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Review

How Can Smart Mobility Innovations Alleviate Transportation Disadvantage? Assembling a Conceptual Framework through a Systematic Review

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Abstract: Transportation disadvantage is about the difficulty accessing mobility services required to complete activities associated with employment, shopping, business, essential needs, and recreation. Technological innovations in the field of smart mobility have been identified as a potential solution to help individuals overcome issues associated with transportation disadvantage. This paper aims to provide a consolidated understanding on how smart mobility innovations can contribute to alleviate transportation disadvantage. A systematic literature review is completed, and a conceptual framework is developed to provide the required information to address transportation disadvantage. The results are categorized under the physical, economic, spatial, temporal, psychological, information, and institutional dimensions of transportation disadvantage. The study findings reveal that: (a) Primary smart mobility innovations identified in the literature are demand responsive transportation, shared transportation, intelligent transportation systems, electric mobility, autonomous vehicles, and Mobility-as-a-Services. (b) Smart mobility innovations could benefit urban areas by improving accessibility, efficiency, coverage, flexibility, safety, and the overall integration of the transportation system. (c) Smart mobility innovations have the potential to contribute to the alleviation of transportation disadvantage. (d) Mobility-as-a-Service has high potential to alleviate transportation disadvantage primarily due to its ability to integrate a wide-range of services.

Keywords: smart mobility; demand responsive transport; connected and autonomous vehicle; Mobility-as-a-Service (MaaS); electric mobility; shared transportation; intelligent transportation systems; smart city; transportation disadvantage; social exclusion

1. Introduction

In recent decades, rural-to-urban migration influenced by factors such as increased employment opportunities, access to services, education, and communication networks has led to a period of rapid urbanization [1]. Over 50% of the world's population live in cities with this number expected to increase to 68% by 2050 [2]. While the environmental impact of providing transportation infrastructure in growing cities remains a primary concern in research [3], another important challenge relates to the provision of an inclusive, accessible, and affordable transportation for all individuals [4]. This is important as having access to transportation is crucial to improve social inclusion and allow people to access essential services, employment, and recreational facilities. Access to transportation is a critical component in achieving quality of life—particularly among vulnerable groups such as the elderly and disabled [5].

Transportation disadvantage relates to an individual's ability to access transport and is particularly prevalent in areas without good access to public transportation. In these areas, individuals must rely on "private motor vehicles" (PMV), which typically come with higher costs than public transport due to purchasing, fuel, maintenance, insurance, and storage costs [6]. This combined with increased population growth has had a significant impact on property values with areas around public transport nodes experiencing higher property values [7]. Lower income earners are then forced into surrounding fringe areas, further increasing transportation costs and exacerbating issues surrounding transport disadvantage [8].

Smart mobility has been identified as a potential solution to alleviate many of the issues associated with transport disadvantage [9]. Smart mobility, a general term used to describe many of the transport-related technologies that have been implemented in urban areas, represents a new way of thinking about transportation including the creation of a more sustainable system that is able to overcome some of the issues associated with PMV [10,11]. While the number of research articles that focus on smart mobility is growing, little research to date has focused on how smart mobility can address transport disadvantage. Similarly, where specific smart mobility innovations, such as "autonomous vehicles" (AV), "flexible transportation services" (FTS), and "free-floating e-mobility" (FFM), or the integration of intelligent technologies have been investigated as a potential solution to transport disadvantage, they are often treated as separate entities with only a few comprehensive attempts to conceptualize how their integration can contribute to or alleviate the issue [12]. This requires explicit consideration as these changes do not happen in a silo, but are rather concurrent, or even dependent, on each other.

This paper attempts to contribute to existing research by analyzing the way that smart mobility innovations can address transport disadvantage in cities. Using a systematic literature review as the research methodology, this paper seeks to answer the research question: How can smart mobility contribute to alleviate transport disadvantage? To answer this question and ensure all technological advances are considered, we first reviewed the literature to determine the innovations relevant to the smart mobility field, how they relate to each other, and what the major benefits of these systems are to urban areas. Then, by looking through the lens of transport disadvantage, major contributions were identified and associated with our research aim and question. From the literature review, a conceptual framework representing the relationship between the benefits of smart mobility innovations and the various aspects of transport disadvantage was developed with the view that it could help researchers better understand the relationship between the two concepts. This paper also highlights future areas of research that can help other look to smart mobility innovations to alleviate issues regarding transport disadvantage.

2. Background to Smart Mobility

Smart mobility as a concept has its roots within the smart cities model: driven by policy, technology, and community, the primary goal of smart cities is to deliver productivity, innovation, livability, wellbeing, sustainability, accessibility, and good governance and planning [13]. The conceptual framework shown in Figure 1 demonstrates this concept through a simple input–output–impact model. In the context of smart cities, the transportation system could be considered an asset of the city which is implemented through various drivers, including technology, policy, and community. When successfully implemented, these drivers should lead to more desirable outputs (or outcomes), the result (or impact) being a smarter city—or in this case a smarter mobility system [13].

Built into this concept of smart cities is the notion of smart mobility [10,14]. Similar to the broader smart city concept, smart mobility is partially driven by community and policy; however, much of the focus is on using technology as a way to transform the transportation system while addressing the societal, economic, and environmental impacts associated with PMV, including issues regarding transport disadvantage [15,16]. Some of these innovations such as "demand responsive transportation" (DRT) have been implemented by local governments as a way of offering services to those most in need or replace underutilized public transport systems. They are often viewed more as an extension of the existing public transport network than a stand-alone system [17]. Similarly, ubiquitous infrastructure ("U-Infrastructure") harnesses technological advances in ICT, "intelligent transportation systems" (ITS), and digital networks to improve efficiency of urban infrastructure [18].

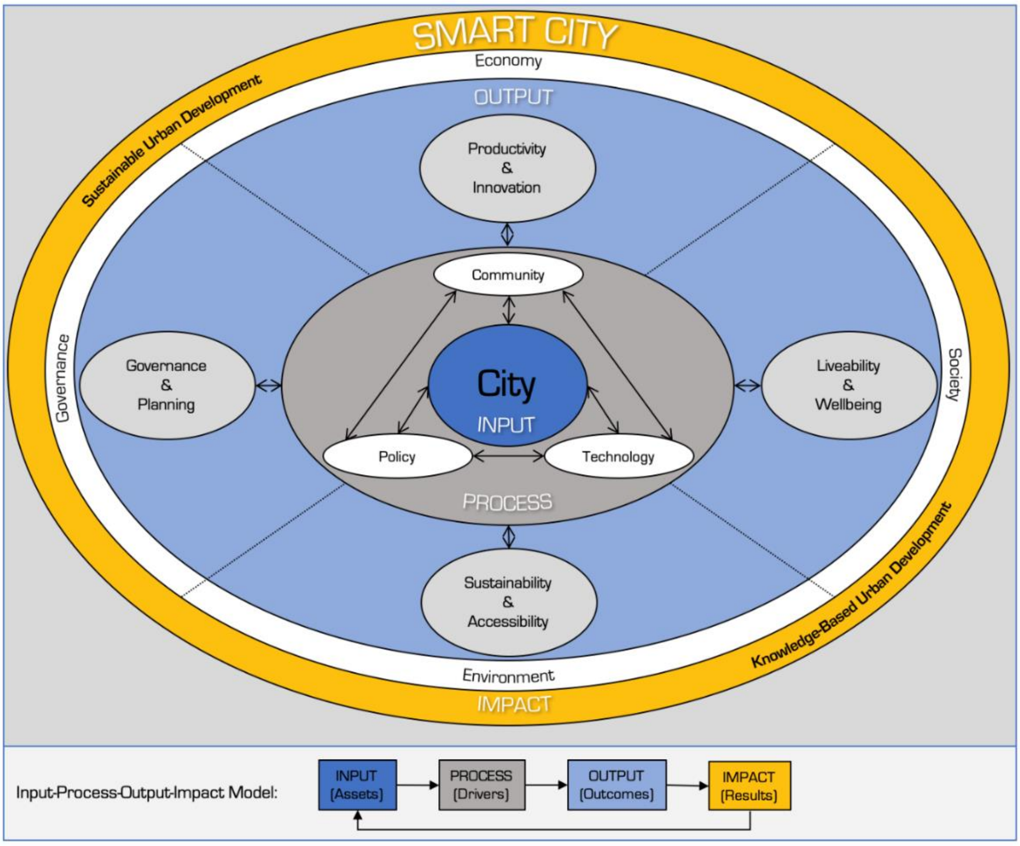

Figure 1. Smart city conceptual framework (derived from [13]).

Other systems including car sharing, ride sharing, FFM, AV, and alternative fuel vehicles are driven by private industry and with rapid advances in technology they are likely to disrupt the transport system, whether their benefits are harnessed by governments or they are left to evolve organically [19,20]. This was seen in 2015 in Australia following the introduction of Uber's ride sharing platform. Regulators were effectively left playing catch-up to a disruptive technology that was implemented and already in widespread use prior to the appropriate legislation being developed. The impact of this lack of foresight not only led to issues regarding overnight loss of value to taxi licenses [21] but has also led to concerns about the underpayment of workers [22], and an eventual oversaturation of the market [23].

There is an important distinction to be made here about how smart mobility innovation are introduced into the market and the importance of managing disruptive technology. While modern visions of smart mobility are generally optimistic and show a transportation system where everybody has equal access and PMV travel is replaced with services that users can access on-demand, the reality could be very different. In fact, as with the introduction of the automobile in the early 1900s, there is a risk that this new technology will create even greater issues that we were unable to see or predict due to a persistent cloud of optimism that shades our judgement. Thus, critical in the realm of urban governance is to develop an understanding of the potential contributions of smart mobility so that its impacts can be managed effectively and the societal, economic, and environmental objectives of the smart city are achieved [24].

The conceptual background for smart mobility outlined above underlines the importance of further investigating the contribution smart mobility can make to urban areas. This is particularly true with regards to the issue of transport disadvantage which could potentially risk further decline if smart mobility innovations are implemented into urban areas without any actions taken by decision-makers. Similarly, misunderstanding the potential benefits of smart mobility could lead to missing opportunities to improve the equity of the transportation system.

3. Materials and Methods

For this study, a systematic literature review was utilized as the methodology and based on the three-stage approach implemented by Yigitcanlar et al. [15]. The purpose of the review was to address the research question: How can smart mobility contribute to alleviate transport disadvantage?

The first stage in this process was planning. Our research objectives were defined as being to identify any relationship between smart mobility innovations and transport disadvantage. Based on this objective research aim and question, several keywords relevant to the subject area were developed. Primary inclusion criteria included articles that were peer-reviewed, published online, and in English. Secondary inclusion criteria were to only include articles that were relevant to the research aim. Exclusionary criteria were articles that did not meet the inclusion criteria. The keywords were then used to undertake an open-ended search to September 2020 using a university library search engine with access to 393 academic databases. Boolean search query was used with keywords, as shown in Figure 2. The initial search yielded 2136 articles.

