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Review

The Integration of Shared Autonomous Vehicles in Public Transportation Services: A Systematic Review

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Abstract: Autonomous vehicles and shared mobility represent two fields of strong innovation in transportation research, and Shared Autonomous Vehicle (SAV) services have been studied as a new promising mobility system. Such services offer a strong potential especially when integrated with the Public Transport (PT) system, increasing its attractiveness by providing first- and last-mile connections to low-demand areas. This paper performs a systematic review on a niche of SAV-related literature, selecting articles that address PT-SAV integrations, the issue of how SAVs should be implemented together with already existing transit systems to enhance collective mobility. Papers have been classified firstly according to the methodological and modelling approaches used by researchers, and then according to the different operational schemes with which SAV systems can be deployed. Common findings have been reported and commented on, identifying the lack of articles aimed at determining the most suitable SAV service typology for specific contexts and network configuration. Many authors indicate that if SAVs are operated as feeder modes to mass transit, they might improve public transport connectivity. However, further research is needed to explore the efficacy of SAV systems as an opportunity to address first/last-mile PT planning issues.

Keywords: shared autonomous vehicles (SAVs); automated vehicles; autonomous taxi; driverless car; public transportation; mass transit; literature review

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1. Introduction

Shared mobility is rapidly growing as a result of a pressing need to make cities and urban settlements inclusive, safe, resilient and sustainable. At the same time, autonomous vehicles (AVs) are gradually becoming familiar and represent the biggest innovation in transportation technology (Patella et al., 2020) [1]). In fact, recent advances in wireless infrastructure systems [2–5] will enable vehicle cooperation, improving safety and efficiency. The synergy between autonomous vehicles and shared mobility has the potential to significantly reshape transportation systems and the urban form, potentially mitigating transport-related environmental impacts. Shared autonomous vehicles (SAVs), also called autonomous taxis, have been proposed as a solution to reduce car ownership, enabling users to get picked up, rather than walking long distances to reach an available vehicle. Fagnant and Kockelman (2014) [6] underlined that SAVs might greatly reduce the number of cars needed for self-owned vehicle trips, but empty rides could increase the total distance travelled (Morfeldt and Johansson, 2022 [7]; De Souza et al., 2020 [8]). Salazar et al. (2018) [9] observed that SAV systems have the potential to induce a shift from public transport to shared cars, increasing congestion and pollutant emissions. Becker et al. (2019) [10] found that SAV systems might bring substantial benefits in car-oriented cities, while in

public transport-oriented cities they might induce a shift from mass transit. Heubeck et al. (2023) [11] found that higher attitudes for shared AV forms can be observed in public transport users, confirming such a rebound effect from SAV deployment. Nevertheless, the interview study by Nordhoff et al. (2019) [12] suggests a positive disposition among respondents toward the use of autonomous shuttles as feeders to public transport systems.

An efficient deployment of SAV systems will require their integration into public transportation services in order to reduce traffic externalities (congestion, noise, greenhouse gas, nitrogen oxides and PM10 emissions). Acting as feeder services by bringing passengers from residential areas to major transit hubs, such as bus or train stations, SAV systems can improve the accessibility of public transport, encouraging more people to use it for their travel needs. SAVs can address the challenge of first/last-mile connectivity, helping travellers to reach public transport stations from their homes or workplaces.

As mentioned by Etminani-Ghasrodashti et al. (2021) [13], the PT-SAVs integration is an understudied subject, and to the best of our knowledge, there are no review articles on this specific topic. In fact, the general reviews on SAVs by Golbabaei et al. (2020) [14] and Narayanan et al. (2020) [15] indicated a need for future research on integrated PT-SAVs systems including the operational and the demand sides.

In this light, the aim of this study was to explore recent literature on PT-SAV integration, reviewing the current understanding of modelling and simulation issues, as well as service organizational aspects. This study distinguishes itself from previous literature reviews by summarizing the available knowledge on methodological and practical issues associated with a synergetic implementation of SAVs in public transportation network. General reviews on the current state of AVs can be found in Shiwakoti et al. (2019) [16] and Faisal et al. (2019) [17].

