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Impacts of connected and autonomous vehicles on urban transportation and environment: A comprehensive review

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Highlights

- AV would significantly influence urban transportation systems and human mobility.
- AVs would encourage dispersed urbanization, reduce parking demand, and enhance network capacity.
- AVs would reduce energy use and protect the environment by reducing GHG emissions.
- AVs would reduce traffic crashes and increase passengers' convenience and productivity.
- The study identifies existing research gaps and proposes directions for further research.

Abstract

The article discusses the short, medium, and long-term effects of Autonomous Vehicles (AVs) on the urban transportation and environment by means of a systematic review of the extant literature on the subject matter. A corpus of 130 articles was collected from multiple sources using selected keywords. The review critically analyzes

key findings of these papers in the light of a SWOT (Strength, Weakness, Opportunity, and Threat) analysis. Although the technology remains to be commercially deployed, broad consensus is found in the literature. First, AV would influence urban transportation and human mobility by reducing vehicle ownership, public and active travel, traffic delay and congestion, travel costs, and by increasing accessibility, mobility, Vehicle Miles Traveled, and revenue generation for commercial operators. Second, AVs would have long-term effects by encouraging dispersed urban development, reducing parking demand, and enhancing network capacity. Third, AVs would reduce energy consumption and protect the environment by reducing Greenhouse Gas emissions. Fourth, AVs would reduce traffic crashes involving human errors and increase the convenience and productivity of passengers by facilitating for multitasking. However, most people are very concerned about personal safety, security, and privacy. Finally, the study identifies critical research gaps and advances priority directions for further research.

Introduction

People have used the automobile as a primary mode of travel within and between urban areas since the mid-twentieth century (Howard & Dai,2014). Nowadays, it has become an integral part of urban life. Technological advancements such as the introduction of Internal Combustion Engines (ICEs), transmission systems, electric motors, steering and cruise control, and emission control technologies are easing people's life and reorganizing city structure (Kim,2018). While providing benefits to populations, automobiles are also adversely affecting human societies and their environment. The massive use of Single-Occupancy Vehicles (SOVs) is associated with travel delays, traffic congestion, traffic crashes, energy consumption, air pollution, and urban sprawl. Mutation of the transportation system by shifting from ICEs to Electric Vehicles (EVs), and by introducing Intelligent Transportation Systems (ITS), ride-sharing, on-demand services, and Travel Demand Management (TDM) measures has shown evidence to reduce energy use and carbon emission, traffic crashes and congestion (Bansal & Kockelman,2017; Howard & Dai,2014). However, a combination of these strategies has the potential to bring dramatic changes to the transportation system, to urban mobility in terms of where people live, where they work, shop and recreate individually and collectively, and hence to the spatial structure of urban environments. This study investigates the impacts of Connected and Autonomous Vehicles (CAVs) on urban transportation and on the geography of urban environments by conducting a state-of-the-art review of the literature.

A number of high tech firms and more traditional automobile companies have been working assiduously to develop Automated Vehicles (AVs), which can arguably be seen as a new mobility option (Moorthy et al., 2017; Narayanan et al., 2020). While institutional bottlenecks and socio-technological challenges continue to frustrate the meaningful commercial deployment of AVs (Day,2021), it is often anticipated that AVs would deeply change human mobility, the built environment, the socio-economic fabric of cities, and city planning and governance (Fayyaz et al., 2022; Grindsted et al., 2022; Lee et al., 2022). Meanwhile, decision makers and city planners should prepare policies and plans consistent with a mobility landscape where AVs occupy a prominent position. To date, much research has been conducted on the potential impacts of AVs on people's travel behaviors and on the urban built environment to facilitate the process (Fagnant & Kockelman,2015; Fraedrich et al., 2019; Kapser & Abdelrahman,2020; Meyer et al., 2017). Considering the preeminence of people's safety and security in shaping travel patterns, previous studies have also explored urban futures with AVs from the perspectives of personal safety, privacy, and security. These studies have serious drawbacks including a heavy reliance on assumptions, simulations and hypothetical driving settings, which may deviate from real-world situations. Nonetheless, they are significantly contributing to the current body of literature aimed at unraveling the possible responses to AV adoption in human travel patterns and in the urban built environment. Thus, it is timely to have a comprehensive overview of the current literature and to synthesize the existing knowledge domain.