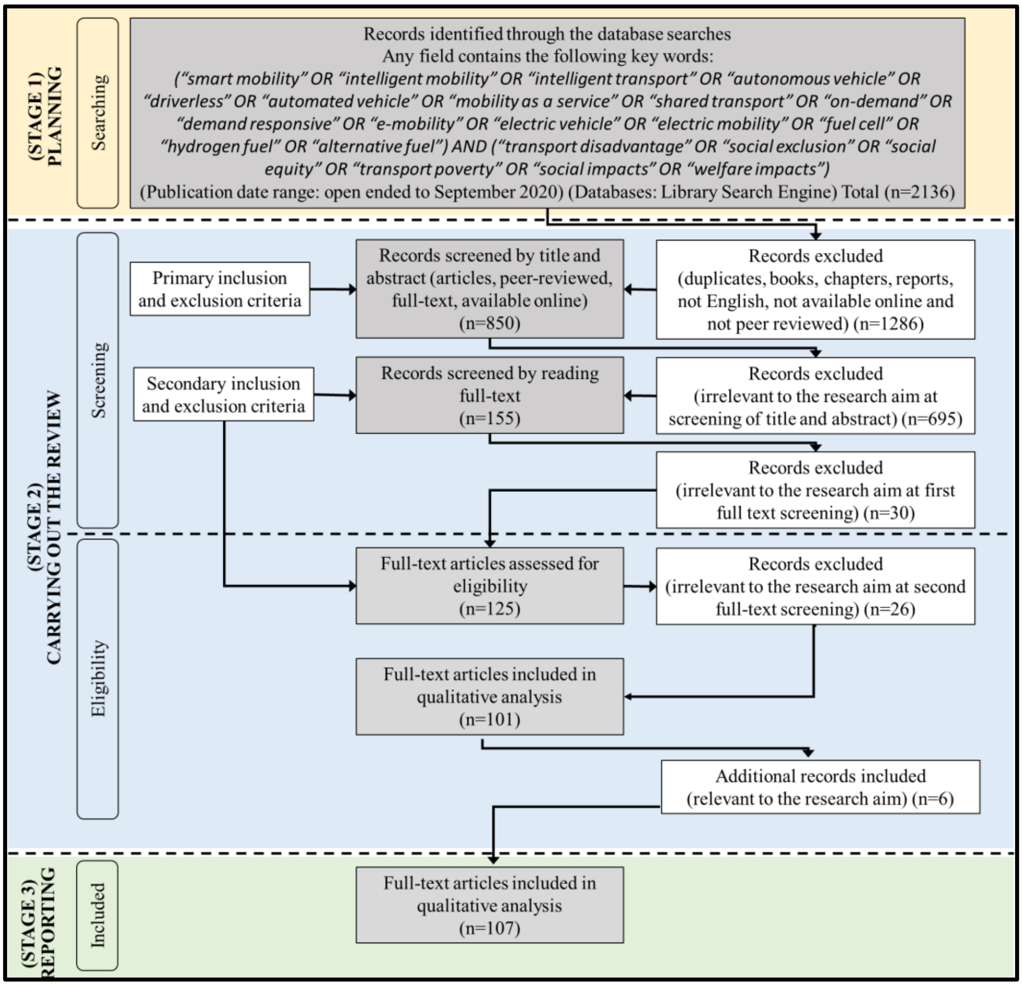

Figure 2. Literature selection procedure (source: authors).

The second stage of the process was performing the review. Abstracts of the proposed articles were scanned against the primary inclusion and exclusion criteria; duplicates and articles that did not comply with the criteria were removed. Following this, the full text of the remaining articles was read twice to ensure compliance with the secondary inclusion criteria. Articles irrelevant to the research aim were removed. In total, 99 articles were considered relevant to the research aim and included in the final qualitative review. Figure 1 provides a step by step outline of the literature selection and review.

The remaining articles (n = 101) were categorized using a directed content analysis method, whereby major themes were selected based on a theory or framework identified in the literature. An additional six publications relevant to research topic but not otherwise meeting the search criteria were also added to the study. As the purpose of the review was to determine the contribution smart mobility innovations could make to alleviate transport disadvantage, a framework was selected to ensure all relevant dimensions were considered. Based on a previous review of transport disadvantage by Yigitcanlar et al. [4], it was decided that Suhl and Carreno's [25] six dimensions for transport disadvantage—i.e., physical, economic, spatial, temporal, psychological, and information—would be used as it was the most comprehensive. The articles were then reviewed using a descriptive rather statistical technique. Pattern matching and other qualitative techniques, such as scanning for common subjects, were also used to group the articles into the pre-defined categories. As a result, relationships were identified between the transport disadvantage dimensions and the number of final categories reduced to three: (a) Physical and Economic (n = 39); (b) Spatial and Temporal (n = 33); and (c) Psychological and Information (n = 28). Following a review of the literature a seventh category, "institutional disadvantage", was also discussed (n = 7). A description of the relevant dimensions is shown in Table 1.

Table 1. Dimensions of transportation disadvantage (derived from [4,25]).

Dimension	Description
Physical	Relates to the physical barriers that may limit a person from accessing transportation. Limitations may include inability to operate a motor vehicle and inability to physically access a vehicle or public transport due to a disability.
Economic	Relates to the economic barriers that may limit a person from accessing transportation. Specifically concerns the personal cost of transportation and can include ticket price, fuel, insurance, storage, purchase, and travel time.
Spatial	Relates to the spatial barriers that may limit a person from accessing transportation. Often associated with geographic-related transport disadvantage in areas where public transport coverage is inadequate, and individuals are forced to own PMV to satisfy transportation needs.
Temporal	Relates to the temporal barriers that may limit a person from accessing transportation. Often associated with geographic-related transport disadvantage in areas where public transport frequency is inadequate, and individuals are forced to own PMV to satisfy transportation needs.
Psychological	Relates to the psychological barriers that may limit a person from accessing different transportation modes. This barrier can include issues associated with perception and safety.
Information	Relates to the information barriers that may limit a person from accessing different transportation modes. These barriers relate to an individual's ability to use and understand how to use transportation modes.
Institutional	Relates to the institutional and governance barriers that may limit a person from accessing different transport modes. These barriers include policy, regulations, registration requirements, and other local laws that may limit an individual's ability to use transportation.

The third and final stage of the process was reporting. In this stage, the analysis of the 107 articles completed during the screening stage was used to present the results by preparing and writing the final article. Finally, additional publications (n = 31) were used to support our findings, elaborate on our results, and provide a contextual background to this research.

4. Results

4.1. General Observations

Interest in the social issues surrounding smart mobility has grown over the past two decades. In fact, while only 2 of the selected articles were published before 2005, that number has continued to grow with 4 articles published during 2006–2008, 5 articles during 2009–2011, 13 articles during 2012–2014, 20 articles during 2015–2017, and 63 since 2018. Leading authors are affiliated with universities in Europe ($n = 58$), Oceania ($n = 19$), North America ($n = 18$), Asia ($n = 9$), South America ($n = 1$), and Middle East ($n = 2$). The articles were published in a wide-range of journal including Research in Transportation Economics ($n = 9$), Sustainability ($n = 9$), Transport Policy ($n = 7$), Journal of Transport Geography ($n = 6$), Transport Research Part A ($n = 5$), Transportation ($n = 5$), Travel, Behaviour & Society ($n = 4$), Transport Planning and Technology ($n = 4$), Transport Reviews ($n = 4$), Journal of Transport & Health ($n = 3$), Energies ($n = 2$), Energy Research & Social Science ($n = 2$), Land Use Policy ($n = 2$), Local Economy ($n = 2$), and Transportation Research Part D ($n = 2$). The remaining 41 articles were published in 36 different journals from a range of research areas including urban planning and policy, transportation, ethics, sociology, and health.

Articles were categorized into three groups based on the defined categories: Physical and Economic ($n = 33$), Temporal and Spatial ($n = 31$), and Psychological and Information ($n = 26$). With reference to the main smart mobility innovations, DRT were discussed in 40 articles, followed by AV ($n = 38$), ITS ($n = 25$), shared mobility ($n = 17$), "Mobility-as-a-Service" (MaaS) ($n = 12$), and "alternative fuel vehicles" ($n = 12$). Twelve articles discussed smart mobility generally but were not specific regarding technological innovations.

4.2. Smart Mobility Impacts

This section discusses the main innovations identified in the literature that are associated with smart mobility and what impacts these innovations will make to transportation. Understanding the broad impacts each of the innovations will have on the transportation system is important so that the flow on effects can be analyzed against each of the transport disadvantage dimensions.

The six major smart mobility innovations identified in the literature are: (a) DRT; (b) shared mobility; (c) ITS; (d) alternative fuel vehicles; (e) AV; and (f) MaaS. ITS, alternative fuel vehicles, and AV represent direct technological advances that will affect vehicles and infrastructure. On the other hand, while technology is critical to the development of DRT, shared mobility, and MaaS, they are more associated with innovations to the way transportation services are provided to the community rather than a direct impact to the vehicles and infrastructure in the transport system. A description of each of these innovations and relevant literature is shown in Table 2.

Table 2. Smart mobility innovations (source: authors).

Innovation	Description	Reference
DRT	DRT provides a transportation options distinct from traditional fixed-route services in that they utilize dynamic, semi-fixed, or fixed routes with users able to pre-book based on travel needs and services operated on-demand. The main impacts on the transportation system relate to ability to provide greater coverage and flexibility. Although existing DRT services have been criticized for their inability to manage high demand and provide the required service coverage at an appropriate cost unless supported by other innovations including ITS, AV, and shared mobility.	[26–33]

Table 2. *Cont.*

Innovation	Description	Reference
ST	Shared mobility refers to services where rides are shared with other users (e.g., ride-sharing) or vehicles are shared but used at different times (e.g., car sharing or bike sharing). Traditional types of shared mobility include car rentals, public transport, or taxis. Recent shared mobility innovations that make use of ITS, DRT, or battery-operated systems include FFM and peer-to-peer ride sharing apps such as Uber. The main advantage of shared mobility is that resources are shared among multiple users resulting in improved efficiencies in operation, storage, and cost. A move towards the shared mobility is a critical component for smart mobility innovations including DRT, AV, and MaaS to achieve sustainable city goals.	[34–42]
ITS	ITS refers to applications which utilize advances in ICT to effectively shared data between vehicles, infrastructure, and between users. ITS covers a broad range of applications including transport telematics, automatic information signs (ATIS), electronic ticketing, smart infrastructure, and in-car assistance, sensors, and other safety features. ITS is enhanced by advances in big data, Internet of things (IoT), cloud computing, and artificial intelligence (AI), which contribute to more efficient data collection, processing, and analysis. The primary advantage of ITS within the transportation field relates to its ability to optimize the performance of other technological innovations.	[43–46]
Alternative Fuel	Alternative fuel vehicles refer to those vehicles which do not rely on petroleum-based fuel sources. These vehicles use batteries for their primary fuel source, which in turn are fueled by non-petroleum sources such as the electrical grid, hydrogen, or solar power. Most literature focuses on the environmental benefits of this technology. However, with reference to transport disadvantage, the primary benefits of battery-operated vehicle relate to the convenience of FFM which provides users an assortment of conveniently placed powered transportation options which they can access on-demand.	[47–50]
AV	AV refer to vehicles that can be operated without input of a human driver. While there are various levels of autonomy for the purpose of this article any reference to AV assumes the vehicles can operate without human input in all conditions—unless otherwise stated. The primary advantage of AV relates to improved accessibility, operational efficiency, and safety.	[51–57]
MaaS	MaaS is a concept whereby a range of transportation options, including ride-sharing, car-sharing, public transport, and FFM, is offered to customers via a single online platform, or app. Users subscribe to the service which gives them access to various transport options that were traditionally offered separately. The advantage of MaaS is that as an integrated system it can provide the platform from which mobility providers are able to shared resources, and could contribute to better transport outcomes as any issues can be better considered by looking at the transport system as a whole rather than only concentrating on individual parts. MaaS can also provide the operational structure from which new transport innovations are released into the market.	[24,38,58–60]

The innovations often overlap to optimize the potential positive impacts. DRT systems and AV enabled by ITS technology are often referred to as real-time or dynamic FTS [61] and connected AV (CAV), respectively [55,62]. Shared AV (SAV) incorporates elements of shared mobility and AV [44], and FFM is essentially a combination of shared mobility, battery electric vehicles, and DRT [63]. MaaS forms an overarching platform in which each of these services can be bundled together [64]. A conceptual diagram is shown in Figure 3 to better understand the relationships between these innovations. This diagram is by no means exhaustive, for example free floating e-mobility incorporates elements of ITS, and, when offered as a bicycle service, it might not rely on electric powered engines. In addition, DRT are typically offered as shared mobility to improve efficiency and costs [65]. Nonetheless, the figure provides a conceptual outline to better understand the relationships between the various smart mobility innovations identified in the literature.