The reminder of the paper is organized as follows. Section 2 outlines the methodology used to perform the literature review, with results presented in Section 3. Section 4 concludes and summarizes the paper, including remarks for future research endeavors.

2. Methodology

The literature selection procedure is shown in Figure 1 and inspired by Golbabaei et al. (2020) [14]. The keyword combination used in the search strategy was ("shar* autonomous vehicle" OR "shar* driverless car" OR "shar* driverless vehicle" OR "shar* automated car" OR "shar* automated vehicle" OR "shar* autonomous taxi") AND ("public transport" OR "mass transit") within the article title, abstract or keywords. The asterisk (*) enables to include different forms of the same word: shared or sharing. Books, editorials, notes, errata, articles not in English and conference reviews were not included. Book chapters were excluded because they had been published in journals or were reprints of published papers. In addition, reviews were not included since they represent a synthesis of already published articles. A large amount of articles (109) were excluded as not relevant for the scope of this study. In most of those cases, SAVs are intended as potential substitutes or competitors of PT systems, instead of being seen as an integrative service.

Table A1 in the Appendix A summarizes the main contributions of the papers included in this review.

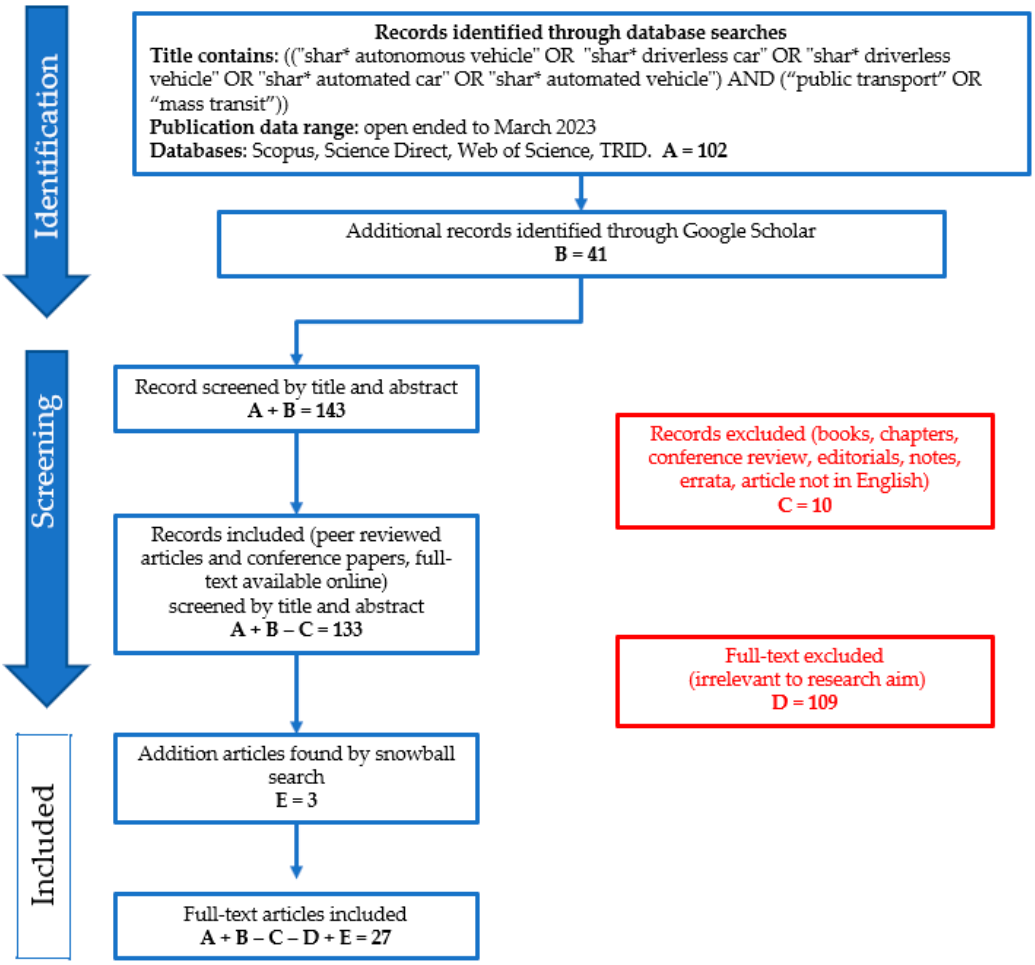


Figure 1. Literature selection procedure. The asterisk (*) enables to include different forms of the same word.

