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Transport innovations for elderly people

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ABSTRACT

Recently published transport innovation, transport service, mobility narratives and transportation alternatives literature focus on mounting needs for older people in reflection of increasing longevity and active and healthier lifestyles over previous generations. The aim of this review is to raise awareness and stress the knowledge gap on the importance of transport innovations for this age group, particularly in regards to needs and innovative requisites (i.e., vehicle, transport infrastructure and organisational makeup). A scoping literature search identified 106 publications as relevant literature from the more than 2500 reviewed publications. Transport need for the elderly is discussed by way of accessibility, affordability, availability and acceptability. Vehicle innovation examines pedestrian data, vehicle design (i.e., private cars and vehicles in public transport), fixed route services, paratransit vehicles and slow mode alternatives such as cycling, motorised mobility scooters and powered wheelchairs. Transport infrastructure innovation takes into account technical infrastructural adjustments, related recommendations and guidelines and specific solutions for peri-urban and rural areas. Organisational innovation investigates governmental support mechanisms, legislation, financial limitations, education and social-based training and internet as well as relating information and communication technology-based findings. Vast majority of the research is centric to developed countries. Identified gaps in the literature and novel areas for future research are examined.

1. Introduction

A vast body of research focuses on demographic change and population ageing. It should come as no surprise, therefore, new terms like "greying" of society (i.e., relating to people living longer and being more active and healthier than earlier generations) (OECD, 2001) and silver economy amplified within Japan and the European Union (EU) (i.e., a part of the general economy that is relevant to the need and demand of older adults) (Chéron, 2011; European Commission, 2018) have become commonplace. As a result, a number of studies examine traditional approaches to the problem and focus of transport need for older people (Alonso et al., 2013; Hounsell, Shrestha, McDonald, & Wong, 2016; Shrestha, Millonig, Hounsell, & McDonald, 2016). A separate line of research centres on elderly attitude to travel (Li, Raeside, Chen, & McQuaid, 2012; Luiu, Tight, & Burrow, 2018c) while other core pieces examine population trend, ageing affect and economic life and well-being in the twenty-first century (Su & Bell, 2009). Evidence has mounted that proactive and thorough planning is needed to ensure senior citizens' safe, lifelong mobility (Nordbakke & Schwanen, 2015). Accordingly, several international institutions are confronting these issues by developing practical guidelines for policymakers via decision-oriented methods. For example, in 2001 the Organisation for Economic Co-operation and Development (OECD) established a specialised working group – comprised of road safety research practitioners, transport planners and engineers, medical professionals and policy-makers – that overlook present-day travel patterns, transport and safety needs and mobility implications for the elderly (OECD, 2001). In the United States similar achievements were put together by the Transportation Research Board in which major adjustments toward transport need of the elderly have been introduced (Transportation Research Board, 2004). Findings suggest, increased access to efficient and effective transport services is closely associated with a better quality of life (Banister & Bowling, 2004; Hjorthol, 2013; Li et al., 2012; Luiu et al., 2018c; Metz, 2000; Nordbakke & Schwanen, 2015). As such, travel tendency and flexibility change pending older persons' need, preference and behaviour (Alsnih & Hensher, 2003; Fiedler, 2007; Luiu, Tight, & Burrow, 2017, 2018b; Musselwhite & Haddad, 2010, 2018; Rosenbloom, 2009; Whelan, Langford, Oxley, Koppel, & Charlton, 2006).

The aim of this review is to raise awareness and stress the gap in knowledge in regard to transport innovation for the elderly with the core focus on need and relating innovation requisites. The term transport innovation is understood as the implementation of new products, processes and organisational solutions within the transport sector.

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Innovation is viewed as complex interaction between potential users and new development in science and technology. Innovation for transport is, by in large, two-sided: technological or non-technological (Hyard, 2013). This undoubtably interplays an important part in demand-driven invention and innovation for older people especially in an ageing society. Public transport operators, for example, often face difficulty in creating innovative solutions due to lack of incentive and funds by industry actors (Klasing Chen et al., 2014). As such, novel applications using information and communications technology (ICT), mobile technology and autonomous vehicles have enormous potential at integrating various transport modes and facilitating travel for the elderly in general. High expectation is associated with the implementation of modern technologies which should increase the attractiveness of transportation alternatives in relation to private passenger cars.

In coding the review, specific objectives are examined, including: (1) to identify different typologies and gaps in the literature; (2) to synthesize findings on varying transport needs (i.e., accessibility, affordability, availability and acceptability) and innovation (i.e., vehicle, infrastructure and organisation) from relevant literature; and (3) to provide indicators and technical recommendations regarding design, planning and management of transport innovation for the elderly. A breakdown of the paper is structured as follows: Section 2 contains the methodology, Section 3 illustrates the results, Section 4 elucidates a discussion on the varying transport innovation areas, Section 5 looks at recommendations for incorporating research gaps and Section 6 the conclusion.