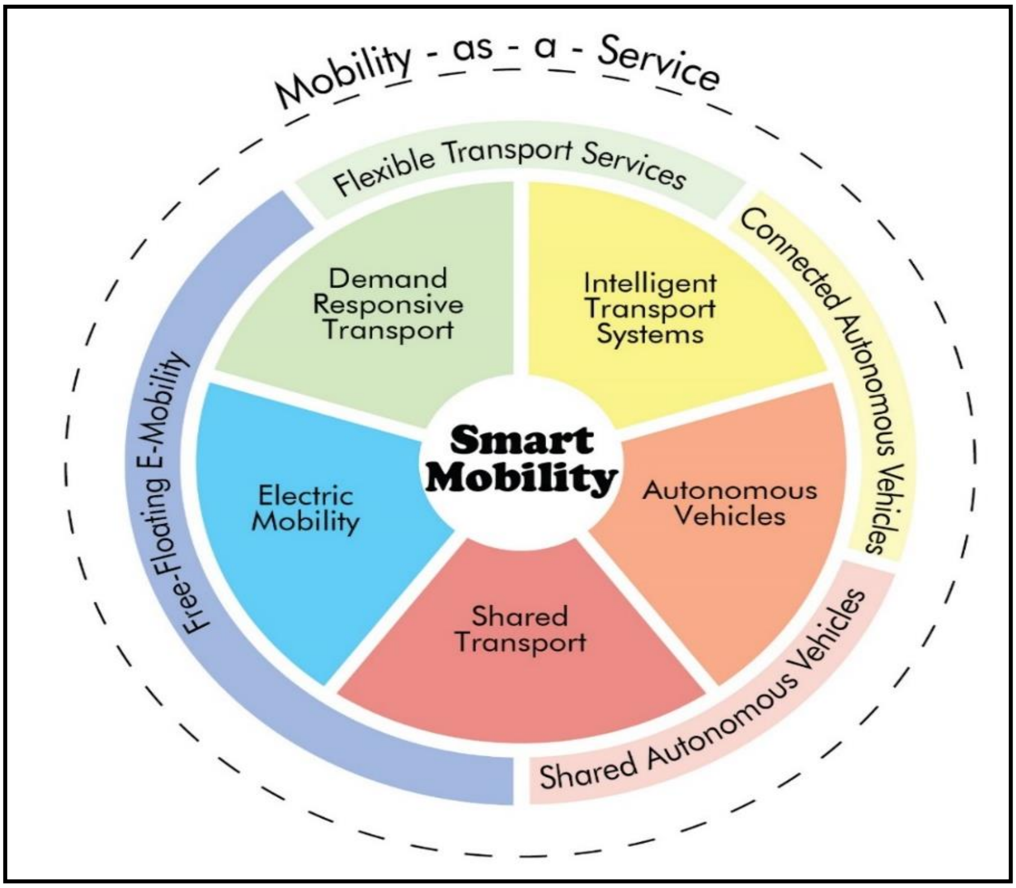

Figure 3. Relationship between smart mobility innovations (source: authors).

4.3. Physical and Economic Dimensions

This section discusses how smart mobility innovations can contribute to the alleviation of the physical and economic dimensions of transport disadvantage. Based on the reviewed literature smart mobility could alleviate the physical and economic dimensions of transport disadvantage by: (a) improving accessibility to transportation for those unable to access or operate a vehicle; (b) creating a transportation system in which services are more responsive to user needs; (c) reducing the cost for users by improve the efficiency of the transportation system and promoting a move towards shared mobility; and (d) improving the "value of time" (VOT) spent in transit. A list of all reviewed literature is shown in Appendix A.

Firstly, various smart mobility innovations have been shown to improve accessibility for those physically unable to access transportation or operate a vehicle. Access to a vehicle is an important factor in maintaining a good standard of living and providing security and freedom of movement to access social activities, employment, and other services, including healthcare [57,66], particularly in low-density areas [67]. DRT services that provide door-to-door transportation have been shown to improve user accessibility by reducing issues surrounding the first- and last-mile access of public transport [68]. In fact, when compared to traditional public transport services, one study showed high satisfaction with flexible DRT services resulting in a doubling of older users [69]. Furthermore, when operated as a shared service they have been shown to increase social interactions resulting in reduced feelings of isolation [68].

Despite the benefits of DRT, another commonly cited innovation to improve accessibility relates to AV [57,70]. As AV are able to drive without human input, the elderly, disabled, young, unlicensed, and those unfamiliar with local conditions may no longer be excluded from operating a PMV [51,71–73]. Even in a semi-AV setting, in-vehicle technologies such as crash avoidance; warnings for lane departure, collision, and blind spots; navigation systems; parking assistance; and adaptive cruise control may result in more elderly residents being able to hold onto their license for longer [52,74]. Some may also benefit from improved access to FFM including bike sharing, which would add additional accessibility options—particularly for short distance trips [75]. Due to these advantages, it is important that these services are implemented with regulations to ensure equal access [40].

Nevertheless, increased accessibility means that there is a risk of increasing accessibility to PMV. This could result in more demand for car ownership and increased per capita “vehicle kilometers traveled” (VKT) [10]. This premise is supported by research which predicts that AV will result in a mode shift away from public and active transport, increasing total VKT by 15–59% [57]. This could lead to increased externalities including congestion and urban sprawl and result in greater infrastructure and transit costs [53,57,76]. Due to this potential impact, researchers consistently highlight the benefits of shared mobility [53,56]. If fact, research shows that SAV would actually decrease VKT by 10–25% [57]. However, this shift is dependent on how shared mobility appeals to consumers and will require a significant cultural shift supported by policy and regulation, public awareness campaigns, and land use interventions—particularly in areas where PMV is the dominate mode choice [66,77].

Secondly, smart mobility innovations present an opportunity to provide services to the transport disadvantage populations that are more responsive to their specific needs. In fact, when enabled by other smart technology, DRT systems have been able to use advances in data collection, distribution, and analysis to improve decision-making, simplify ticketing, and enhance route planning, scheduling, and vehicle selection [29,78,79]. Data obtained from smart ticketing systems can be integrated and used to analyze the behavior of passengers and identifying service gaps [80]. AV are also important because without the need for a driver the internal layouts can be reconfigured to provide comfort and access based on special needs [72].

This is important as studies have found that, for shared mobility to be appealing, it needs to be flexible and able to satisfy individual needs—particularly with regards to having both on- and off-peak access to employment, healthcare, and recreational areas [81]. Integrated services such as MaaS can help by facilitating better multi-stakeholder collaboration and the sharing of information. The needs and trends of each individual user can then be used collaboratively to support the day-to-day operation of the entire system [82] and connect potential users with the most suitable providers [42].

Thirdly, there is potential for smart mobility to reduce transportation costs by improving the efficiency of the transportation system and promoting a move towards shared mobility. The integration of services through a MaaS-like system and the use of ITS has the potential to reduce administration and management costs. Cost savings related to the design of transportation systems could theoretically be passed onto the consumer or used to supply transportation services to the disadvantaged [24,79]. Using shared mobility as a replacement for PMV would also remove many of the economic barriers associated with ownership—e.g., purchasing, maintenance, insurance, and storage costs [39]. Parking costs would also be reduced under a shared system as vehicles would spend less time in idle [34,83]. However, the distribution of shared services is likely to favor areas with high demand and is unlikely to reduce issues associated with geographic-related transport disadvantage. Furthermore, disability related disadvantage is unlikely to benefit from car and bike schemes alone [34]. AV would be beneficial in this regard as removing the need for a driver would significantly reduce operational costs and help solve issues associated with accessibility. In fact, SAV have the potential to reduce total transportation cost by over 80% when compared to traditional PMV [39].

However, new technology also brings high upfront costs and low short-term return on investment. Thus, while research continues to show that there is a huge demand for more sustainable vehicles [84], residents are willing to pay extra for more environmentally friendly options [49], and shared mobility is cheaper than car ownership [85], it may be difficult to guarantee economic sustainability—particularly in the short term. For example, while the use of alternative environmentally friendly fuels often achieves better economic performance, the high cost of vehicles—particularly hydrogen fuel cell vehicles—can make the economic sustainability of such vehicles difficult [48]. Similarly, despite potential for lower maintenance costs, reduced accidents, and overall efficiency, the high upfront cost may limit potential for market penetration [85].

Finally, cost alone might be not be enough to sway users to a shared system. In fact, in many countries, the modes with the lowest cost of operation—e.g., public and active transportation—are often not the ones with the highest market share. Other factors, such as comfort and prestige, also play a part [39]. AV could transform interior of private vehicles into mobile offices, dwellings, or entertainment and communication hubs improving the VOT by facilitating the ability to work, eat, socialize, and rest while in transit [56]. This could improve work life balance and reduce stress—particularly among those who travel regularly. Conversely, increasing VOT may also lead to an increase in VKT, further exacerbating issues associated with infrastructure demand and urban sprawl [39,86].

From an economic perspective, the increase in demand for private AV may also lead to disadvantaged populations being priced out of the market, leaving them unable to benefit from the advantages of the technology [40,56,87]. Similarly, with alternative fuel vehicles, users unable to afford the new technology may be charged with a Pigouvian tax to discourage the use of fossil fuels [47,50,88,89]. Increased use in private AV and shared mobility may also lead to a reduction in public transport use, reducing revenue and resulting in higher costs and future degradation of services. This is likely to impact lower income and geographically disadvantaged residents the most [56,90].

There is also economic risk associated with an integrated transportation system such as MaaS. Where a single entity is responsible for the selection and distribution of mobility providers, the system itself may become a barrier to new transportation companies entering the market. This could result in monopolization, increasing the risk of uncompetitive markets, price gouging, and other unfair businesses practices [76,91]. Conversely, government control could create tension with the private sector, which is critical in the development and funding of new transportation innovations [24,76]. If we are to rely on private companies to provide most of the services, it is unlikely that off-peak and low demand services would be provided, and significant subsides, political engagement, and planning would be required to ensure that societal goals are being maintained [92].

4.4. Spatial and Temporal Dimensions

This section discusses how smart mobility innovations can contribute to the alleviation of the spatial and temporal dimensions of transport disadvantage. Due to the association with time and distance, this dimension is most closely related to issues surrounding geographic-related transport disadvantage. Based on the reviewed literature, smart mobility could alleviate the spatial and temporal dimensions of transport disadvantage by: (a) filling gaps in the public transport network by improving the coverage and frequency of services; (b) strengthening the connection with public services by designing services to act as a feeder system which connects to major public transport nodes and employment centers; (c) improving the flexibility of public transport by offering services on-demand; and (d) creating more transportation choices in areas where choice is traditionally limited. A list of all reviewed literature is shown in Appendix A.

Firstly, literature on smart mobility consistently identifies smart mobility innovations as a way to fill gaps in the public transport network. In doing so, smart mobility can contribute to improved coverage and frequency of services [43,93]. DRT services, in particular, have been highlighted as a way to provide door-to-door transportation by using fleets of smaller shared vehicles as opposed to fixed route services [94]. Other advantages of using smaller vehicles over traditional buses is that they have a lower operational cost per passenger and can access areas with smaller road widths [94]. However, these services often require significant government subsidies as they do not have the required number of users to support profitability over the required coverage [35,95]. While subsidizing these services may be more economical than providing fixed route public transport [96], ITS can also help better match supply and demand and develop locally specific strategies that also contribute to lower costs and better efficiency [95,97]. ITS has been shown to allow better real-time control over the networks and enhance the potential for DRT to provide increased flexibility and greater coverage while bringing costs closer to that of public transport [27,43]. SAV has also been identified as a way to improve coverage particularly by reducing the instance of dead runs [33,98].

Notwithstanding, there will also be issues associated with providing the necessary infrastructure to facilitate suitable network coverage [99,100]. Furthermore, when promoting alternative fuel vehicles that generate electricity from the grid, there may be issues associated with grid capacity. Infrastructure issues are intensified in low density and rural areas due to inadequate infrastructure and longer transmission distances [47,50,101]. As such, low-density areas would still attract higher transportation costs than high density areas, and significant investment is required for ensure geographic equity [101]. One solution relates to cross-subsidization where profits made in areas with high demand are used to subsidize and fund the required infrastructure in areas with lower demand [47,95]. By sharing information and resources across the transportation system MaaS can help facilitate this cross-subsidization to ensure maximum profitability and promote social equity [83]. Furthermore, since subsidies may make low density housing more attractive, planning interventions that promote walking, cycling, higher densities around employment and transit centers, and investment in high speed public transport remain important [59,102].

Secondly, smart mobility can be used to support investment in high-speed public transport by using innovative services to act as a feeder system, which acts as a first- and last-mile connection to major public transport nodes and employment centers [96]. Theoretically, improved access to public transport would reduce car dependency and therefore reduce transportation costs [103]. DRT systems could be timed to public transport hubs to ensure reductions in transfer times. Public transport would therefore form the backbone of these “pulse networks”, which could also allow for integrated ticketing and services [103]. The overall coverage of these networks could be supported by shared mobility such as FFM that would provide connections for shorter distances and provide more transportation options [37,104]. By limiting long trips, directly into denser urban areas congestion will be reduced, which means individuals who are required to travel by PMV will likely see a reduction in fuel price and time spent in traffic [96].