3. Results

The search produced 27 items. Figure 2 shows the publication trend until March 2023, underlining the increasing attention in the literature to the integration of SAVs into public transportation systems. Research production has become systematic from 2016, gaining more popularity over the last few years.

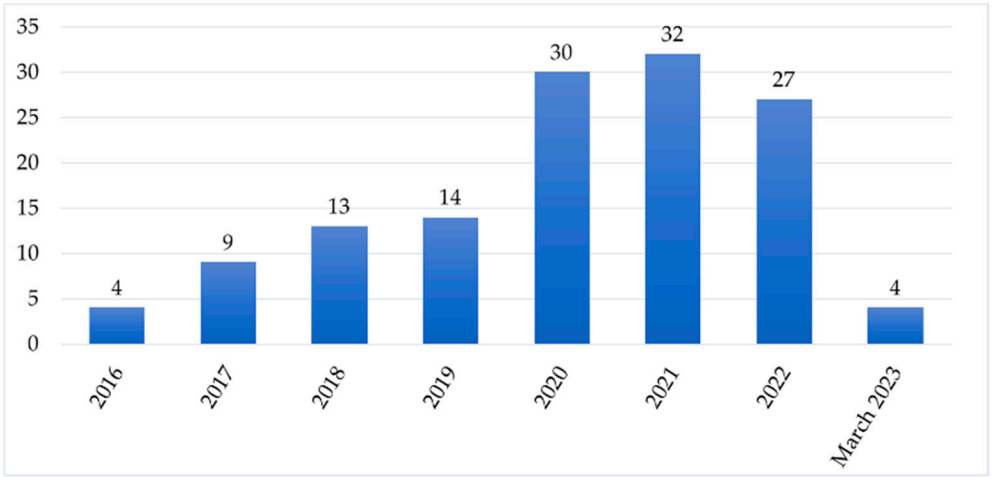


Figure 2. Publication trend until March 2023.

The rest of this section is divided into two parts. First, all papers are analyzed by the modelling approaches used to study the integration between SAV services and public transport. Common approaches include agent-based simulation for the evaluation of SAV fleet performance, optimization-based methods addressed to solve traffic assignment, fleet sizing or vehicle redistribution and behavioural modelling based on surveys. Next, papers are reviewed based on the operational schemes used for SAVs services, analyzing the hailing, how SAVs are reserved, and sharing, ridership modelling and policies, as well as the typology of integration to public transport.

3.1. Methodological Approach

Agent-based simulations are the most practiced approach when dealing with SAV-PT integration, since they permit to model the interaction between vehicles and passengers. Such simulation tools allow to assess the effectiveness of different fleets and the appropriateness of operational services and strategies to the study area. Shen et al. (2018) [18] simulate 52 scenarios for different fleet sizes and sharing and no-sharing policies. Wang et al. (2019) [19] simulate different operational schemes, comparing door-to-door and station-to-station service and combining them in scenarios that switch between these schemes or allowing both of them to operate in parallel, while also varying fleet size and vehicle assignment method. Mo et al. (2021) [20] perform the AV-PT competition process simulating five dynamic adjustable supply strategies for the transit and AV operators. Lau and Susilawati (2021) [21] develop different scenarios varying passenger mode choice's relevant attributes, such as SAV waiting time and cost and personal vehicle costs. Tak et al. (2021) [22] simulate different scenarios based on the implementation of PT-integrated services, the provisioning of autonomous driving-based services, different levels of reliability for bus arrival times and changes in the supply/demand ratio for shared mobility vehicles. Huang et al. (2020) [23] performed a sensitivity analysis to understand the impact of fleet size and transit frequency on the performance of the SAV mode. Huang et al. (2021) [24] used a toolkit in SUMO named TraCI (Traffic Control Interface) to microsimulate scenarios varying the demand, adding an extra station bay and dedicated traffic signals for SAVs, and changing the load factors to affect SAV dispatching headways. Huang et al. (2022) [25] also analyzed the performance of PT-SAV integration varying train headways, SAV fleet sizes and seat capacities. Zhou et al. (2019) [26] used an agent-based simulation software (artisoc 4.0) to perform sensitivity analysis on fleet sizes, variations on demand segments, speed of vehicles and Park-and-Ride schemes. Scheltes and De Almeida Correia (2017) [27] simulate 10 different operational scenarios that vary in network structure by adding and removing links, vehicle relocation strategies, charging and hailing policies and allowing passengers to drive. Wen et al. (2018) [28] use activity-based models to explicitly model the interaction between demand and supply, analyzing the effects of fleet size, vehicle capacity, hailing policy, fare policy and the preference for the PT-SAV service. Imhof et al. (2020) [29] define two different scenarios and simulate the possible effects of an on-demand and door-to-door SAV service on the public transportation system to discuss the regulatory context of the proposed services.