Some of the early reviews of the extant literature systematically evaluated the short-term (i.e., within 3 - 5 years) – such as travel time, convenience, people's productivity, and medium-term (i.e., within 6 - 10 years) effects –such as car ownership, privacy, cyber security, of AVs, but disregarded the long-term (i.e., more than 10 years) effects on the urban built environment, such as people's household and employment location decisions and parking demand (Ahmedetal., 2022; Bahamonde-Birkeetal., 2018; Kopeliasetal., 2020; Othman,2022; Tafidisetal., 2021; Tengilimogluetal., 2023). Although the phasing of the effects is still unsettled, may remain in question for some time, and is subject to adjustments (Hancocketal., 2019; Milakis,2019), it is assumed that short-term effects will be realized starting with the introduction of AVs for public use rather than in the more distant future. On the other hand, long-term effects will continue for a long time period after adoption of AVs. However, researchers have argued that long-term effects of AVs are uncertain and largely depend on the level of market penetration of AVs and on the evolution of vehicle travel demand (Milakisetal., 2017). Mid-term effects fall in between short- and long-term effects of AVs. To the best of our knowledge, no prior review has explored the current status of AV adoption and the anticipated evolution over a certain time horizon. In this study, we aim to understand current scenarios and potential benefits and costs of AVs after reviewing relevant published scholarship. Considering the timeliness of the research topic and gaps in the literature, the following research questions are investigated in this systematic review:

1) What is the current status of AV research and adoption in different study contexts around the globe?

2) What are the impacts of AVs on human mobility, transportation system, energy and environment, and the built environment?

3) What are the impacts of AVs on people's safety from traffic, privacy from cyber-attacks, travel convenience, and productivity?

4) What are the research gaps in the existing literature that warrant further investigation?

Thus, the present review makes significant contributions to the literature by consolidating existing bodies of literature. Its main contributions are threefold. First, the paper critically reviews the state-of the-art literature on the short, medium, and long-term effects of AVs on urban transportation and mobility. Second, it looks at the possible longer-term adjustments to the geography of the built and natural environments of urban regions in the wake of shifts towards more AVs as future markets for AVs become more grounded. Finally, the paper identifies key concepts and provides a foundation for future research by pinpointing research gaps in the literature.

The rest of the paper is structured as follows. Our study approach is presented in Section Two. The third section discusses the definition, concept, evolution, and adoption of AVs in different countries. The potential impacts of AVs are presented in the fourth section. Under Section Four, Subsection4.1 outlines the impacts of AVs on transportation and human mobility, Subsection4.2 explains the impacts of AVs on traffic safety and convenience to people, Subsection4.3 summarizes the impacts on energy and environment, and Subsection4.4 discusses impacts on the urban built environment. Research problems and directions for future study are discussed in the Fifth Section. Finally, conclusions are drawn in Section Six.

Section snippets

Study approach

This systematic literature review is conducted to identify, evaluate, and critically analyze relevant scholarship on the current status and impacts of AVs. To this end, a literature search is conducted to select published articles and reports to be included in the review process. The articles and reports are selected based on (1) whether the article/report was written in English, (2) whether the study was conducted within the last five years, and (3) whether the study has investigated the …

The concept and evolution of autonomous vehicles

AV (also known as a self-driving car, driverless car, robotic car) is able to drive and navigate without direct human inputs by using sensing technology (e.g., radar, Global Positioning System (GPS), and computer vision) and advanced control systems (i.e., sensors) (Howard & Dai,2014; Narayananetal., 2020). These automated vehicles are expected to bring revolutionary changes in people's mobility, transportation systems, and land-use patterns (Brownetal., 2014; Meyeretal., 2017). A …

The potential impacts of AVs

AVs would have both positive and negative effects on people and society. To better understand the potential impacts of AVs and their associated advantages and disadvantages, a SWOT (Strength, Weakness, Opportunity, and Threat) analysis is performed after reviewing the existing literature, following (Litman,2017; Universityof Kentucky,2020). This SWOT analysis provides a framework and helps us organize and discuss the Strengths, Weaknesses, Opportunities, and Threats of AVs in a single …