Efficient trip chaining is also important as studies have shown that users are more sensitive to travel time than travel cost; thus, ensuring transfers are easy and free from unnecessary delays can contribute to improving the appeal of public transport [105]. ITS has a role in improving the efficiency of these transfer, by improving the ability to apply real-time alterations to routing [26,104,106]. In fact, studies have shown that DRT services that connect directly to major transportation hubs and are enabled by ITS contribute to increases in total public transport ridership [27,107]. Furthermore, significant modal shift away from PMV has been observed when “artificial intelligence” (AI) is used to configure routes to reduce travel time [108] or through the use of MaaS systems to create synergies between mobility providers [109].

Thirdly, by improving the flexibility of public transport and offering services on-demand, transportation systems can be designed to respond directly to the specific geographic and social characteristics of the local area [32,97]. For example, in some areas, such as those with large numbers of tourists, conventional public transport with fixed schedules and timetables may be more advantageous [28,110]. In addition, in areas with higher numbers of people unable to operate a vehicle, car sharing schemes should be limited in favor of more flexible routes and timetables [111]. Similarly, in very low-density areas, semi-fixed, as opposed to door-to-door, services may be more efficient [33]. In designing transportation systems, planners should consider how changes respond to local characteristics and ensure the optimal allocation of available resources [32]. Furthermore, any local transportation plan should be able to be scaled up if demand increases to ensure equal and equitable coverage [96].

Finally, using smart mobility to create more options for users in areas where transportation choice is limited can be beneficial [59]. Having more mobility options available to users has been identified as an important step to overcome the culture of PMV ownership. Similarly, supportive policies with awareness of shared services would be useful [112]. MaaS provides an opportunity to bundle services and offer a range of options to consumers through a single online platform [83,109]. Alternatively, transportation choice may also include the choice to not travel. Advances in the design of digital neighborhoods, smart homes, ICT, and home delivery has the potential to remove the need for physical trips—particularly those related to employment [94,112]. Similarly, with the view to reduce PMV, ICT and data obtained from ITS can be used to help residents make more informed decisions regarding residential or work location [113].

4.5. Psychological and Information Dimensions

This section discusses how smart mobility innovations can contribute to the alleviation of the psychological and information dimensions of transport disadvantage. Based on the reviewed literature, smart mobility could alleviate the spatial and temporal dimensions of transport disadvantage by: (a) improving the safety of travel; (b) improving the perception of existing transportation options; and (c) improving the ability to make informed decisions. A list of all reviewed literature is shown in Appendix A (Table A1).

Firstly, smart mobility innovations have been shown to contribute to improved safety in the transportation system. This is important as the perception of safety is critical to ensure individuals want to use smart mobility [54]. AV have the potential to significantly reduce the number of vehicular accidents caused by human error [54,55,114]. CAVs can use advances in ITS, ICT, and AI data processing to communicate with other vehicles, infrastructure, and sensors, identifying dangers early and further improving safety for drivers and pedestrians [55]. In addition, given that no driver is required in the internal configuration, it can be reconfigured to add to the safety of the vehicle [55]. Similarly, DRT that offers door-to-door transportation and shared mobility are perceived as a safer option than public transport—particularly at nighttime [30,31,115].

Nonetheless, from the perspective of the user, safety not only comes from feeling safe while engaged in journey, but also with regards to digital safety [36,116]. In fact, lack of trust in technology is consistently identified as a reason for not using new transport technologies, particularly among the elderly [54,117–119]. This is understandable as increased reliance on technology introduces additional risks including those related to data privacy, cyberterrorism, grounding of fleets due to grid failures, faulty data [55,120], unconscious bias [114], and questions of legal liability [121]. To build trust, significant investment is required in cyber and data safety. Information campaigns are also beneficial to garner support among late adopters [119].

Secondly, there is potential for smart mobility innovations to improve the perception of existing DRT and public transport systems. Many DRT have been implemented around the world; however, the perception of these services is often that they are for the old and disabled—even when they are offered to all in the community [122,123]. Furthermore, users who benefit the most from the services are often confused and unclear about how these new transportation services could serve them [123–125]. In fact, research has shown that attitudes towards smart mobility among those with disabilities was entirely dependent on having prior knowledge of the technology [125]. Those with more knowledge tended to be more positive [126].

More information about potential routes and scheduling could help users better navigate new transportation innovations [124]. MaaS can help with this by providing all services and relevant information through a single digital platform giving users unbiased choice of various modes [38,60]. In addition, as all services are effectively bundled together, any offerings that are targeted towards those with special needs may no longer be viewed as an entitlement but would instead be part of a city, regional, or nationwide system that is synergized to benefits all of society [58].

Finally, smart mobility could improve the ability for commuters to make informed decisions. Technological advances in ITS can facilitate the collection and analysis of large amounts of data from cameras, sensors, vehicle locations, smart ticketing systems, social media, credit cards, mobile phones, and many other sources [13,45,127]. Automating the analysis of this "big data" could help individuals with route planning and vehicle selection [44,46,128]. The ability to make informed decisions based on real-time data can help commuters reduce uncertainty, fear, discomfort, enhance user experience, and improve confidence [44,45,115].

However, given the reliance on smart technology, there are issues associated with technical literacy and the digital divide [36,38,116,117]. The digital divide refers to the gap between those who can access ICT and those who cannot. This issue is not only associated with the spatial distribution of network coverage or equality of access to physical smart devices but also the ability for particular socioeconomic groups to use and understand the technology [36,117,127]. Statistically, the elderly, lower income, female, and disabled are less familiar with new technology due to lower lifelong exposure to ICT. Therefore, they often struggle to quickly learn the required skills to access and pay for digital services [117,127,129]. This is where an integrated system such as MaaS can help. By integrating a range of mobility providers into a single platform, it could simplify the process for accessing transport by reducing complexity and the need to cycle through various mobility applications [127]. Stakeholder engagement and public participation is also important to understand existing challenges within the community [130].

4.6. Institutional Dimensions

Upon review of the literature, a seventh and final transport disadvantage dimensions has emerged. The "institutional" dimension includes institutional and governance related barriers including policy, regulation, and institutions that may limit an individual's ability to use a transport mode or service. Based on the reviewed literature, smart mobility innovations do not necessarily directly contribute to the alleviation of this barrier. However, given the fast pace nature of technological change within the transport sector—including widespread trials of smart mobility services including DRT, AV, and MaaS and the rapid emergence of new technologies associated with car-, bike-, and scooter-sharing—it is important that decision makers understand the strengths and weakness associated with them so that opportunities and risks can be identified. This is important because public sector does not necessarily function adequately in times of uncertainty [76] and a failure to address the short- and long-term issues associated with these transport services could exacerbate negative externalities associated with the transport system. It is therefore important that strategies remain flexible so that they can adapt to changing circumstances and community needs [30,131].

It is critical that institutional barriers do not inhibit the ability for users to access services which could have wider societal benefits including high cost and inconvenience of registering for new services [132], laws that explicitly ban the use or inhibits the ability to use a mode or services within a particular area [133], or lack of available infrastructure to support mode choice—e.g., lack of dedicated active and public transport infrastructure [134]. Of equal importance is the use of institutional measures to promote and support the development of smart mobility. These could include: (a) establishment of standards for data management and sharing, which should be established on a national or transnational level [135]; (b) institutional support structures to assist with community adaptation to new technology, particularly among disadvantaged groups including elderly, migrants, or disabled [136]; (c) development of parking restrictions to discourage private vehicle use [131], engaging the public in decision-making [130]; and (d) ensuring public value and societal goals are maintained [24,137].

5. Discussion

5.1. Key Findings

This review study investigated the impact of smart mobility innovations through the lens of transport disadvantage. Specifically, the review sought to answer the research question: How can smart mobility contribute to the alleviation of transport disadvantage? Firstly, some common smart mobility innovations were identified and the relationships between these innovations shown. These innovations include new vehicular and infrastructural innovations such AV, ITS, and alternative fuel vehicles, in addition to new and existing ways of offering services to the community including DRT, shared mobility, and MaaS. These innovations will likely benefit urban areas by improving accessibility, efficiency, coverage, flexibility, safety, and integration of the transportation system.

The study also showed how smart mobility innovations have the potential to contribute to the alleviation of all six dimensions of transport disadvantage: (a) physical; (b) economic; (c) spatial; (d) temporal; (e) psychological; and (f) information. We also discussed some implications associated with a seventh, "institutional", dimension. Potential risks have been identified, and there are a number of key actions that can be taken to alleviate these risks. Of these actions, the implementation of MaaS and shared mobility appears as a common thread to overcoming the risks associated with smart mobility.

Firstly, a move towards the shared mobility is critical to ensure resources are shared efficiency and services offered have the required accessibility, coverage, and flexibility to reach all users and do not result in excess consumer costs or reliance on government subsidies. This conclusion is reflected in studies on DRT [66], AV [39,40,52], and MaaS [40].

Secondly, the review showed that it is often a combination of innovations that will best benefit the transport disadvantage. For instance, DRT and AV are shown to work more efficiently, and safely, when enabled by ITS and other smart technology including big data and cloud computing. Furthermore, the negative externalities associated with AV use, including increased VKT, suburbanization, and infrastructure demand, are significantly reduced when operating within a shared economy. This highlights the specific advantages of MaaS, which as an integrated system can provide the operational structure from which new innovations are trialed and released into the market. It also can help connect users to shared mobility and provide a platform from which mobility providers share resources. Sharing data between mobility providers could help decision-makers achieve better outcomes as issues associated with transport disadvantage can be considered by looking at the transportation system as a whole rather than concentrating on individual parts. Similar conclusions regarding the importance of MaaS as an overarching operational structure is supported by a number of studies including Gonzalez-Feliu et al. [82], Mulley and Kronsell [58], Soares Machado et al. [38], and Beecroft et al. [116].

Lastly, a summary of smart mobility potential contribution and risks and their association with transport disadvantage dimensions is shown in Table 3.

5.2. Conceptual Framework

Within the realm of smart mobility, a key challenge to overcome transport disadvantage is to understand how the specific benefits of new transportation innovations can be harnessed to respond to each of the dimensions of transport disadvantage. The results of the literature review highlight important relationships between the benefits of smart mobility innovations and the different dimensions of transport disadvantages. Specifically, the review showed that the benefits of smart mobility can be specifically aligned with the corresponding transport disadvantage dimension. A conceptual framework showing the relationship between these factors is shown in Figure 4. For the purpose of providing a conceptual framework related to how smart mobility can alleviate transport disadvantage, the institutional barrier has been excluded from the framework as it is not a barrier that can be overcome by smart mobility innovations alone. Nevertheless, supportive policy, regulations, and other governance structures are critical to the implementation smart mobility in a way that strengthens its benefits while responding to issues of transport disadvantage.

Table 3. Summary of literature review findings (source: authors).