2. Methodology

A scoping literature search was conducted using the following electronic journal databases: Web of Knowledge, Scopus, Science Direct, ProQuest, Sage, Directory of Open Access Journals, Google Scholar and Google. The scoping review, or scoping study, synthesised exploratory keywords aimed at mapping key concepts, types of evidence and gaps in research by systematically searching, selecting and synthesising existing knowledge. The explanatory keywords were derived by using a combined starbusting and brainstorming approaches as well as the stepladder method of accumulating additional keywords from new papers found. Initial key papers were used as a starting point (Haustein & Siren, 2015; Luiu et al., 2017; Shrestha et al., 2016) after which a comprehensive list of specific keywords and terms were developed (Supplementary Note 1). From this original compilation of literature, we identified and analysed relevant information regarding (1) transport need and requirement of older people and (2) areas of transport innovation for ageing societies (Haustein & Siren, 2015; Luiu et al., 2017; Shrestha et al., 2016). An additional synthesised table of keywords was then generated using these two points based on four concepts: population, transport mode, area of innovation and other kinds of terms (Table 1) (Haustein & Siren, 2015; Luiu et al., 2017; Luiu, Tight, & Burrow, 2018a; Shrestha et al., 2016; TRACY, 2012).

The literature was compiled, publications were systematically analysed, using strategic and critical reading methods (Matarese, 2013; Renear & Palmer, 2009), so as to identify those presented based on Table 1. At length, we identified more than 2,500 articles, reviews and grey literature in the first step of the search. To better focus our review, we filtered out articles published before 1990 and considered articles with a socioeconomic and demographic change perspective. We omitted articles discussing medically-related sciences or narrow technological and engineering-based perspectives, leaving us with approximately 200 publications that included literature published in the form of books, scientific articles and technical reports. To further elucidate our review's perspective, the analysis identified six key research areas central to transport and the elderly. Due to the vastness of the subject matter, the scope of the review predominately focused on need and innovation (i.e., rows labelled with an asterisk in Table 2). Once these publications were filtered, we compiled and sorted them according to key topics and indicators stressing spatial context, wider benefit, perspective research agenda, disruptive innovation and geographic coverage. Spatial context examined whether the indicator focused on urban, peri-urban, rural or all three types of area. Responses for wider benefit (i.e., facilitating mobility, generating additional demand and improving quality of life) and perspective research agenda (i.e., state-of-the-art, examination scenario, benefits and future vision) were based on generalised descriptive answers. Responses for disruptive innovation were based on a polar approach of "Yes" or "No", in which if "Yes" explanatory reasons are listed. Disruptive innovation is based on innovation that created a new market or value and significantly disrupted the concurrent status quo. Geographic coverage recorded key countries from each study, noting a number of studies were multi-country. Studies that assessed intergovernmental organisations (IGOs) (i.e., the EU and OECD) are independently categorised. We conclude with specific gap-focused recommendations – with possible policy uptake – for developing elderly-oriented transport need and innovation planning and guidelines.

3. Results

After initial filtering out of non-relevant publications, we identified 106 scientific reports that were related to our scope on transport need and innovation for the elderly. Distributed among the different typologies, a number of studies fit into multiple indicators, for a total of 336. The geographical distribution of related studies was predominately developed countries-centric. For example, approximately, 59 % of the studies were need-oriented versus 41 % innovation-oriented; while the majority of studies were from the EU (i.e., 22.4 %), the United Kingdom (i.e., 18.4 %) and the United States (i.e., 16.1 %) – see Fig. 1.

The scientific journal "Transport Policy" was the most published journal, with the majority of the studies sparsely found throughout the literature. When analysed according to discipline, most of these were in the social sciences (i.e. transportation, planning and development, geography, psychology and safety research) as well as a number of economic- and engineering-based disciplines. However, a few studies, such as that of Taylor and Tripodes (2001), focused on public health as well as environmental and occupational health inclusive within our reviewed typologies. Using the results from our finalised literature, we identified the most commonly reported transport need and innovation types and their characteristics that matched our scope concerning the elderly. The reviewed publications were found to be across a vast array of contexts (e.g., spatial framing and government initiatives) in 19 countries and two IGOs. We also used the literature to identify key research areas central to transport and the elderly (Table 2) in

Table 1
Secondary synthesised terms and combinative keyword search used for the methodology.

Concept	Search term
Population	"older people" OR "older population" OR "older adults" OR "elderly" OR "aged people" OR "ageing society"
Transport mode	AND "transport" OR "transportation" OR "public transport" OR "bus" OR "tram" OR "taxi" OR "cars" OR "cycling" OR "walking" OR "car sharing" OR "demand responsive transport" OR "flexible transport services"
Area of innovation	AND "vehicle" OR "transport infrastructure" OR "information" OR "operational innovations" OR "ICT"
Other kind of terms	AND "innovation" OR "new solution" OR "improvement" OR "upgrading" OR "need" OR "requirements"

Table 2
Key research areas central to transport and the elderly, rows labelled with an asterisk identify the two research areas of this review.