Optimization techniques are also often found when dealing with PT-SAV integration. Liang et al. (2016) [30] use Integer Programming to maximize the total profit during a typical day of operations, optimizing the trips to be served and the service area of a SAVs system as an access/egress mode to train stations. Salazar et al. (2018) [9] present a generic multi-commodity flow-based optimization approach to minimize the customers' travel time together with the operational costs of different transportation modes. With the hypothesis of SAVs replacing taxis in the near future, Bojic et al. (2021) [31] compare bus and taxi trips and determine the overlap between the two to understand how many PT trips could be served by SAVs, and calculate a maximal weighted matching to determine an optimal assignment of passengers to SAVs maximizing the total travel time savings. Additionally, Levin et al. (2019) [32] use total passenger travel time as an objective function in a linear program to optimize SAV routes, pick-up and drop-off location strategies, relocation of empty vehicles

and transit headways. Various authors also explicitly include the design of the transit service as part of the optimization problem. Maruyama and Seo (2022) [33] propose a multi-objective optimization problem for an integrated SAV-BRT system, minimizing travel times and distances and cost of buses, SAVs and their infrastructure. Shan et al. (2021) [34] developed a fixed-point algorithm to optimize the railway transit with SAV service as an integral part of the design. The joint RTS-SAVs (RTS stands for railway transport system) problem is solved with mixed-integer linear programming formulation, minimizing the total cost of the combined services and commuters' waiting time. Pinto et al. (2019) [35] include both bus and rail transit patterns in a joint transit network redesign and SAV fleet size determination problem. While the upper-level problem modifies a transit network frequency setting problem formulation, the lower level is solved using an iterative agent-based assignment-simulation approach.

A third line of research follows questionnaire-based surveys and behavioural modelling techniques to study the integration between SAVs and PT. Yap et al. (2016) [36] apply a stated preference experiment for a discrete choice model studying the potential of AVs for the last-mile trips between a train station and the travellers' final destination. They underline that the perception of safety is an important aspect for the deployment of AVs as access/egress mode. Zubin et al. (2021) [37] used a stakeholder survey to define a set of scenarios for the introduction of driverless shuttles as a first/last-mile option in multimodal trips. They argue that a dedicated lane configuration will benefit safety and security; nevertheless, they found that survey respondents are more inclined towards a mixed traffic configuration, as it requires lower investment costs, with no or little infrastructure changes needed.

Fraedrich et al. (2019) [38] propose a quantitative online survey and qualitative interviews to assess the impacts of autonomous driving on the built environment and providing urban planning policy guidance for the future development of SAVs alongside PT. Song et al. (2021) [39] also analyze survey responses and use text mining, factor analysis and regression analysis to understand people's attitudes toward AVs and transit.