Dimension	Contribution	Risk	Potential Actions
Physical	Improved accessibility to vehicle Door-to-door transportation Connection to public transport Increased social interactions More transportation options More responsive to specific need	Unequal access to services Increased VKT per capita Increased suburbanization Unappealing to user	Integration of services (MaaS) Marketing and education Policy and Regulation Promote shared mobility
Economic	Improved efficiency of system Reduced consumer costs Increased VOT	Unequal access to services Increased VKT per capita Increased infrastructure demand Increased suburbanization Monopolization	Integration of services (MaaS) Promote shared mobility Land use planning interventions Subsidies Stakeholder engagement
Spatial	Improved coverage of services Fill gaps in public transport network Feeder system to public transport	Increased infrastructure demand Network coverage Grid capacity Unequal access to services	Active transportation infrastructure Cross-subsidization Digital neighborhoods Integration of services (MaaS) Marketing and education Promote shared mobility
Temporal	Improved flexibility of services Better real-time control of network Better match supply and demand Reduced transfer times Reduced congestion	Routing should be specific to needs	Analysis of local characteristics Digital neighborhoods Invest in intelligent technology (ITS) Integration of services (MaaS) Marketing and education
Psychological	Improved safety of vehicle Safety of door to door transportation Improved perception	Data safety Cyber safety Unconscious bias Legal liability	Invest in intelligent technology (ITS) Marketing and education Promote shared mobility
Information	Improved integration Improve decision-making	Digital divide Technology literacy	Integration of services (MaaS) Invest in intelligent technology (ITS) Stakeholder engagement
Institutional	Opportunity for change	Rapid technological change Increase negative externalities Lost opportunity	Adaptive policy and regulations Supportive governance structures

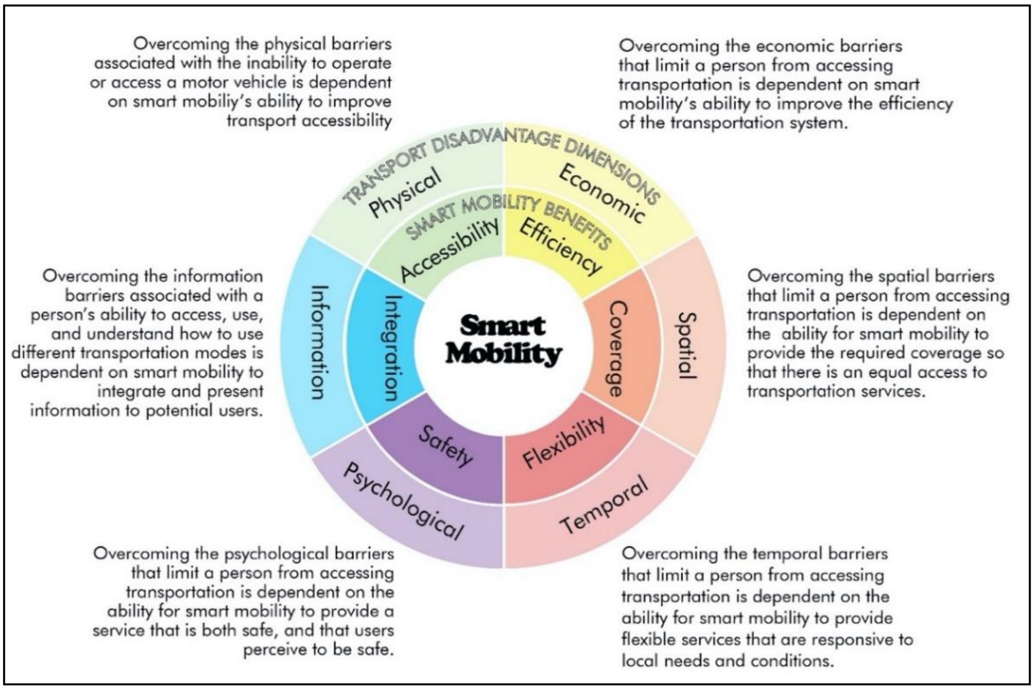

Figure 4. Conceptual framework of smart mobility and transportation disadvantage (source: authors).

Firstly, when looking through the *physical* dimension of transport disadvantage, the primary contribution of smart mobility is its ability to improve transportation *accessibility* through implementation of AV, flexible door-to-door transportation, strengthening connections with existing public transport networks, providing more mode options, or specifically targeting user needs. Similarly, when looking through the *economic* dimension of transport disadvantage, the primary contribution of smart mobility is its ability to improve transportation *efficiency*, which could contribute to reduced consumer costs—whether by reducing cost of actual travel or increasing the VOT spent in traffic.

Secondly, when looking through the *spatial* dimension of transport disadvantage, the primary contribution of smart mobility is its ability to improve transportation *coverage* by filling gaps in public transport or acting as a feeder system to major public transport nodes. Similarly, when looking through the *temporal* dimension of transport disadvantage, the primary contribution of smart mobility is its ability to improve *flexibility* by moving towards dynamic routing of transportation services, having more real-time control over the transportation network, better matching supply and demand, reducing transfer times and reducing congestion for those who are required to travel by PMV.

Finally, when looking through the *psychological* dimension of transport disadvantage, the primary contribution of smart mobility is its ability to improve transportation *safety*, whether through the use of AV which removes the need for a human driver, ITS that communicate with vehicles and drivers regarding potential hazards, or door-to-door transportation that removes safety concerns associated with accessing fixed-route public transport stops—particularly in low occupancy areas. Similarly, when looking through the *information* dimension of transport disadvantage, the primary contribution of smart mobility is its ability to integrate a wide range of data and services which can be used to improve decision-making whether those decisions are made autonomously or following analysis of available data regulators, mobility providers, and users.

Given the relationship between smart mobility and transport disadvantage, the challenge for decision-makers and mobility providers is to analyze specific case study areas to determine the issues associated with transport disadvantage that are most relevant. From there, the smart mobility benefits that most closely represent each of these dimensions can be used to identify which innovation is best suited for the local area.

5.3. Research Directions

Few studies identified in this review considered the six smart mobility innovations together as a broad driver for change in the transportation system. Given that alternative fuel vehicles, such as battery electric and hybrid electric, and ITS have already started to be introduced into urban areas, and trials of AV are prevalent throughout the world, it is problematic to analyze each of these technological drivers as individual entities that will not interact and influence the success, or failure, of each other. The management of these technological innovations is therefore necessary to harness their benefits in response to transport disadvantage. That is why new operational structures and ways of looking at the transportation system including DRT, shared mobility, and MaaS remain important.

Nonetheless, while DRT systems are not new and have been implemented throughout the world—as an alternative to public transport and targeted toward those experiencing disadvantage—it has developed a stigma whereby it is often viewed as an option for only the aged and disabled. Similarly, shared mobility offered by private industry including ride-sharing, car-sharing, and FFM are typically targeted towards users in centralized, denser areas where the highest demand is available to ensure maximum profit. These services, therefore, rarely benefit those experiencing transport disadvantage, and often only exacerbate existing issues with unequal accessibility. As an integrated service, MaaS represents a new way of branding DRT, while enhancing public transport, shared mobility, and other elements of the transportation system. Furthermore, MaaS presents a unique opportunity to provide the platform from which new innovations are introduced into market, the data analyzed, shared, and used to assess its suitability for alleviating transport disadvantage, and other related issues.

Prospective research should, hence, look at ways to use MaaS to harness the benefits of smart mobility innovations and attract users to shared mobility and public transport. MaaS is a relatively new topic so further research could focus on the barriers, and risks associated with implementing MaaS within urban areas. Analysis throughout a range of case study areas using transportation modeling, consumer surveys, expert opinion, and trials could also identify issues specific to the varying characteristics of different regions, including those associated with regulatory systems, policy frameworks, cultural differences, and geographic conditions.

Secondly, research could also focus on other innovative ways to integrate transportation modes, attract users to shared mobility, or develop alternatives systems. Research could explore the role of other technological advances outside the field of transportation including 5G, AI, digital twins, virtual reality, blockchain, IoT, big data, and cloud computing. For example, the use of virtual reality and augmented reality could be used to educate, market, and promote new transportation innovations towards individuals and business. Similarly, it could be used to let users experience new transportation technology prior to analyzing their attitudes.

Finally, given the recent events associated with the COVID-19 pandemic and its potential implication on consumer attitudes towards shared mobility, there is also a need to analyze whether the experience has changed user perspectives and willingness-to-ride shared, and public transport. This is important as attitudes may be changing due to increased awareness of vulnerabilities associated with virus transmission from passengers sharing close quarters in vehicles that often rely on centralized air-conditioning and little ventilation [138]. Furthermore, given these unprecedented events and the pressure on individuals and business to quickly adopt remote working and social environments transportation researchers may be more inclined to ask whether no mobility is smarter than smart mobility. From a transport disadvantage perspective research could be undertaken to compare individual transportation needs before, during, and after the lockdown experiences. Representatives from the commercial sector could be interviewed to discuss experiences with remote working, and how the experience will shape business models into the future, as one of the advantages of remote working is that for many jobs individuals may no longer be limited to employment opportunities due to location or issues with being able to afford or access transportation that is responsive to their needs.

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Appendix A

Table A1. Reviewed literature pieces.