Research area	Key topics in each research area			
Impairment (i.e., medically-oriented)	Mobility impairments (i.e., inability to use one or more of a person's extremities to walk, grasp or lift objects)	Visual impairments (i.e., decreased ability to see to a degree that causes problems not fixable by usual means, such as glasses)	Hearing impairments (i.e., partial or total inability to hear)	Cognitive impairments (i.e., trouble remembering, learning new things, concentrating or making decisions)
* Need	Accessibility (i.e., accessible vehicles, stops and stop approaches)	Affordability (i.e., reduced fares for older people)	Availability (i.e., regular services within acceptable distance)	Acceptability (i.e., safety, driver attitude and information)
Handicapped (i.e., physically challenged persons)	Vehicle design (i.e., specific to the requirements for the handicapped)	Physical infrastructure and barriers	Information and guidance	Social acceptance
Mobility mode	Privately used vehicle	Public transport (i.e., traditional and new forms)	Vehicles under 50 cc (e.g., minicars and grey motorised electric scooters)	Walking and cycling
* Innovation	Innovation in vehicles	Innovation in transport infrastructure (i.e., road, public transport and slow mode infrastructure)	Organisational innovation (i.e., information and guidance, flexible services and trainings)	
Barriers[1]	Technological change and speed of change (i.e., in-vehicle infrastructure and information systems)	Built environment and organisational improvements	Health, safety and personal security	Service provision and comfort

[1] Partially adopted from Luiu et al. (2018b)

conjunction with related quantitative and qualitative indicators. Following commonly applied typologies (e.g., Luiu et al. (2017) and Shrestha et al. (2016)), the two chosen research areas were subdivided into key topics: (1) transport need into accessibility, affordability, availability and acceptability and (2) transport innovation into vehicle, infrastructure and organisational. Topics were then divided into indicators to provide a detailed examination of the research. The scope of the review considered spatial context by separating urban, peri-urban and rural environments. This was done since level of access to mobility for older people is often location-specific. Next, identifying the effects of implemented solutions and undertaken actions was investigated. In addition to direct effects, which mainly focus on researchers, there are also wider effects, referred to as indirect in economics. We analysed the available research in terms of indirect effects in the form of wider benefits. This is important due to the fact that these effects are often overlooked in research due to the difficulty of identifying and measuring them. We were also interested in the nature of innovation and focused on disruptive innovative trends. It should be noted that given the typologies we assembled from the literature, the wider benefits and disruptive innovation for all the transport need research was not applicable or unavailable. One of the purposes of the review was also to identify gaps in the literature, and once overlapped with the perspective research agenda, a brief overview for each indicator was noted. Finally, for each indicator, we synthesised the relevant literature within a geographic focus, by way of scientific jargon and correlating terminology (Table 3).

4. Discussion

4.1. Transport needs

In terms of mobility needs and behaviour, there is a clear difference between the working population and retired persons. Older persons are not homogeneous; they differ in terms of state of health, travel need and preference for mode of travel. As such, the elderly can be active and fit as well as suffer from poor health and decreased mobility (Fiedler, 2007). Biological age explains, to a limited extent, the possibility in mobility of older people. Cognitive, psychosocial, physical, environmental and financial factors vary between older adults and their biological age (Neven et al., 2018). Age-related changes and consequences for mobility have been identified by various researchers (Nordbakke & Schwanen, 2015; Shrestha et al., 2016). Some of these consequences are associated with disability rather than ageing, since a significant proportion of the elderly have disabilities (Mackett, 2014). Much of the research suggests older people tend to make fewer journeys than other adults (McDonald et al., 2012). Beyond this reduction in overall mobility, transport modes by older people also change with age as car usage decreases, whilst walking increases and public transport becomes a more frequented alternative. For example, in Germany the decrease of daily travel has recently been documented from 50 km for ages 50–59 to 14 km for those over 80. Likewise, the percentage of people driving a personal vehicle has dropped from 57% for ages 50–59 to 32 % for 80 plus. With age, older people start to walk more and use more public transport (Bundesministerium für Verkehr und digitale Infrastruktur, 2019). The importance of walking and public transport for older persons' sense of independence is highlighted in research carried out in the London area, noting policy implications to mode choice as highly important (Su & Bell, 2009).