Three papers not falling in the abovementioned categories need to be mentioned. Feys et al. (2020) [40] use a multi-actor multi-criteria analysis method, weighting stakeholder criteria and overall performance scores for the following scenarios: first/last-mile feeders, on-demand point-to-point service, robo-taxis, autonomous carsharing and Bus Rapid Transit. Whitmore et al. (2022) [41] use cost-efficiency analysis to compare direct operating costs of SAVs to a conventional transit bus, with a Monte Carlo simulation to estimate levelized costs across a range of feasible scenarios. Finally, Levin (2022) [42] studied the applicability of the minimum-drift-plus-penalty (MDPP) dispatch policy, previously defined by Li et al. (2021) [43], to PT-SAV systems. Through a ridesharing simulation, he finds that when SAVs are integrated with public transit, the number of customers served per SAV increases significantly.

3.2. PT-SAVs Operational and Strategic Aspects

An optimal integration between public transport and SAVs is of interest to researchers and practitioners because of their different operational characteristics: the former is mainly based on fixed routes and schedules and it is more appropriate for corridors with high demand, while the latter offers high potential to adapt to a low density and scattered demand with low ridership. This is especially the case for car–sharing systems with small automated vehicles that can carry only one passenger at a time, as is the case in several applications (Levin et al., 2019 [32]; Zhou et al., 2019 [26]; Scheltes and de Almeida Correia, 2017 [27]; Salazar et al., 2018 [9]; Shan et al., 2021 [34]). However, researchers argue that the introduction of SAVs with absence of ridesharing would have a negative impact on traffic congestion, since it could also attract demand from transit modes, and it would increase the number of kilometers traveled due to the additional empty runs for vehicle relocations (Levin et al. 2019 [32]). Hence, ridesharing is a feature of SAVs that has been thoroughly investigated by researchers, even though only Shen et al. (2018) [18] explicitly simulated

and compared scenarios with and without ridesharing. Lau and Susilawati (2021) [21] impose ridesharing by fixing a minimum of two passengers per vehicle, while Mo et al. (2021) [20] impose a passenger ride-sharing agreement of 50%. In Yap et al. (2016) [36], ridesharing is permitted only between passengers having the same origin and destination, while in Wang et al. (2019) [19], passengers may have different origins and destinations but must both belong to the same zone. Levin (2022) [42] assumes that vehicles pick up all customers before dropping them off at their respective destinations. Several works allow detours to pick up and drop off other passengers while already performing trips (Huang et al., 2022 [25]; Wen et al., 2018 [28]; Pinto et al., 2019 [33]). Ridesharing becomes compulsory when dealing with large vehicles: Huang et al. (2021) [24] simulate different types of vehicles ranging from five to 40 seats, while Zubin et al. (2021) [37] and Whitmore et al. (2022) [41] simulate driverless shuttles with a capacity from eight to 12 passengers.

SAVs can act efficiently as a feeder service for public transport because of their potential use as a demand-responsive service: the possibility to relocate empty vehicles and the low number of passengers per ride permit SAVs to serve a flexible demand with high variability in time and space. Two main types of hailing policies (or booking type) are used by researchers: in-advance requests (reservation-based) or real-time booking (on-demand services). Real-time booking is desirable for users that benefit from a flexible service with less constraints, while reservation-based systems can increase the efficiency of a SAV fleet and permit an optimal planning and scheduling of integrated trips. Works which provide an optimization for vehicle assignment require in-advance requests (Liang et al., 2016 [30]; Maruyama and Seo, 2023 [33]), but reservation-based systems are used also by Lau and Susilawati (2021) [21] with flexible timetables and capacity with a predetermined route. Most of the analyzed papers (Salazar et al., 2018 [9]; Scheltes and De Almeida Correia, 2017 [27]; Shan et al., 2021 [34]; Shen et al., 2018 [18]; Wang et al., 2019 [19]; Imhof et al.,2020 [29]; Levin et al., 2019 [32]; Huang et al., 2020 [23]; Huang et al., 2022 [25]; Wen et al., 2018 [28]; Mo et al., 2021 [20]; Pinto et al., 2019 [33]) use on-demand hailing systems and assign vehicles to trips requested by passengers in real time.