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Mageean, J., and Nelson, J. D.	2003	The evaluation of demand responsive transport services in Europe.	Journal of Transport Geography	UK	Temporal and Spatial	Finding presents results from an evaluation of DRT in sites across Europe	Identifies transportation telematics as a way to improve the efficiency DRT systems.
Brake, J., Nelson, J. D., and Wright, S.	2004	Demand responsive transport: towards the emergence of a new market segment.	Journal of Transport Geography	UK	Temporal and Spatial	Findings highlight issues relating to the development of DRT.	Describes how DRT services can be enhanced by ITS to better deal with high demand, route planning, and integration.
Brake, J., and Nelson, J. D.	2007	A case study of flexible solutions to transport demand in a deregulated environment.	Journal of Transport Geography	UK	Temporal and Spatial	Findings demonstrate the evolution of public transport in the case study area and highlights the potential for better integration if deregulated	Provides insights into the use of the DRT to fill gaps in public transport networks particularly in dispersed areas.
Ferreira, L., Charles, P., and Tether, C.	2007	Evaluating Flexible Transport Solutions.	Transportation Planning and Technology	Australia	Temporal and Spatial	Findings report on a recent study of the use of FTS in Brisbane, QLD.	Describes how FTS have the potential to increase public transport use by providing a more customer centric and adaptive solution to the first-last-mile problem.
Hensher, D. A.	2007	Some Insights into the Key Influences on Trip-Chaining Activity and Public Transport Use of Seniors and the Elderly.	International Journal of Sustainable Transportation	Australia	Psychological and Information	Findings show that "the loss of a driver's license and a partner have the potential to be major contributors to social isolation in the absence of inadequate flexible public transport and or support mechanisms that enable access to the car as a passenger."	Identifies the potential for ATIS and ITS signs to provide dynamic information targeted directly to elderly drivers, such as avoiding challenging routes.
Zografos, K., Androutsopoulos, K., and Sihvola, T.	2008	A methodological approach for developing and assessing business models for flexible transport systems.	Transportation	Greece	Physical and Economic	Develops a methodology for the development of flexible transport systems.	Describes how FTS allow flexibility in assigning routes, schedule, vehicles, and ticketing systems making them more responsive to local needs.
Battellino, H.	2009	Transport for the transport disadvantaged.	Transport Policy	Australia	Temporal and Spatial	Findings brings attention to the potential for scheduled transport services to fulfil transport needs in rural communities	Describes how DRT could be used to enhance the availability and scope of community transport to better service residents who need it most.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Mulley, C., and Nelson, J. D.	2009	Flexible transport services.	Research in Transportation Economics	Australia	Temporal and Spatial	Findings that if implemented correctly flexible transport systems have the potential to improve bus services	Describes how the use of ITS to better match supply and demand can improve the efficiency of DRT and lead to lower costs more reflective of PT.
Nelson, J. D., Wright, S., Masson, B., Ambrosino, G., and Naniopoulos, A.	2010	Recent developments in Flexible Transport Services.	Research in Transportation Economics	UK	Physical and Economic	Proposes the introduction of an organizational structure (FAMS) to help with the introduction of flexible transport services	Discusses the use of FTS to compliment conventional public transport by responding directly to user-demand.
Santos, G., Behrendt, H., and Teytelboym, A.	2010	Part II: Policy instruments for sustainable road transport.	Research in Transportation Economics	UK	Temporal and Spatial	An analysis of policies related to sustainable road transport which fall into three categories: physical, soft, and knowledge policies.	Discusses how subsidized demand responsive taxis could replace conventional public transport in rural and low-density areas.
O'Shaughnessy, M., Casey, E., and Enright, P.	2011	Rural transport in peripheral rural areas.	Social Enterprise Journal	Republic of Ireland	Physical and Economic	Findings show that users of DRT are typically long-term residents, female, elderly, and those who live alone in isolated areas.	Describes how DRT services have helped increase independence, reduced feelings of social isolation and improve access to services for residents in rural areas without access to a PMV.
Broome, K., Worrall, L., Fleming, J., and Boldy, D.	2012	Evaluation of flexible route bus transport for older people.	Transport Policy	Australia	Physical and Economic	Findings show that when replacing fixed route with flexible service in Australia the use by older people almost doubled.	Provides insights into how DRT has improved accessibility and social inclusion for elderly.
Lucas, K., and Currie, G.	2012	Developing socially inclusive transportation policy.	Transportation	UK	Temporal and Spatial	Findings identify that there are important differences between transport disadvantage in low income populations in UK and Australia.	Identifies that more flexible routes and timetabling is required to meet the needs of TDA.
Nelson, J. D., and Phonphitakchai, T.	2012	An evaluation of the user characteristics of an open access DRT service.	Research in Transportation Economics	UK	Psychological and Information	Results reveal that DRT system can improve accessibility, particularly for older residents.	Describes how users are more satisfied with DRT over conventional PT, particularly regarding safety of door-to-door services at night.
Shergold, I., and Parkhurst, G.	2012	Transport-related social exclusion amongst older people in rural Southwest England and Wales.	Journal of Rural Studies	UK	Psychological and Information	Findings reveal that the availability of private vehicles "is not a strong indicator of overall location, although non-availability was important in limiting access to particular types of location."	Describes issues relating to DRT systems reliability and its perception as being for old people.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Velaga, N. R., Beecroft, M., Nelson, J. D., Corsar, D., and Edwards, P.	2012	Transport poverty meets the digital divide: accessibility and connectivity in rural communities.	Journal of Transport Geography	UK	Psychological and Information	Concludes that the provision of adequate transportation services to rural communities presents significant challenges because of issues relating to transport poverty and the digital divide.	Describes the use of GPS, ICT and other technology to enhance DRT.
Wells, P	2012	Converging transport policy, industrial policy and environmental policy.	Local Economy	UK	Temporal and Spatial	The "article identifies inter- and intra-regional dimensions of inequality that are emerging around the convergence of transport policy, industrial policy and environmental policy."	Provides insights into social equity issues surrounding future EM introduction.
Newman, D.	2013	Cars and consumption	Capital and Class	UK	Physical and Economic	Concludes that electric vehicle will never be the ideal solution to promoting sustainable transport systems if they are used to promote increased consumption.	Discusses how electric vehicles are significantly more expensive than traditional vehicles.
Ward, M. R. M., Somerville, P., and Bosworth, G.	2013	Now without my car I don't know what I'd do'	Local Economy	UK	Psychological and Information	Findings show that, "while community transport services play a vital role in rural communities, many older people are confused or unclear about what these services do, how they can be used, and how to access them"	Describes how older people often confused and unclear about how DRT could serve them and that more information could help.
Akgöl, K., and Günay, B.	2014	Prediction of Modal Shift Using Artificial Neural Networks.	TEM Journal	Turkey	Temporal and Spatial	Findings reveal the potential of applying machine learning to calculate modal shift.	Provides insights into modal shift away from PMV when AI is used to optimize route planning.
Harrison, G., and Shepherd, S	2014	An interdisciplinary study to explore impacts from policies for the introduction of low carbon vehicles.	Transportation Planning and Technology	UK	Physical and Economic	Establishes an ethical framework to "balance obligations to reduced greenhouse gases (GHG) emissions and rights to car ownership"	Provides insights into the importance of having access to a PMV.
Martinez, L. M., Viegas, J. M., and Eiro, T.	2014	Formulating a New Express Minibus Service Design Problem as a Clustering Problem.	Transportation Science	Portugal	Temporal and Spatial	"Presents a novel and simple modelling approach to design innovative transportation services, such as the express minibus service."	Describes how future DRT models can be developed with real-time booking systems allow real-time routing changes to ensure the most direct routes for customers.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Stanley, J., and Lucas, K.	2014	Workshop 6 Report: Delivering sustainable public transport.	Research in Transportation Economics	Australia	Physical and Economic	Develops "a set of general principles intended to further promote sustainable public transport."	Provides insights into how technology can improve DRT systems.
Wang, C., Quddus, M., Enoch, M., Ryley, T., and Davison, L.	2014	Multilevel modelling of Demand Responsive Transport (DRT) trips in Greater Manchester based on area-wide socio-economic data.	Transportation	UK	Psychological and Information	Findings show that "the demand for DRT services was higher in areas with low car ownership, low population density, high proportion of white people, and high levels of social deprivation, measured in terms of income, employment, education, housing and services, health and disability, and living environment."	Describes how DRT appeals to areas of low population density, low car ownership and high levels of social deprivation. Explains that the perception of DRT is that it is safer than other forms of road transport.
Beecroft, M., and Pangbourne, K.	2015	Future prospects for personal security in travel by public transport.	Transportation Planning and Technology	UK	Psychological and Information	Develops "a set of policy recommendations, operator, and business opportunities, knowledge gaps and research priorities to support and enhance provision for personal security in travel by public transport."	Provides insights into the use of technology to improve safety and security on shared mobility services.
Bigerna and Polinori	2015	Willingness to Pay and Public Acceptance for Hydrogen Buses.	Sustainability	Italy	Physical and Economic	"The results confirm that residents in Perugia are willing to pay extra to support the introduction of H2B."	Provides evidence that users are willing to pay more for sustainable public transport (Hydrogen Buses)
Evans, G., Guo, A. W., Blythe, P., and Burden, M.	2015	Integrated smartcard solutions.	Transportation Planning and Technology	UK	Physical and Economic	"Findings suggest there is potential for an integrated TranCit card, facilitating easier access to services and travel options across boundaries, even at the international level."	Describes how data obtained from smart card ticketing systems can be used to better understand the behavior of passenger and improve services.
Gomes, R., Pinho de Sousa, J., and Galvão Dias, T.	2015	Sustainable Demand Responsive Transportation systems in a context of austerity.	Research in Transportation Economics	Portugal	Temporal and Spatial	Finding show that "service design is critical" to ensure DRT services "answer sustainability and social inclusion challenges" while keeping costs low.	Discusses how DRT services can reduce costs and improve efficiency of transport network by using fewer, smaller vehicles, incorporating dynamic route planning and passenger allocation, and reducing instances of dead-runs.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Grieco, M.	2015	Social sustainability and urban mobility.	Social Responsibility Journal	UK	Temporal and Spatial	Findings show that "databases and methodologies around social sustainability have not been sufficiently developed to permit ready operationalisation" of advances in urban mobility.	Describes how intelligent data collection can help local authorities identify where transport services are required in order to reduce social inequalities resulting from physical or geographic conditions.
Haustein, S., and Siren, A.	2015	Older People's Mobility.	Transport Reviews	Denmark	Physical and Economic	Propose a hypothetical model based on the findings from a systematic comparison study. The modal "integrates the most relevant determinants of older people's mobility patterns and their interrelations.	Discusses how e-mobility, in-car assistance technology, and AVs will offer good opportunities for the elderly to remain mobile for longer.
Kammerlander, M., Schanes, K., Hartwig, F., Jäger, J., Omann, I., and O'Keeffe, M.	2015	A resource-efficient and sufficient future mobility system for improved well-being in Europe.	Journal of Futures Research	Austria	Temporal and Spatial	Findings show that to achieve the vision of resource efficiency in the transport section a new way of thinking about mobility is required. "It is not about travelling fastest and frequently, but unhurried, infrequently, and sustainably."	Describes how DRT, and door-to-door transport, can reduce demand for PMV travel by providing a viable option in low populated regions.
Mackett, R.	2015	Improving accessibility for older people—Investing in a valuable asset.	Journal of Transport and Health	UK	Physical and Economic	Findings show that the travel patterns of older people are consistent with the assumption that they contribute to society economically, by frequenting local shops and through volunteer work and childcare. The barriers older people face with regards to transportation may hinder an even greater contribution.	Describes how the potential ability for AVs to drive without human input means degenerative disabilities will no longer inhibit elderly and disabled individuals.
Thomopoulos, N., and Givoni, M.	2015	The autonomous car—a blessing or a curse for the future of low carbon mobility?	European Journal of Futures Research	UK	Physical and Economic	Concludes that the introduction of AV is only likely to create a more desirable transport system if it is accompanied by social change.	Provides insights into how AV could eliminate transport related exclusion.
Cheyne, C., and Imran, M.	2016	Shared transport.	Energy Research and Social Science	New Zealand	Physical and Economic	Findings from a survey, focus group, and analysis of census data in New Zealand highlight "a growing need for alternatives to private transport for residents of small towns."	Provides insights into the important of shared mobility being flexible in order to accommodate individual needs.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Clark, J., and Curl, A.	2016	Bicycle and Car Share Schemes as Inclusive Modes of Travel?	Social Inclusion	UK	Physical and Economic	"Argues that there is a need to consider the social inclusivity of sharing schemes and to develop appropriate evaluation frameworks accordingly."	Describes how shared bicycle and car schemes can remove economic barriers associated with owning your own car and how those with disabilities are unlikely to benefit from car and bike schemes alone.
Davidsson, P., Hajinasab, B., Holmgren, J., Jevinger, Å., and Persson, J.	2016	The Fourth Wave of Digitalization and Public Transport.	Sustainability	Sweden	Psychological and Information	Concludes that for transport operators, planners, and users to take advantage of the opportunities related to IoT and its impact on public transport a number of technical and non-technical challenges need to be addressed.	Discusses how smart mobility enabled by IoT could improve data collection and contribute to providing accurate, real-time information about vehicles, users, traffic, and air quality.
Leibert, T., and Golinski, S.	2016	Peripheralisation.	Comparative Population Studies	Germany	Temporal and Spatial	Findings argue "that the peripheralisation approach is a helpful tool to better understand how interaction of out-migration, dependence, disconnection, and stigmatisation shape the future of rural regions."	Describes there is a need for local specific strategies to address how DRT can be used more efficiently and equitably.
Petersen, T.	2016	Watching the Swiss.	Transport Policy	Australia	Temporal and Spatial	Analyses the characteristics of public timetable networks in the contest of rural transportation in Switzerland. Findings identify lessons for their potential application in other locations.	Discusses how first-mile, last-mile transport networks may provide better coverage and be more efficient they are timed to connect to public transport hubs to ensure reductions in transfer times.
Chen, Y., Ardila-Gomez, A., and Frame, G.	2017	Achieving energy savings by intelligent transportation systems investments in the context of smart cities.	Transportation Research Part D	USA	Psychological and Information	Findings from literature review, case studies and interviews has "found that the smart cities context has transformed traditional ITS into smart mobility with three major characteristics: people-centre, data-driven, and powered by bottom-up innovations."	Describes how technological improvements in ITS and ICT can facilitate the collection and analysis of data which can be used to improve the efficiency of the transportation system.
McLeod, S., Scheurer, J., and Curtis, C.	2017	Urban Public Transport.	Journal of Planning Literature	Australia	Temporal and Spatial	The "findings of this systematic review support the paradigm of PT oriented urban mobility and provide an optimistic insight into the future of sustainable travel in cities."	Discusses how DRT enabled by autonomous technology and shared mobility has the potential to increase the catchment of traditional public transport systems.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Melo, S., Macedo, J., and Baptista, P.	2017	Guiding cities to pursue a smart mobility paradigm.	Research in Transportation Economics	Portugal	Psychological and Information	Results show that traffic management systems that re-route can reduce travel times and enhance the efficiency of roads.	Describes how traffic management systems enabled by advances in ICT and data collection provide guidance information to drivers to assist route planning.
Milakis, D., van Arem, B., and van Wee, B.	2017	Policy and society related implications of automated driving.	Journal of Intelligent Transportation Systems	The Netherlands	Physical and Economic	Findings show that "first-order impacts (of autonomous vehicles) on road capacity, fuel efficiency, emissions, and accidents risk are expected to be beneficial. The magnitude of these benefits will likely increase with the level of automation and cooperation and with the penetration rate of these systems."	Describes how AV provide another transportation option for those unable to drive a PMV.
Newman, D.	2017	Automobiles and socioeconomic sustainability	Transfers	UK	Physical and Economic	Proposes a mobility bill of rights that states: (1) everybody should have access to affordable mobility which meets basic needs; (2) transport should not harm us or the environment; (3) transport should not threaten health, safety or the environment; (4) transport pricing should not penalize those who use it less; (5) transport should be accessibly so we are not excluded from society; (6) we should not have to rely on private vehicles for our travel; (7) everyone should have access to a public transport system; and (8) transport should not contribute to depletion of natural resource	Discusses how electric vehicles offer very little to overcome transport related social exclusion.
Sun, Y., Olaru, D., Smith, B., Greaves, S., and Collins, A.	2017	Road to autonomous vehicles in Australia.	Road and Transport Research	Australia	Physical and Economic	Findings identify a number of key issues associated with the introduction of AV in Australia.	Discusses how increased VOT in AV could have a positive impact on those impacted by geographic-related TDA and there is potential for SAV to significantly reduce the costs of DRT.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Adnan, N., Md Nordin, S., Bin Bahruddin, M. A., and Ali, M.	2018	How trust can drive forward the user acceptance to the technology?	Transportation Research Part A	Malaysia	Physical and Economic	Findings show "that the level of trust, which may vary on the sociodemographic profile of the users, has been studied as one of the factors for user acceptance."	Describes AV could improve accessibility for elderly and disabled including the potential for increased social interactions, greater connection to employment and health services, improved comfort, and increased VOT.
Docherty, I., Marsden, G., and Anable, J.	2018	The governance of smart mobility.	Transportation Research Part A	UK	Physical and Economic	Identifies public value as the key governance aim that should be implemented for the transition to smart mobility.	Describes how MaaS can facilitate the integration of a wide range of mobility providers and help strengthen the efficiency of public transport and DRT.
Gonzalez-Feliu, J., Pronello, C., and Salanova Grau, J.	2018	Multi-stakeholder collaboration in urban transport.	Transport	France	Physical and Economic	Provides an analysis and overview of a set of papers which focus on "the field of multi-stakeholder and collaboration in urban transport"	Discusses how an integrated system such as MaaS can facilitate multi-stakeholder collaboration, and the sharing of information and resources.
Graham, H., de Bell, S., Flemming, K., Sowden, A., White, P., and Wright, K.	2018	The experiences of everyday travel for older people in rural areas.	Journal of Transport and Health	UK	Psychological and Information	Identifies three themes related to older people and their experiences of everyday travel: (a) experience with inadequate transport system; (b) importance of everyday travel to maintain lives; and (c) the symbolic importance of travel.	Describes how DRT and community transport is often stigmatized within the community and there is confusion about how to, and who can access it.
Guo et al.	2018	Impacts of internal migration, household registration system, and family planning policy on travel mode choice in China.	Travel, Behavior and Society	USA	Institutional	Findings "suggest that—among other factors—continuing internal migration, relaxation of household registration system, and changes in family planning policy, are likely to affect travel mode choices."	Provides insights into the impact of policy and laws on travel mode choice.
Hopkins and Schwanen	2018	Automated Mobility Transitions.	Sustainability	UK	Institutional	Results "suggest that the UK has adopted a reasonably comprehensive approach to the governing of automated vehicle innovation but that this approach cannot be characterized as sufficiently inclusive, democratic, diverse and open."	Discusses importance of including general public in decision making