Since 2000, Haustein and Siren (2015) reviewed studies using a segmentation approach for older people and their travel behaviour patterns and modes. Segmentation is distinguished by type (i.e., behavioural, demographic, spatial and attitudinal components) using cross-referencing characteristics. The majority of the recorded studies come from Europe, with one exception from Canada which in contrast to European countries all groups of seniors used a car for the majority of their trips. Haustein and Siren (2015) noticed that certain aspects of

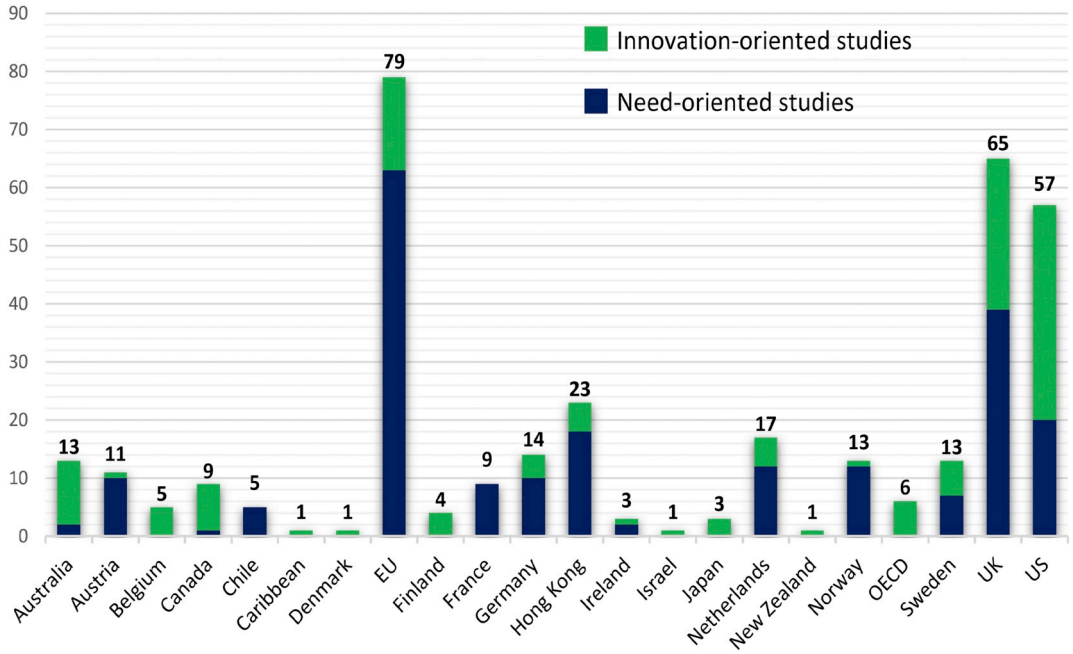

Fig. 1. Stacked geographic distribution of scientific reports of transport need and innovation for the elderly, with accumulative totals for both per country and IGO.

mobility and characteristics of transport users were used in all of the reviewed studies. To describe older travellers' segments, activities were broken down into the following groups: car-orientation, activity level, socioeconomic resources (i.e., personal or household income and in most cases level of education), gender and health (i.e., existence of specific symptoms or diseases), mobility restrictions and being handicapped. Further findings correlated a theoretical model of four additional segments in relation to activity level and mode of travel: active car usage, car-dependence with restricted mobility, mobile multi-modal and dependency of public transport and other services. Results suggest different determinants work in unison and segments that are likely to increase or decrease with future generations of older people depend on whether or not support mechanisms are set in place.

Similarly, the "Growing older, staying mobile: Transport needs for an ageing society" (GOAL) project developed profile categories of older people – over the age of 50 – with specific cross-European research focused on differing need and travel patterns (Shrestha et al., 2016). Five clusters, with a relating catch phrase, were differentiated based on variables relating to physical and mental health and socio-demographics: (1) "fit as a fiddle" – the youngest, healthiest and most active group; (2) "hole in the hearth" – relatively young people from 50 to 75, who suffer from illness and are limited in activities; (3) "happily connected" – members between 60 and 80 that are characterised by a very active and social lifestyle; (4) "an oldie but a goodie" – people advanced in years, majority of them living alone, quite healthy and not severely limited in activities; and (5) "the care-full" – as the oldest, most fragile and least active group (i.e., those who suffer from severe physical and mental diseases and depend on care, assistance and help of others) (Millonig et al., 2012). The GOAL project exemplifies an advancement in aged-transport development and assisted in further elevating the wider European-centric debate on the topic. In other relating research, Sixsmith and Gutman (2013) categorised older persons in terms of their healthiness and activity level, whether they were living with chronic disease, had any mild cognitive impairment or dementia. The focus interlinked ICT by enhancing independence and active ageing. This is especially important due to increased use of ICT, in all areas of life, and the potential of these technologies to facilitate daily mobility of elder people. The GOAL project, and its use of ICT, exhibit important milestones in breaking down and identifying elderly groups and potential overlap. In summary, active and healthy older people more often than not are car-oriented, while persons who suffer from physical or mental disease are dependent on public transport and other services. However, this is not the rule of thumb as many persons with minor disabilities still independently drive and healthy people travel by public transport. Fulfilling the need of older people in the field of mobility must therefore apply to both personal and public transport. Older people with disabilities are frequently identified as one group that suffer social exclusion due to their reduced mobility and problems with public transport as one relevant cause of their exclusion (Aarhaug & Elvebakk, 2015; Cepeda et al., 2018). From the transport user perspective, impairment of older people is based on four barriers: mobility, visual, hearing and cognitive impairment (Shrestha et al., 2016). For each of these barriers, impairment requirements necessitate additional measure and action as well as technological innovation and organisational improvement.