The most common approach when modelling the integration between SAVs and PT is to use SAVs as a feeder service to public transport providing a first-mile-last-mile connection to transit stations or stops. Transit lines with lower frequency and high demand are the most suitable scenarios to apply a SAV feeder service, generating a demand more concentrated in time and space for which ridesharing offers high potential. In most applications, it is not specified if SAVs are free to roam around all the urban area (or a part of it) to find the closest customers or must operate within a limited distance from a specific station to enlarge their access coverage. However, Huang et al. (2020) [23] designs buffer areas around public transport stations to define the operational extent of SAVs. Applications to rail networks are the most studied case (Yap et al., 2016 [36]; Liang et al., 2016 [30]; Wen et al., 2018 [28]; Imhof et al., 2020 [29]; Shan et al., 2021 [34]; Huang et al., 2022 [25]), while Maruyama and Seo (2023) [33] pair SAVs with a Bus Rapid Transit (BRT) system. SAVs providing access to and egress from train stations or public transport stops are generally structured as a door-to-service, with passengers selecting their pick-up and drop-off location when booking a request. Wang et al. (2019) [19] propose various systems including both door-to-door and station-to-station services, evaluating them according to the convenience of service providers and customers. Levin (2022) [42] also discusses the case where passengers are picked up and dropped off at stations and not at their final destinations.

Numerous papers evaluate SAV systems as a replacement of transit lines, in many cases introducing autonomous vehicles such as driverless shuttles for fixed routes. These have not been included in this review, since it is the belief of the authors that this approach eludes the investigation around how SAV systems should be introduced to provide a more efficient transport network when paired with public transit systems that already exist. Among these, an exception has been made for the following papers that base their contributions on analyzing which segments of public transport demand are more suitable to be replaced with SAVs services. Imhof et al. (2020) [29] compared two scenarios where

SAVs replaced in the first case the whole study area transportation system, and in the second only the current bus system integrating SAVs with the existing railway network. Pinto et al. (2019) [35] redesign the transit network together with determining SAV fleet size to optimally replace public transport routes that are inefficient in certain areas at certain times. While many authors consider multimodal trips for which public transport is used in the main trip stage, Bojic et al. (2021) [31] allow the whole public transportation segment to be replaced with a shared trip in an automated vehicle, and Levin et al. (2019) [32] consider transit to be used instead of or to complement SAVs only when total travel time is reduced. The integration problem between SAVs and PT has also been studied from a competitive perspective by Mo et al. (2021) [20], where the private enterprises which operate the two services are under government regulation but profit-oriented. The competition process as well as the system performance are evaluated from the perspective of four stakeholders: SAVs operator, PT operator, passengers, and transport authority.

4. Conclusions

The research presented in this paper proposed a literature review to identify recent studies that could provide an insight into the integration of shared autonomous vehicles (SAVs) in public transportation services. The literature is mainly focused on the context (urban or suburban extra-urban), the characteristics of the service (sharing and hailing policies, integration type), and the type of infrastructure for SAVs (dedicated or mixed traffic lanes). As for the methodological approaches, optimization and simulation tools are frequently used to model SAV services and determine the SAV fleet size and evaluate the appropriateness of different dispatch policies and operational strategies. In addition, behavioral approaches based on discrete choice modelling often occur in the literature; findings indicate that public transport users are more inclined to shift to SAVs than car users, who might potentially shift to private AVs (e.g., Song et al., 2021 [39])

Many authors indicate that if SAVs are operated as feeder modes to mass transit (first mile/last-mile solution) they could increase the attractiveness of the public transport, (e.g., Lau and Susilawati, 2021 [21]; Huang et al., 2020 [23]; Huang et al., 2022 [25]; Song et al., 2021 [39]; Fraedrich et al., 2019 [38]). On the other hand, a free-floating SAV service has the potential to foster competition with public transportation, increasing car travel and its adverse consequences (e.g., Tak et al., 2021 [22]; Lau and Susilawati, 2021 [21]; Feys et al., 2020 [40]; Levin et al., 2019 [41]). In fact, Lau and Susilawati (2021) [21] and Imhof et al. (2020) [29] underline that un-optimized PT-SAVs implementation may worsen existing traffic conditions.

Autonomous shared-ride schemes, as opposed to single-occupant rides, have higher potential to reduce traffic volumes in access and egress to and from public transport stations. We would therefore be inclined to say that a one-way SAV scheme connecting public transport terminals to sparse and low-demand areas seems to be the most effective system to integrate with public transport, as found for traditional non-autonomous ridesharing services (Stiglic et al., 2018 [44]; Bian and Liu, 2019 [45]). From an infrastructure point of view, a dedicated lane configuration has many advantages in terms of increased safety, but it requires higher investment costs than mixed traffic (Zubin et al., 2021 [37]).

