). The study focuses on passenger vehicles to assess CAV technology adoption and network performance during peak hours, considering factors like congestion, vehicle delay, low speeds, and journey times.

Table 1. Network Modelling Results [8]

Scenario	Strategic Road Network						Urban Road Network					
	Average Delay		Average Journey Time		Journey Time Variability		Average Delay		Average Journey Time		Journey Time Variability	
	(s)	%	(s)	%	(s)	%	(s)	%	(s)	%	(s)	%
Base	35.84	-	539.7	-	20.17	-	65.9	-	277.7	-	88.38	-
25% penetration (1)	36.17	0.9	538.4	-0.2	19.38	-3.9	57.7	-12.4	219.5	-21.0	19.74	-77.7
50% penetration (2)	33.39	-6.8	533.6	-1.1	17.65	-12.5	54.4	-17.4	20535	-26.1	10.01	-88.7
75% penetration (3)	29.77	-16.9	527.7	-2.2	15.33	-24.0	51.8	-21.3	198.8	28.5	7.24	-91.8
100% penetration (4)	23.72	-33.8	517.7	4.1	10.52	47.9	48.0	-27.1	192.6	-30.7	6.00	-93.2
Upper bound (5)	21.38	-40.3	472.2	-11.2	9.14	-54.7	46.3	-29.7	184.2	-33.7	5.71	-93.5

The strategic road network results indicate a potential delay reduction of over 40% with 100% CAVs, but significant benefits require high CAV penetration. At a 25% CAV fleet composition, benefits are minimal. Conversely, the urban model shows substantial improvements even at 25% CAV penetration, with a 12% delay reduction, 21% quicker journeys, and an 80% enhancement in journey time reliability [8].

Connected Vehicle Data Research Project (2020) – ATKINS/Jacobs

This report outlines a strategy for optimising connected vehicle (CV) data for improved traffic management. The Department for Transport sought to leverage CV data to improve the transport network, benefiting the environment, reducing congestion, improving safety, and strengthening the economy. The proposed approach simplified data services such as asset management, parking, vehicle data analysis, and public transport. The study identified six key strategic themes: establishing a demonstrator, creating national facilities, addressing skill gaps, supporting CV data migration, offering procurement aid, and providing service design guidance [9].

Market Forecast for Connected and Autonomous Vehicles (2020) - Catapult

This report highlights the potential of CAVs development in the automotive market, bringing changes in transportation, improving safety, efficiency, and user experience. The automotive sector is a significant contributor to the UK economy, and CAVs offer opportunities for growth and job creation. The report aims to quantify those opportunities, with key findings including an estimation of the UK CAV market value of £41.7 billion in 2035 and potential job growth in CAV-related industries. These estimates are subject to uncertainties related to adoption rates, costs, and technology development [10].

The Great Self-Driving Exploration: A citizen view of self-driving technology in future transport systems (2023) - University College London (UCL) and Aurrigo

Self-driving vehicles (SDVs) could bring significant benefits, but the government needs to ensure their safety and public trust. To achieve this, the government undertook research to understand how people perceive SDVs and what they expect from them. Previous research showed that while people are excited about SDVs, there is a need for more understanding and trust in the technology. Those who participated in the shuttle and pod SDV trials shared an overall positive experience. These participants, including both passengers and pedestrians, consistently expressed a heightened sense of security. Notably, stress levels were found to be significantly reduced. This sense of safety surpassed initial expectations, indicating the successful implementation of the SDV trials. This research shows that giving people the chance to try SDVs is valuable. It helps them become accustomed to the technology and can lead to more informed views, ultimately contributing to the development of better SDVs in the future [11].

4. CASE STUDIES

4.1. MultiCAV: Mobility as a Service (MaaS)

The MutiCAV passenger-carrying trial aims to showcases the practical implementation of CAVs technology in Didcot, Oxfordshire. In March 2023, Mi-Link service was introduced at Milton Park, marking the launch of the first zero-emission bus service for public use on a private road operating with SAE Level 4 autonomy. Building on this success, the trial was later extended in September 2023 to include a public road connecting Milton Park with Didcot Parkway railway station [12]. This project utilises real-world transport data to evaluate user behaviour and commercial viability, with the goal of integrating MaaS and CAV into a multi-modal mobility solution. The project aims to set a benchmark for what integrated MaaS solutions.