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Howard, A., and Borenstein, J.	2018	The ugly truth about ourselves and our robot creations.	Science and Engineering Ethics	USA	Psychological and Information	Concludes that a range of measures should be taken to ensure bias is removed or mitigated from robotic technology - including self-driving vehicles.	Discusses how AVs will have to make decisions based on a range of alternative options and are therefore at risk of bias.
Illgen, S., and Höck, M.	2018	Establishing car sharing services in rural areas.	Transportation	Germany	Temporal and Spatial	"Findings indicate a certain feasibility of rural car sharing development, while highlighting the positive effect it could have on car sharing demand in urban areas."	Provides insights into how ride sharing can contribute to further TDA.
Jin, S. T., Kong, H., Wu, R., and Sui, D. Z.	2018	Ridesourcing, the sharing economy, and the future of cities.	Cities	USA	Psychological and Information	Findings describe how it is unlikely that ride sharing will reduce car ownership.	Describes how shared mobility and AVs can help smaller communities that do not have access to public transport by providing more options, more frequently.
Lam, D., and Givens, J.W.	2018	Small and smart.	New Global Studies	USA	Temporal and Spatial	Using South Bend, Indiana as an example the study looks at the potential for smart cities in smaller communities.	Discusses the use of free-floating bike sharing for first- and last-mile connection to PT.
Li, X., Zhang, Y., Sun, L., and Liu, Q.	2018	Free-floating bike sharing in Jiangsu.	Energies	Singapore	Temporal and Spatial	Findings show that: (a) bike sharing was mainly used for travelling short distances; (b) lower costs, more education, and promotion of health benefits could be used to promote bike sharing; and (c) bike sharing is more attractive to higher income residents.	Describes how important the perception of safety is to ensure successful operation and use of AV.
Lim, H. S. M., and Taeihagh, A.	2018	Autonomous vehicles for smart and sustainable cities.	Energies	Singapore	Psychological and Information	Findings describe how addressing privacy and cybersecurity related to AV is crucial to the development of smart and sustainable cities.	Describes how AV may lead to increased suburbanization or density.
Milakis, D., Kroesen, M., and van Wee, B.	2018	Implications of automated vehicles for accessibility and location choices.	Journal of Transport Geography	The Netherlands	Physical and Economic	Findings from Q-method study showed that experts expect AV to influence accessibility through all four level (land use, transport, temporal and individual)	Discusses advantage of a MaaS system would be that unlike existing DRT services the subsidized provision of transport may not be seen as an entitlement but instead be part of a larger system that benefits all.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Mulley, C., and Kronsell, A.	2018	The "uberisation" of public transport and mobility as a service (MaaS).	Research in Transportation Economics	Australia	Psychological and Information	Findings of workshop discussion show a difference between policy and mobility provider views, a need for flexibility, the importance of collaboration, and a need to address user safety.	Discusses how MaaS provides an opportunity to cross subsidize which could improve the transportation for disadvantaged groups (e.g., aged, disabled, and rural areas).
Mulley, C., Nelson, J. D., and Wright, S.	2018	Community transport meets mobility as a service.	Research in Transportation Economics	Australia	Temporal and Spatial	Findings show that CT operators in Australia are very enthusiastic about the potential for MaaS to offer mobility packages to services their users.	Discusses how AVs with the absence of strict policy measures could result in more demand for car ownership and miles travelled.
Noy, K., and Givoni, M.	2018	Is "Smart Mobility" Sustainable?	Sustainability	Israel	Physical and Economic	Findings from a survey of 117 entrepreneurs "shows that there is a mismatch between interpretation and understanding of what is 'smart' and what is 'sustainable'."	Discusses that for shared mobility to help achieve sustainable mobility objectives it is important to identify how existing public transport and shared mobility can be synergized to make them complementary and benefit the transport system as a whole.
Soares Machado, C., de Salles Hue, N. P. M., Berssaneti, F. T., and Quintanilha, J. A.	2018	An Overview of Shared Mobility.	Sustainability	Brazil	Psychological and Information	Findings determine that based on literature review the introduction of shared modes alone "will not solve transportation problems in large cities."	Discusses how people with visual impairment would greatly benefit if existing door-to-door transportation services were improved.
Wong, S.	2018	Traveling with blindness.	Health and Place	USA	Physical and Economic	Findings show "space-time constraints of people with visual impairments are closed linked to their access to transportation, assistive technologies, and mobile devices."	Describes how providing transportation for low density dispersed neighborhoods is challenging due to dispersal of individuals and destinations.
Allen, J., and Farber, S.	2019	Sizing up transport poverty.	Transport Policy	Canada	Temporal and Spatial	Recommends that future investments in major transportation infrastructure should be focused in areas with high density of low-income households and low levels of accessibility. In areas of low density, subsidized ride sharing and DRT should be considered.	Describes how SAV could reduce total cost of ownership by over 80% per km travelled compared to a conventional car.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Axsen, J., and Sovacool, B. K.	2019	The roles of users in electric, shared and automated mobility transitions.	Transportation Research Part D	Canada	Physical and Economic	Findings summarize "characteristics of early users, as well as practical insights for strategies and policies seeking societally-beneficial outcomes from mass deployment of" transport innovations.	Describes how FTS can contribute to rural connectivity by providing door-to-door transport that does not rely on fixed routes and how MaaS is promising because it provides integrated customer experiencing linking users with a range of transport options on demand.
Beecroft, M., Cottrill, C. D., Farrington, J. H., Nelson, J. D., and Niewiadomski, P.	2019	From infrastructure to digital networks.	Scottish Geographical Journal	UK	Psychological and Information	Identifies connectivity as a central theme when looking at the development and evolution of transport geography research at the University of Aberdeen.	Provides insights into attitudes towards AV among those with intellectual disability.
Bennett, R., Vijaygopal, R., and Kottasz, R.	2019	Willingness of people with mental health disabilities to travel in driverless vehicles.	Journal of Transport and Health	UK	Psychological and Information	Findings show "three categories of attitude towards AVs arose from the STM; respectively involving freedom, fear and curiosity."	Discusses how public transport providers should look to integrated systems such as MaaS which can help with sharing of data, identification of demand, and connect potential users with the most suitable providers.
Bennett, R., Vijaygopal, R., and Kottasz, R.	2019	Attitudes towards autonomous vehicles among people with physical disabilities.	Transportation Research Part A	UK	Psychological and Information	Findings show that "attitudes towards AVs among people with disabilities were significantly influenced by their levels of interest in new technology, generalized anxiety, intensity of a person's disability, prior knowledge of AVs, locus of control and action orientation."	Provides insights into how AV could perpetuate or create new social inequalities.
Canitez, F.	2019	Pathways to sustainable urban mobility in developing megacities.	Technological Forecasting and Social Change	Turkey	Physical and Economic	Findings "proposes a socio-technical transition perspective to examine and analyze the urban mobility systems in developing megacities. In addition, a multi-level perspective is offered to understand the dynamics of sustainable urban mobility transitions"	Provides insights into attitudes towards AV among those with intellectual disability and those without.
Creitzig et al.	2019	Leveraging digitalization for sustainability in urban transport.	Global Sustainability	Germany	Institutional	Concludes that "only strong public policies can steer digitalization towards fostering sustainability in urban transport."	Provides insights into the importance of policy in smart technology development.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Curtis, C., Stone, J., Legacy, C., and Ashmore, D.	2019	Governance of future urban mobility.	Urban Policy and Research	Australia	Physical and Economic	"Findings from industry engagement workshop highlight the complexity of issues and questions surrounding MaaS implementation."	Discusses how the change from a PMV to more sustainable system is reliant on the cost of transport, regulations, planning, land use, technology, public awareness and culture.
Dean, J., Wray, A., Braun, L., Casello, J., McCallum, L., and Gower, S.	2019	Holding the keys to health?	BMC Public Health	Canada	Psychological and Information	Findings show "there is general agreement that AVs will improve road safety overall, thus reducing injuries and fatalities from human errors in operating motorized vehicles. However, the relationships with air quality, physical activity, and stress, among other health factors may be more complex."	Discusses how when MaaS is implemented with AV there is a risk that those currently able to operate a PMV will have access to private AV.
Freemark, Y., Hudson, A., and Zhao, J.	2019	Are cities prepared for autonomous vehicles?	Journal of the American Planning Association	USA	Physical and Economic	Findings show that: (1) planning for AV is not widespread; (2) bigger cities are more likely to have started planning for AV; (3) there is optimism among local officials regarding the potential increase in safety, and decrease in costs and pollution associated with AV; and (4) over one-third of local officials are concerned about the impact AV will have on VKT and public transport ridership.	Discuss how AVs can contribute to the improved safety but increased reliance on technology opens up additional risks.
Goggin et al.	2019	Disability at the centre of digital inclusion.	Communication Research and Practice,	Australia	Psychological and Information	Concludes "that 'disability and digital inclusion' should be specifically also placed at the heart of digital economy policy and plans"	Provides insights into digital divide and disability
Groth, S.	2019	Multimodal divide: Reproduction of transport poverty in smart mobility trends.	Transportation Research Part A	Germany	Psychological and Information	Findings show that smart mobility can potentially contribute to transport poverty by: (a) providing an unequal distribution of mode options; (b) excluding those who are unable to use technology; and (c) excluding those who are unwilling to us technology due to privacy concerns.	Discusses how improved costs and accessibility associated with AV may reduce public transport use.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Hawkins, J., and Habib, K. N.	2019	Heterogeneity in marginal value of urban mobility.	Transportation	Canada	Temporal and Spatial	"Findings reveal the potential for social exclusion follow the adoption of MaaS."	Discuss how smart mobility may contribute to social exclusion.
Jokinen, J.-P., Sihvola, T., and Mladenovic, M. N.	2019	Policy lessons from the flexible transport service pilot Kutsuplus in the Helsinki Capital Region.	Transport Policy	Finland	Temporal and Spatial	Findings "provide a range of guidelines and lessons for future urban FMTS"	Discusses how MaaS would likely result in higher transport costs for those in low density areas and governments will likely need to provide subsidies and planning interventions in order to ensure equitable access to transport.
Kandt, J., and Leak, A.	2019	Examining inclusive mobility through smartcard data.	Journal of Transport Geography	UK	Temporal and Spatial	Findings show "first, the decline in patronage occurs in three waves across the study period according to distinct activity patterns; second, formerly frequent (daily) passengers tend to abandon the bus and thus show the largest impact on the overall trend; third, the neighbourhood context of withdrawing passengers indicates social disadvantage, higher instance of ethnic minorities and lower car ownership rates, in other words higher risk of social exclusion."	Provides insights into the importance of DRT to direct users to major transport hubs, how users are more sensitive to travel time than cost, and how technology can improve efficiency of DRT.
Kuzio, J.	2019	Planning for Social Equity and Emerging Technologies.	Transportation Research Record	USA	Physical and Economic	Findings show that 80% of metropolitan planning organizations have plans that included a response to social equity, however, only 20% of plans considered how new technologies would impact on social equity.	Describes how MaaS can contribute to improved public transport use in low density, less accessibility areas by providing a connection to major public transport hubs, and creating synergies between a range of transport options.
Le Boennec, R., Nicolaï, I., and Da Costa, P.	2019	Assessing 50 innovative mobility offers in low-density areas.	Transport Policy	France	Temporal and Spatial	Develops a two-step decision-making tool to assist local governments with planning and implementing transportation policies.	Describes how the benefits of AV including the ability to work, eat, and rest while in transit could be highly desirable and result in increased cost, VKT, and demand on infrastructure.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Legacy, C., Ashmore, D., Scheurer, J., Stone, J., and Curtis, C.,	2019	Planning the driverless city.	Transport Reviews	Australia	Physical and Economic	Findings reveal "the conceptual gaps in the framing of AV technology—the prospects and limits—and how these are conceived"	Discusses how despite new technology encouraging walking is still key to reducing social exclusion as walking is costless, and contributes to improved health.
Liu, C., Yu, B., Zhu, Y., Liu, L., and Li, P.	2019	Measurement of rural residents' mobility in western China.	Sustainability	China	Temporal and Spatial	Findings "show that Qingyang's rural mobility is at a low level, but differences in the types of rural residents, districts and counties, and dimensions of mobility are observed."	Discusses how for AV to reduce some of the social equity issues associated with the PMV it should be introduced as part of a system integrated with existing transport providers.
Martin, G.	2019	An Ecosocial Frame for Autonomous Vehicles.	Capitalism Nature Socialism	USA	Physical and Economic	"As is usually the case with a new technological consumer product, discourse centers on its promises, not its perils. Largely ignored are potential impacts on social justice and environmental sustainability."	Provides insights into how information availability in lower density areas is critical for the success of many smart mobility applications.
Martínez-Díaz, M., Soriguera, F., and Pérez, I.	2019	Autonomous driving: a bird's eye view.	IET Intelligent Transport Systems	Spain	Psychological and Information	Provides an overall state-of-the-art of the development of AV and identifies the issues critical for its success.	Discusses risk that AV will be expensive and exclude low income residents and how subsidized SAV may provide a viable alternative.
Meelen, T., Frenken, K., and Hobrink, S.	2019	Weak spots for car-sharing in The Netherlands?	Energy Research and Social Science	The Netherlands	Physical and Economic	Findings "demonstrate how the relation between niche innovation and the socio-technical regime of private car ownership affects adoption patterns."	Discusses how while AV are expected to bring a much safer driving environment, acceptability among people over 50 is still quite low.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Nordhoff, S., Kyriakidis, M., van Arem, B., and Happee, R.	2019	A multi-level model on automated vehicle acceptance (MAVA).	Theoretical Issues in Ergonomics Science	Switzerland	Psychological and Information	Findings reveal "that 6% of the studies investigated the exposure of individuals to AVs (i.e., knowledge and experience). 22% of the studies investigated domain-specific factors (i.e., performance and effort expectancy, safety, facilitating conditions, and service and vehicle characteristics), 4% symbolic-affective factors (i.e., hedonic motivation and social influence), and 12% moral-normative factors (i.e., perceived benefits and risks). Factors related to a person's socio-demographic profile, travel behavior and personality were investigated by 28%, 15% and 14% of the studies, respectively. "	Discusses how car sharing contributes to improved accessibility for those without access to a vehicle—satisfying basic needs relating to transportation.
Ortar, N., and Ryghaug, M.	2019	Should all cars be electric by 2025?	Sustainability	UK	Temporal and Spatial	Findings show that there is much uncertainty regarding how the transition between fuel-based and electric vehicles occurs including issues of efficiency, affordability and sustainability	Discusses how the general public perceives AV and identifies risks they associate with the technology.
Ruan et al.	2019	Social adaptation and adaptation pressure among the "drifting elderly" in China.	International Journal of Health Planning and Management,	China	Institutional	"The drifting elderly had poor adaptation regarding self-identity, daily activities, and social context."	Discusses issues of digital divide among elderly migrants
Sener, I. N., Zmud, J., and Williams, T.	2019	Measures of baseline intent to use automated vehicles	Transportation Research Part F	USA	Psychological and Information	Findings show "the strongest associations with intent to use (AVs) were observed for attitudes toward self-driving vehicles, performance expectation, perceived safety, and social influence."	Describes social equity issues surrounding the introduction of EM.
Sovacool, B., Martiskainen, M., Hook, A., and Baker, L.	2019	Decarbonization and its discontents.	Climatic Change	UK	Temporal and Spatial	Develops a framework for "energy justice" with four distinct dimensions: (a) distributive justice; (b) procedural justice; (c) cosmopolitan justice; and (d) recognition justice.	Discusses how AV bring a significant, and uncertain impact on the transport system.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Tang, C. S., and Veelenturf, L. P.	2019	The strategic role of logistics in the industry 4.0 era	Transportation Research Part E	USA	Psychological and Information	Concludes that companies must take measures to ensure underlying risks associated with technological advancements including: (a) cyber-attacks; (b) faulty data; (c) safety regulations; and (d) privacy.	Discusses how those in rural, or low density, sparsely populated areas may not be able to fully benefit from smart technology due to network coverage, and electricity prices.
Viergutz, K., and Schmidt, C.	2019	Demand responsive - vs. conventional public transportation.	Procedia Computer Science	Germany	Temporal and Spatial	Findings show that DRT services may not be the solution to public transport in rural areas and further research is need to balance access, financial, service, and pollution issues associated with DRT.	Discusses risks associated with AV and ITS.
Waseem et al.	2019	Integration of solar energy in electrical, hybrid, autonomous vehicle	SN Applied Science	India	Physical and Economic	"Overview of electric and hybrid vehicles suggests that in a developing country such as India, there is a huge demand for green-powered electric vehicles for the transportation sector."	Discusses demand for green-powered vehicles.
Yigitcanlar, T., Han, H., Kamruzzaman, M., Ioppolo, G., and Sabatini-Marques, J.	2019	The making of smart cities.	Land Use Policy	Australia	Psychological and Information	Findings "disclose the need for a comprehensive smart city conceptualization to inform policymaking and consequently the practice."	Discusses how AV could assist the development of DRT in low demand areas, reducing costs, and making the system operate more efficiently.
Zhou, J.	2019	Ride-sharing service planning based on smartcard data	Transport Policy	China	Physical and Economic	Findings show "that some low-demand transit routes can probably be replaced by Uber at a lower level of overall costs."	Provides insights into cities that use technology enabled smart traffic systems.
Becker et al.	2020	Assessing the welfare impacts of Shared Mobility and Mobility as a Service (MaaS).	Transportation Research Part A	Switzerland	Psychological and Information	"Results show that in Zurich, through less biased mode choice decisions alone, transport-related energy consumption can be reduced by 25%"	Discusses role of MaaS in providing users an unbiased choice of modes.
Bissell, D., Birtchnell, T., Elliott, A., and Hsu, E. L.	2020	Autonomous automobilities.	Current Sociology	Australia	Physical and Economic	Shows "how a mobilities approach provides an ideal conceptual lens through which the broader social impacts of autonomous vehicles might be identified and evaluated."	Discusses social issues surrounding introduction of AV