Future research should attempt to confirm these hypotheses by determining which SAV service typology is the most suitable for specific contexts and network configurations. Comparative studies are fundamental to understand which service configuration better adapts to urban or suburban contexts. SAV dispatch policies are yet to be addressed under a sustainable perspective, promoting the use of collective transport while avoiding competition. It has not yet been thoroughly discussed (i) which are the criteria or general procedures to identify the best candidate transit stops where SAVs serve as the first- and last-mile feeder, (ii) SAVs operating area extension and distribution on the road network, and (iii) which strategies to adopt for selecting pick-up and drop-off locations when SAVs are used as collector-distributor for transit system. Lastly, SAVs are likely to be electric vehicles;

thus, appropriate charging infrastructure at PT terminals and "opportunity charging" strategies have to be further investigated.

As for the limitations of this review, results could have been limited by the potential omission of relevant studies not covered by the chosen keywords. Moreover, the search excluded records which may potentially be relevant such as books, chapters, editorials, and articles not in English.

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Appendix A

Table A1. Details of articles included in this review.

Reference	Pub. Year	Title	Main Topic
Bojic et al. [31]	2021	Identifying the Potential for Partial Integration of Private and Public Transportation.	Overlap analysis between taxi and bus trips to understand how many PT passengers could be served by SAVs, assuming SAVs to replace all taxi services
Feys et al. [40]	2020	Understanding stakeholders' evaluation of autonomous vehicle services complementing public transport in an urban context	Using the multi-actor multi-criteria analysis method, representatives from each stakeholder group were consulted to evaluate different PT-SAVs scenarios
Fraedrich et al. [38]	2019	Autonomous driving, the built environment and policy implications	Quantitative online survey and qualitative interviews with representatives from transport planning authorities in Germany
Imhof et al. [29]	2020	Shared Autonomous Vehicles in rural public transportation systems	Simulation of the possible effects of on-demand and door-to-door SAVs service to the public transportation system
Lau and Susilawati [21]	2021	Shared autonomous vehicles implementation for the first and last-mile services	Mesoscopic traffic simulation that couples SAVs to PT in intermodal context considering the travelers' mode choice preferences
Levin [42]	2022	A general maximum-stability dispatch policy for shared autonomous vehicle dispatch with an analytical characterization of the maximum throughput	Applicability of the minimum-drift-plus-penalty (MDPP) dispatch policy to PT-SAVs systems
Levin et al. [32]	2019	A linear program for optimal integration of shared autonomous vehicles with public transit.	Optimization procedure to integrate SAVs with transit to minimize passenger travel times
Liang et al. [30]	2016	Optimizing the service area and trip selection of an electric automated taxi system used for the last mile of train trips	Optimization approach to analyze the potential of using automated taxis as a last-mile connection of train trips