4.2. CAVForth: Bus Service

The CAVForth Project successfully introduced the first fleet of 20 autonomous buses in the UK, operating at the SAE Level 4 of autonomy on public roads, launching in May 2023, covering a 22.5-kilometer route in Edinburgh. These buses have the capability to travel in mixed traffic at a maximum speed of 80km/h (50mph) and can transport up to 10,000 passengers per week [13]. Operating primarily on motorways managed by Transport Scotland, these full-size autonomous buses are responsible for safely interacting with other vehicles, navigating junctions, and making stops. In collaboration with the CAVForth and the overseeing authority, a comprehensive approach has been taken involving designing and implementing essential infrastructure measures, utilising the Traffic Scotland National Control Centre for real-time trial monitoring, ensuring an effective incident management response.

5. POTENTIAL IMPACT ON INFRASTRUCTURE

Infrastructure is crucial for the implementation of CAVs in the transport ecosystem, necessitating improvements in highway design, including lane markings and electronically readable signs [14]. With technological advancements, the operational efficiency of the highway network is expected to increase, enabling higher capacity at roundabouts and junctions, and potentially resulting in narrower carriageway lanes [15]. Designated locations for safe and convenient pick-up/drop-off should also be provided. The shift from private to shared vehicles has the potential to reduce total vehicle ownership and parking demand [14]. It should be noted that shared CAVs represent a long-term vision and may not be immediately evident. As CAVs become the majority on the road, traditional traffic signs, lane markings, and even traffic lights may become obsolete. While CAVs offering door-to-door service could reduce walking and cycling, this could have negative impacts on health and wellbeing [16]. This concern also extends to potential negative consequences, such as reduced opportunities for socialising and a diminished sense of public space ownership. The integration of CAVs would also require robust communications infrastructure to ensure reliable data services for CAVs and reduce network disruptions.

6. POTENTIAL IMPACT ON TRANSPORT PLANNING

The transport industry is currently navigating a future filled with uncertainties, posing significant challenges for long-term planning. Exploring the transition to CAVs and its impact on transport planning involves a comprehensive examination of how it influences policies, the evaluation of new transport initiatives, and design considerations. Governments will play a key role in developing legislation and standards to allow for interoperability, preventing manufacturers from creating monopolies by developing their own standards that might not be compatible with others, as has been seen in the electric vehicle charging sector [17]. Furthermore, with established technologies like vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-everything (V2X) communication, CAVs can share real-time traffic information, allowing them to adjust their routes and speeds accordingly [3]. This can lead to a more efficient use of the road network and a reduction in travel times, giving them the potential to improve traffic management by reducing congestion and optimising traffic flow. The elimination of the need for traffic signals by CAVs is feasible but limited to areas where all traffic is autonomous [14]. As CAVs become more dominant, the need for parking spaces is expected to decrease. The introduction of CAVs will require changes in the design and functionality of transportation infrastructure. Highways may need to be adapted to accommodate dedicated lanes, while traffic signals and signage will need to be updated to facilitate V2X communication. CAVs have the potential to improve accessibility for people with disabilities, the elderly, and those without access to personal cars, by providing convenient and affordable transport options. The adoption of CAVs may lead people to choose to live further away from urban centres, resulting in changes in land use patterns and the emergence of new development patterns.

7. CONCLUSION

CAVs have the potential to significantly impact transport planning, from modelling and highway design to decision-making processes. This paper has discussed the multifaceted impacts of CAVs, covering road safety, highway capacity, mobility, the environment, and the economy. They hold the promise of reducing traffic congestion, improving travel times, enhancing traffic flow, and increasing accessibility to public transport. However, their integration presents challenges such as high initial costs, the need for infrastructure upgrades, and concerns about cybersecurity.

In conclusion, the effects of CAV adoption can be categorised into three key phases: introduction, transition, and full integration into the transport ecosystem. While the timing of each effect remains uncertain, short-term effects are expected to emerge within the first 3-5 years of CAV adoption, including improvements in travel time, convenience, and productivity. Conversely, medium-term effects, anticipated within 6-10 years, may involve shifts in car ownership, privacy concerns, and cybersecurity. Long-term effects, extending beyond 10 years, relate to impacts on the urban built environment, such as decisions regarding household and employment locations, and changes in parking demand [3].

One of the key benefits of CAVs is their potential to reduce energy consumption and mitigate environmental impacts. Studies show that CAVs can optimise routes and adapt to traffic conditions in real-time, minimising travel delays and reducing congestion [8]. Although private cars continue to dominate, CAVs have the potential to encourage a shift away from private cars by offering convenience, availability, and frequency. A remaining concern is whether the provision of highly accessible services could deter people from walking and cycling as they are attracted by the benefits CAVs have to offer.

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