Discussion and directions for future study

Investigating the current status of implementation, researchers reported that AVs will be available for people's regular use incrementally over the coming decades. The findings from the existing literature show that AV would influence urban transportation and human mobility by reducing vehicle ownership, public and active travel, traffic delay and congestion, travel costs, and increasing accessibility, mobility, VMT, and revenue generation for commercial operators. Some studies also mentioned …

Conclusion

This state-of-the-art comprehensive literature review investigated the short, medium, and long-term effects of AVs on urban transportation and urban environments. To understand the advantages and disadvantages associated with AVs, this review study critically analyzed previous papers and summarized the key findings based on a SWOT analysis (Fig.7). The important takeaways from this study include that AVs would encourage dispersed urban development, would reduce parking demand, and would …

Declaration of Competing Interest

The authors have no conflicts of interest to declare. …

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M.J. Alam *et al.*
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Procedia Computer Science (2018)

M. Amirgholy *et al.*
Traffic automation and lane management for communicant, autonomous, and human-driven vehicles
Transportation Research Part C: Emerging Technologies (2020)

J. Auld *et al.*
Impact of privately-owned level 4 CAV technologies on travel demand and energy
Procedia Computer Science (2018)

P. Bansal *et al.*
Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies
Transportation Research Part A: Policy and Practice (2017)

P. Bansal *et al.*
Assessing public opinions of and interest in new vehicle technologies: An Austin perspective
Transportation Research Part C: Emerging Technologies (2016)

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Autonomous mobility in the built environment

S. Carrese *et al.*
A preliminary study of the potential impact of autonomous vehicles on residential location in Rome
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A. Chehri *et al.*
Autonomous vehicles in the sustainable cities, the beginning of a green adventure
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Near-(2020) and long-term (2030–2035) costs of automated, electrified, and shared mobility in the United States
Transport Policy (2020)

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A joint optimization of resource allocation management and multi-task offloading in high-mobility vehicular multi-access edge computing networks

2025, Ad Hoc Networks

> *Citation Excerpt :*
>
> …For example, vehicles can send alerts about road conditions, accidents, or traffic jams to nearby cars. These capabilities make driving safer and reduce travel time and fuel consumption [8,9]. However, as more vehicles connect, communication management becomes more critical to ensure a smooth and reliable system [10,11].…

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Analysis of mixed traffic flow with different lane management strategy for connected automated vehicles: A fundamental diagram method

2024, Expert Systems with Applications

> *Citation Excerpt :*
>
> …Therefore, how CAVs will influence the characteristics of the mixed traffic flow at different stages during the transition period has become a hot research topic. To investigate the potential impact of CAVs on the mixed traffic flow at different stages during the transition period, scholars have already investigated in terms of the fundamental diagram (T. Chen et al., 2021; Ngoduy et al., 2021; Tian et al., 2023; Wu et al., 2022; Yao et al., 2019; J. Zhou & Zhu, 2020, 2021), stability (Gu et al., 2022; T. Wang et al., 2022; Yao et al., 2021), safety (Garg & Bouroche, 2023; Nazir et al., 2023; X. Wang et al., 2022), fuel consumption and emissions (Rahman & Thill, 2023; Shi et al., 2022; Vellamattathil Baby et al., 2022; S. Zhou et al., 2023; Zong & Yue, 2023), etc. However, it is difficult for CAVs to accurately identify and predict the driving behavior of HDVs in the mixed traffic flow.…

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Private vehicle drivers' acceptance of autonomous vehicles: The role of trait mindfulness

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Assessment of future parking systems with autonomous vehicles through agent-based simulation: A case study of Hangzhou, China

2024, Sustainable Cities and Society

> *Citation Excerpt :*
>
> …However, the self-repositioning ability of AVs offers new solutions to parking problems, where a parking space at the destination of a trip may not be a necessity anymore. Many studies about the future city with AV have envisioned a reduction in the parking demand (Chehri & Mouftah, 2019; Miskolczi et al., 2021; Rahman & Thill, 2023). For the parking of traditional HDVs, the distance between the destination and the parking lot and the parking fees are always the primary considerations.…

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