Studies on the use of passenger cars by older people usually focus on improving safety and facilitating its usage. Since age-related changes are perceptual, cognitive and motor abilities contribute to increased crash risk and decreased comfort with driving; hence, it is especially important to modify roadway environments to better match the ability of ageing drivers (Boot et al., 2013). Similarly, other research examines the identification for reasons of why older people opt-out of using public transport in place of a passenger car. As such, public transport facilities that have adequate and acceptable levels of mobility for specific needs of older people correlate a lowering in personal vehicle usage with an increase in public transport (Luiu et al., 2018a,c). Luiu et al. (2017, 2018b) piece together an overview of the barriers identified for public transport and flexible transport services by reviewing attitude, comfort, health, information and awareness, safety and personal security, service provision, built environment and affordability. To make public transport an attractive alternative for older people, all elements of the public transport chain need to be considered, especially door-to-door service, since any obstacle can make older persons unlikely or unable to complete a journey – trip-dependent. It is worth mentioning that vehicle access as well as holding a driving license are considered a significant role in later life mobility, since it provides autonomy, flexibility and independence (Davey, 2007; Haustein & Siren, 2015). It is especially important in rural areas due to the lack of

Table 3
Key topics and indicators for each transport and elderly research area reported in scientific reports.

Research area	Key topic	Indicator (i.e., within each key topic)	No. of papers	Reference	Spatial context [1]	Wider benefit[2]	Perspective research agenda[3]	Disruptive innovation[4]	Geographic coverage[5]
Need	Accessibility	Equipment in transport means	18	Aarhaug and Elvebakk (2015); Cepeda, Galilea, and Raveau (2018); Fiedler (2007); Hjorthol (2013); Luiu et al. (2017); Luiu et al. (2018c); Mackett (2014); McDonald et al. (2012); McDonald et al. (2013); Millonig et al. (2012); OECD (2001); Shrestha et al. (2016); Su and Bell (2009); Sze and Christensen (2017); TRACY (2013); Wasfi, Levinson, and El-Geneidy (2014); Wong, Szeto, Yang, Li, and Wong (2017); Wong, Szeto, Yang, Li, and Wong (2018)	U P	Not applicable	State-of-the-art; examination of new solutions	Not applicable	Austria = 1; Chile = 1; EU = 7; France = 1; Germany = 1; Hong Kong = 3; Netherlands = 1; Norway = 2; UK = 3; US = 1
		Equipment of bus/tram/rail stops	16	Aarhaug and Elvebakk (2015); Cepeda et al. (2018); Ettelman et al. (2017); Fiedler (2007); Luiu et al. (2017); Luiu et al. (2018c); Mackett (2014); McDonald et al. (2012); McDonald et al. (2013); OECD (2001); Shrestha et al. (2016); Su and Bell (2009); Sze and Christensen (2017); TRACY (2013); Wasfi et al. (2014); Wong et al. (2017)	U P R	Not applicable	Examination of needs and new solutions	Not applicable	Austria = 1; Chile = 1; EU = 6; France = 1; Germany = 1; Hong Kong = 2; Netherlands = 1; Norway = 1; Sweden = 1; UK = 3; US = 2
		Information facility	13	Aarhaug and Elvebakk (2015); Cepeda et al. (2018); Fiedler (2007); Hounsell et al. (2016); Luiu et al. (2018c); Mackett (2014); McDonald et al. (2012); McDonald et al. (2013); OECD (2001); Shrestha et al. (2016); TRACY (2013); Waara, Risser, and Ståhl (2013); Waara and Stahl (2004)	U P R	Not applicable	State-of-the-art; examination of new solutions	Not applicable	Austria = 2; Chile = 1; EU = 6; France = 1; Germany = 2; Netherlands = 1; Norway = 1; Sweden = 2; UK = 3
		Bus/tram stop approach	14	Aarhaug and Elvebakk (2015); Ettelman et al. (2017); Luiu et al. (2017); Luiu et al. (2018c); Mackett (2014); McDonald et al. (2012); Shrestha et al. (2016); Smith et al. (2007); Su and Bell (2009); Sze and Christensen (2017); TRACY (2013); Wasfi et al. (2014); Wong et al. (2017); Wong et al. (2018)	U P R	Not applicable	State-of-the-art; examination of needs and new solutions	Not applicable	Austria = 1; EU = 3; France = 1; Germany = 1; Hong Kong = 3; Netherlands = 1; Norway = 1; Sweden = 1; UK = 4; US = 2
	Affordability	Simple fare structure and concessionary fares	11	Ettelman et al. (2017); Fiedler (2007); Luiu et al. (2018c); Mackett (2014); McDonald et al. (2012); OECD (2001); Shrestha et al. (2016); Smith et al. (2007); Su and Bell (2009); TRACY (2013); Wong et al. (2018)	U P R	Not applicable	State-of-the-art; examination of needs	Not applicable	Austria = 1; EU = 5; France = 1; Germany = 1; Hong Kong = 1; Netherlands = 1; Sweden = 1; UK = 4; US = 1
		Transferable and flexible tickets	3	Luiu et al. (2018c); McDonald et al. (2012); Shrestha et al. (2016)	U P R	Not applicable	State-of-the-art; examination of needs	Not applicable	EU = 3; UK = 1
	Availability	Location of bus/tram/rail stops	13	Aarhaug and Elvebakk (2015); Banister and Bowling (2004); Böcker, Van Amen, and Helbich (2017); Fiedler (2007); Hjorthol (2013); Luiu et al. (2018c); McDonald et al. (2012); Nordbakke and Schwanen (2015); OECD (2001);	U P R	Not applicable	State-of-the-art; future visions	Not applicable	Austria = 1; EU = 4; France = 1; Germany = 1; Hong Kong = 1; Netherlands = 2; Norway = 3; UK = 2; US = 1