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Ferdman, A.	2020	Corporate ownership of automated vehicles.	Transport Reviews	Germany	Physical and Economic	"Proposes a new angle on the relationship between ownership models of automated vehicles and implications for travel."	Describe how for shared mobility to work in rural areas a broad base of users is required, large investments from the start, and strong connection with the broader region - particularly cities.
Guo and Peeta	2020	Impacts of personalized accessibility information on residential location choice and travel behavior.	Travel, Behavior and Society	USA	Temporal and Spatial	Results "show that personalized accessibility information can potentially make relocators more informed about travel-related information, and assists them in selecting a residence that better addresses their travel needs based on higher accessibility to potential destinations."	Discusses the use of ICT to help residents make more informed choice.
Guo et al.	2020	Personal and societal impacts of motorcycle ban policy on motorcyclists' home-to-work morning commute in China.	Travel, Behavior and Society	USA	Institutional	"These results suggest that policy and infrastructural support for using public transit, walk, and bike modes, household mobility, and plan to purchase a car were likely to affect the personal and societal impacts of the motorcycle ban policy on travel mode shifts"	Provides insights into the impact of policy and laws on travel mode choice.
Hoque et al.	2020	Life Cycle Sustainability Assessment of Alternative Energy Sources for the Western Australian Transport Sector	Sustainability	Australia	Physical and Economic	"The results show that the environment-friendly and socially sustainable energy options, namely, ethanol-gasoline blend E55, electricity, electricity-E10 hybrid, and hydrogen, would need around 0.02, 0.14, 0.10, and 0.71 AUD/VKT of financial support, respectively, to be comparable to gasoline."	Discusses economic sustainability of alternative fuel vehicles
Liu et al.	2020	A tale of two social groups in Xiamen, China: Trip frequency of migrants and locals and its determinants.	Travel, Behavior and Society	Hong Kong	Institutional	"Highlights the importance of context and population differentiation and calls for more in-depth research on migrants' travel behaviors as well as their determinants."	Provides insights into barriers related to infrastructure provision.

Table A1. *Cont.*

Author	Year	Title	Journal	Country	Category	Findings	Relevance
Meng et al.	2020	Policy implementation of multi-modal (shared) mobility.	Transport Reviews	Australia	Institutional	"Suggests that policy entrepreneurship in collaboration with other partners, policy innovation, and the notions of merit goods and second-best policymaking can enable policy initiatives towards multi-modal shared mobility and provide supporting arguments if policies encounter failures."	Discusses the importance of policy in development of shared mobility
Rojas-Rueda et al.	2020	Autonomous Vehicles and Public Health.	Annual Review of Public Health	USA	Physical and Economic	Provides recommendations for the use of AV to improve public health.	Provides insights into some benefits and issues with AV from a public health perspective.
Soares Machado et al.	2020	Placement of Infrastructure for Urban Electromobility	Sustainability	Brazil	Temporal and Spatial	Results "shows that districts with the largest demand for charging stations are located in the central area, where the population also exhibits the highest purchasing power"	Discusses issues associated with electric mobility in low density and rural areas.
Tao et al.	2020	Investigating the impacts of public transport on job accessibility in Shenzhen, China.	Land Use Policy	China	Physical and Economic	"Highlights land use and transport policy countermeasures to improve job accessibility by public transport."	Discusses how job accessibility is greatly improved if one has access to a PMV
Tomej, K., and Liburd, J. J.	2020	Sustainable accessibility in rural destinations.	Journal of Sustainable Tourism	Austria	Temporal and Spatial	Findings "demonstrates the use of sustainable transport accessibility as a measure for transport evaluation that considers both environmental aspects and social justice framed as sustainable tourism participation for all."	Provides insights into the use of DRT in rural areas with high levels of tourism.
Turoń and Kubik	2020	Economic Aspects of Driving Various Types of Vehicles in Intelligent Urban Transport Systems, Including Car-Sharing Services and Autonomous Vehicles.	Applied Science	Poland	Physical and Economic	"Results indicate the relation of travel parameters (including vehicle type) to the total cost of travel in urban transport systems."	Discusses the economic sustainability of AV and shared transport

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