Table A1. *Cont.*

Reference	Pub. Year	Title	Main Topic
Maruyama and Seo [33]	2023	Integrated Public Transportation System with Shared Autonomous Vehicles and Fixed-Route Transits: Dynamic Traffic Assignment- Based Model with Multi-Objective Optimization	Optimization model based on dynamic traffic assignment for integrated public transportation system with SAVs and fixed-route transits
Mo et al. [20]	2021	Competition between shared autonomous vehicles and public transit: A case study in Singapore.	Agent-based model to simulate the competition between AV and PT, with both parties trying to increase their profit
Pinto et al. [35]	2019	Joint Design of Multimodal Transit Networks and Shared Autonomous Mobility Fleets	Bi-level mathematical program to allocate resources between transit patterns and SAVs in a large metropolitan area
Salazar et al. [9]	2018	On the Interaction between Autonomous Mobility-on-Demand and Public Transportation Systems.	Mesoscopic optimization approach that captures the joint operations of SAVs and mass transit. The objective is to minimize the customers' travel time together with the operational costs
Scheltes and De Almeida Correia [27]	2017	Exploring the use of automated vehicles as last-mile connection of train trips through an agent-based simulation model: An application to Delft, Netherlands	Agent-based simulation to model feeder service for conventional public transport operated by AVs, with a specific focus on last mile (egress)
Shan et al. [34]	2021	A framework for railway transit network design with first-mile shared autonomous vehicles	Optimization framework of railway transit network design and SAVs first-mile service that minimizes the total cost of the combined services as well as commuters' waiting time
Shen et al. [18]	2018	Integrating shared autonomous vehicle in public transportation system: A supply-side simulation of the first-mile service in Singapore	Agent-based simulation to examine the attributes of the interaction among stakeholders in an integrated system (AV operators, PT operators, riders, public authorities, and automakers)
Song et al. [39]	2021	People's attitudes toward automated vehicle and transit integration: case study of small urban areas.	Survey results are analyzed using text mining, factor analysis and regression analysis to understand people's attitudes toward PT-SAVs integration
Tak et al. [22]	2021	The City-Wide Impacts of the Interactions between Shared Autonomous Vehicle-Based Mobility Services and the Public Transportation System.	Agent-based simulation to analyze the potential impacts of future SAV operations on existing PT systems in different types of cities
Wali and Khattah [46]	2022	A joint behavioral choice model for adoption of automated vehicle ride sourcing and carsharing technologies: Role of built environment and sustainable travel behaviors.	The authors propose a novel discrete choice modelling technique to evaluate consumers' affinity towards SAVs with two distinct yet related configurations: automated vehicle (AV) carsharing and AV ride sourcing
Wang et al. [19]	2019	Exploring the Performance of Different On-Demand Transit Services Provided by a Fleet of Shared Automated Vehicles: An Agent-Based Model	Using an agent-based approach, the study simulates the on-demand operations of SAVs in a parallel transit service, considering both door-to-door service and station-to-station service
Wen et al. [28]	2018	Transit-oriented autonomous vehicle operation with integrated demand-supply interaction.	The paper proposes an agent-based simulation platform coupled with a discrete choice model to capture the interaction between service operator and travelers
Whitmore et al. [41]	2022	Integrating public transportation and shared autonomous mobility for equitable transit coverage: A cost-efficiency analysis.	Characterization of the economic feasibility of improving transit coverage and transit equity with SAVs

Table A1. *Cont.*

Reference	Pub. Year	Title	Main Topic
Huang et al. [23]	2020	Use of Shared Automated Vehicles for First-Mile Last-Mile Service: Micro-Simulation of Rail-Transit Connections in Austin, Texas.	Using the Simulation of Urban MObility toolkit (SUMO), the paper investigates SAVs first-mile last-mile connections to transit systems, replacing walk-to-transit or drive-to-transit
Huang et al. [24]	2021	SAV Operations on a Bus Line Corridor: Travel Demand, Service Frequency, and Vehicle Size	Microsimulation of SAVs' operation with SUMO platform on to understand how vehicle size and attributes of such SAV-based transit affect traffic, PT riders, and system cost.
Huang et al. [25]	2022	Shared automated vehicle fleet operations for first-mile last-mile transit connections with dynamic pooling	A dynamic pooling algorithm is applied to investigate the impact of SAVs serving as first/last-mile connections, coordinating the riders' arrival times at the light-rail station
Yap et al. [36]	2016	Preferences of travellers for using automated vehicles as last-mile public transport of multimodal train trips.	Based on an SP survey, the study explores travellers' preferences for AVs, focusing particularly on the use of these vehicles as egress mode of train trips
Zhou et al. [26]	2019	A System of Shared Autonomous Vehicles Combined with Park-And-Ride in Residential Areas.	The study, through an agent-based simulation, investigates the performance of a collaborative scheme involving park-and-ride services associated with public transport and a shared autonomous vehicle system
Zubin et al. [37]	2021	Deployment Scenarios for First/Last-Mile Operations With Driverless Shuttles Based on Literature Review and Stakeholder Survey	Based on surveys, the study formulates a set of deployment scenarios for the introduction of driverless shuttles as a first/last-mile option for intermodal modal trips

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