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Table 3 (*continued*)

Research area	Key topic	Indicator (i.e., within each key topic)	No. of papers	Reference	Spatial context [1]	Wider benefit[2]	Perspective research agenda[3]	Disruptive innovation[4]	Geographic coverage[5]
				Shrestha et al. (2016); TRACY (2013); Wasfi et al. (2014); Wong et al. (2017)					
		Interchange centres	0	–	–	–	–	–	–
		Bus/tram/rail network and connectivity	12	Böcker et al. (2017); Hjorthol (2013); Li et al. (2012); Luiu et al. (2017); Luiu et al. (2018c); Musselwhite and Haddad (2010); Rosenbloom (2009); Smith et al. (2007); Su and Bell (2009); TRACY (2013); Wasfi et al. (2014); Wong et al. (2017)	U P R	Not applicable	State-of-the-art	Not applicable	EU = 2; Ireland = 1; Hong Kong = 1; Netherlands = 1; Norway = 1; UK = 4; US = 2
		Demand responsive transport	15	Alsnih and Hensher (2003); Banister and Bowling (2004); Böcker et al. (2017); Currie and Delbosc (2010); European Commission (2018); Ettelman et al. (2017); Haustein and Siren (2015); Luiu et al. (2017); Luiu et al. (2018c); Metz (2000); Millonig et al. (2012); OECD (2001); Rosenbloom (2009); Shrestha et al. (2016); Su and Bell (2009)	U P R	Not applicable	State-of-the-art; future visions	Not applicable	Australia = 2; Canada = 1; EU = 5; Ireland = 1; Netherlands = 1; Sweden = 1; UK = 3; US = 2
	Accepta-bility	Safety	16	Boot, Stothart, and Charness (2013); Ettelman et al. (2017); Fiedler (2007); Li et al. (2012); Luiu et al. (2017); Luiu et al. (2018b); Luiu et al. (2018c); Mackett (2014); McDonald et al. (2012); McDonald et al. (2013); Rosenbloom (2009); Shrestha et al. (2016); Smith et al. (2007); Sze and Christensen (2017); TRACY (2013); Wong et al. (2017)	U P R	Not applicable	State-of-the-art; scenarios; future visions	Not applicable	Austria = 1; EU = 6; France = 1; Germany = 1; Hong Kong = 1; Netherlands = 1; UK = 4; US = 3
		Driver attitude	7	Aarhaug and Elvebakk (2015); Luiu et al. (2017); Luiu et al. (2018c); McDonald et al. (2012); Musselwhite and Haddad (2018); Shrestha et al. (2016); Wong et al. (2017)	U P R	Not applicable	State-of-the-art	Not applicable	EU = 3; Hong Kong = 1; Norway = 1; UK = 2
		Provision of information	13	Aarhaug and Elvebakk (2015); Hounsell et al. (2016); Luiu et al. (2017); Luiu et al. (2018b); Luiu et al. (2018c); McDonald et al. (2012); McDonald et al. (2013); OECD (2001); Rosenbloom (2009); Shrestha et al. (2016); Smith et al. (2007); Waara et al. (2013); Waara and Stahl (2004)	U P	Not applicable	State-of-the-art; examination of new solutions	Not applicable	Austria = 1; Chile = 1; EU = 6; France = 1; Germany = 1; Hong Kong = 3; Netherlands = 1; Norway = 1; UK = 3; US = 1
		Transition support	5	Aarhaug and Elvebakk (2015); McDonald et al. (2012); OECD (2001); Rosenbloom (2009); Shrestha et al. (2016)	U P R	Not applicable	Examination of needs and new solutions	Not applicable	Austria = 1; Chile = 1; EU = 6; France = 1; Germany = 1; Hong Kong = 2; Netherlands = 1; Norway = 1; Sweden = 1; UK = 3; US = 2
Innovation	Vehicle	Private cars [6]	17	Adler and Rottunda (2006); Behrens et al. (2004); Eby, Molnar, and Kartje (2009); Eby and Molnar (2013); Ellaway, Macintyre, Hiscock, and Kearns (2003); Hakamies-Blomqvist and Peters (2000); Luiu et al. (2017); Luiu	U P R	facilitating mobility; return to social life; safety improvement;	state-of-the-art; benefits of existing solutions; future visions	Yes – design features and technologies; in-vehicle ITS technology; active intelligent transport systems for vehicle	Australia = 3; Belgium = 1; Canada = 3; EU = 2; Finland = 3; Germany = 1; Ireland = 1; Israel = 1; Japan = 1; Netherlands = 1;

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Table 3 (*continued*)

Research area	Key topic	Indicator (i.e., within each key topic)	No. of papers	Reference	Spatial context [1]	Wider benefit[2]	Perspective research agenda[3]	Disruptive innovation[4]	Geographic coverage[5]
				et al. (2018a); Musselwhite (2011); Musselwhite (2017); OECD (2001); Rabbitt, Carmichael, Shilling, and Sutcliffe (2002); Rhiu, Kwon, Bahn, Hwan Yun, and Yu (2015); Shergold, Lyons, and Hubers (2015); Haustein and Siren (2015); Wasfi et al. (2014); Whelan et al. (2006)		identify travel barriers; changes is travel patterns (e.g., ICT); in-vehicle applications and safety		safety; future smart car technologies	Norway = 1; OECD = 3; Sweden = 3; UK = 8; US = 8
		Buses and rail (i.e.; vehicle adaptations and specialised equipment)	12	Adler and Rottunda (2006); Akiyama, Wahira, Kamata, and Fujii (2001); Davey (2007); Ellaway et al. (2003); Luiu et al. (2017); Luiu et al. (2018a); McDonald et al. (2013); Rahman, Strawderman, Adams-Price, and Turner (2016); Shergold et al. (2015); Somenahalli (2015); Taylor and Tripodes (2001); Wong et al. (2018)	U P R	Facilitating access to public transport; identify travel barriers; transportation Alternatives	State-of-the-art; future visions	Yes –information tasks; ITS-orientation; dedicated trips; quality of travel; additional passenger facilities	Australia = 2; Canada = 1; EU = 1; Honk Kong = 1; Japan = 1; New Zealand = 1; UK = 3; US = 4
		Fleet telematics system vehicle and taxi adjustments	5	Broome, Worrall, Fleming, and Boldy (2012); Luiu et al. (2017); Luiu et al. (2018a); OECD (2001); Shergold et al. (2015)	U P R	Facilitating mobility	State-of-the-art; future visions	Yes – new technologies	Australia = 2; Canada = 1; EU = 1; OECD = 1; Sweden = 1; UK = 2; US = 1
		Special types of vehicles for local mobility	6	European Commission (2018); Johnson, Rose, and Oxley (2013); Luiu et al. (2017); Luiu et al. (2018a); OECD (2001); Shergold et al. (2015)	U P R	Facilitating mobility	State-of-the-art; future visions	Yes – new technologies	Australia = 2; Canada = 1; EU = 2; OECD = 1; UK = 2; US = 1
	Infrastru-cture	Specific technical infrastructural adjustments	7	Alonso et al. (2011); Department for Transport (2006); Eby et al. (2009); Figueroa, Sick Nielsen, and Siren (2014); Hughes, Huang, Zegeer, and Cynecki (2000); OECD (2001); Winters, Sims-Gould, Franke, and McKay (2015)	U	Facilitating mobility; adjustments for drivers; pedestrians; cyclists and wheelchair users; investigation of travel patterns affected by infrastructure	State-of-the-art; future research between behavioural adaptations and technical infrastructure; examination of existing and new solutions	No	Canada = 1; Denmark = 1; OECD = 1; EU = 1; UK = 1; US = 2
		Recommendations and guidelines	10	Alonso et al. (2013); Beatty, Higashide, Accuardi, and Duplessis (2016); Cloos et al. (2010); Department of Transportation (2001); Hallgrimsdottir, Wennberg, Svensson, and Ståhl (2016); Johnson, Shaw, Berding, Gather, and Rebstock (2017); Levasseur et al. (2015); Rye and Carreno (2008); Sze and Christensen (2017); Vlahogianni et al. (2015)	U P	Strategies development (e.g., "design for all" approach); reducing road safety risks	State-of-the-art; future research proposed for efficient policy development	No	Canada = 1; Caribbean countries (group of six) = 1; EU = 3; Hong Kong = 1; Sweden = 1; UK = 2; US = 4
		Specific solutions for rural areas	5	Broderick (2018); Currie and Delbosc (2010); Currie and Delbosc (2017); Holley-Moore and Creighton (2015); Vlahogianni et al. (2015)	R	New transport demand in rural areas; role of technology-enabled	State-of-the-art	No	Australia = 2; EU = 1; UK = 1; US = 1

(*continued on next page*)

Table 3 (*continued*)

Research area	Key topic	Indicator (i.e., within each key topic)	No. of papers	Reference	Spatial context [1]	Wider benefit[2]	Perspective research agenda[3]	Disruptive innovation[4]	Geographic coverage[5]
						innovation; reducing road safety risks			
	Organisation	Top-down government facilitation	28	Anderson et al. (2014); Bédard, Isherwood, Moore, Gibbons, and Lindstrom (2004); Blythe (2004); Borst et al. (2009); Broderick (2018); Broome et al. (2012); Cerin et al. (2014); Charlton, Oxley, Fildes, Oxley, and Newstead (2003); Department for Transport (2012); Dickerson et al. (2019); Edelen (2018); Eggermont, Vandebosch, and Steyaert (2006); Ettelman et al. (2017); European Commission (2018); Gorris, de Kruijff, de Goede, Wulf, and Henne (2011); Hounsell et al. (2016); Inoue et al. (2011); Li and Voege (2017); Mitra, Bae, and Ritchie (2019); Morlok, Kulash, and Vandersypen (1971); Obi, Ishmatova, and Iwasaki (2013); Powers, Rinefort, and Jain (2016); Preston and Rajé (2007); Ryser and Halseth (2012); Shrestha et al. (2016); TIDE (2013); Velaga, Beecroft, Nelson, Corsar, and Edwards (2012); Wong et al. (2017)	U P	facilitating mobility; demand creation; regulatory and educational Impacts	examining existing but not widely used schemes; scenarios analysis for urban and rural areas; no futuristic studies based on existing innovations	No	Belgium = 1; Canada = 2; EU = 5; Finland = 1; Germany = 1; Hong Kong = 2; Japan = 1; Netherlands = 2; Sweden = 1; UK = 5; US = 9
		Societal incentives	9	Blodgett, Khani, Negoescu, and Benjaafar (2017); Eggermont et al. (2006); Foreman, Tucker, Flynn, and West (2003); Neven et al. (2017); Neven et al. (2018); Smith et al. (2007); Powers et al. (2016); Shrestha et al. (2016); Wong et al. (2017)	U P	Facilitating mobility; inclusion aimed solutions	Research based on existing innovations; case study focused	No	Austria = 1; Belgium = 3; EU = 1; Hong Kong = 1; Germany = 1; Netherlands = 2; UK = 1; US = 3
		Bottom-up schemes	8	Blodgett et al. (2017); Cerenio and Soper (1993); Patrick and Roseland (2005); Petrie et al. (1996); Preston and Rajé (2007); Vivoda, Harmon, Babulal, and Zikmund-Fisher (2018); Waara et al. (2013); Waara and Stahl (2004)	U P R	Self-developed elderly dedicated solutions evolving into broad use by all user groups (e.g., businesses)	Research based on existing innovations; case study focused	No	Canada = 1; Germany = 1; Sweden = 1; UK = 2; US = 4

[1] Urban = U; peri-urban = P; rural = R.
[2] Based on descriptive answers of facilitating mobility, generating additional demand and improving quality of life.
[3] Based on descriptive answers of state-of-the-art, examination scenario, benefits and future vision.
[4] Based on polar answers of "Yes" or "No", if "Yes" explanatory reasons are listed.
[5] IGO scientific reports from the EU and OECD are independently categorised.
[6] Vehicle design and adaptations related to impairments, driving problems and in-vehicle interventions and equipment.

public transport as an alternative (Ellaway et al., 2003). Several studies indicate that over 90 % of older drivers point out that giving up driving would restrict their independence and mobility (Rabbitt et al., 2002). It is worth stressing that before older people stop driving, they usually reduce how much they drive and limit their driving to local journeys in familiar areas and under easy driving conditions. Several studies on driving cessation found that the passenger car remains the preferred option; once people have stopped driving, it moves toward a reliance on lifts from family or friends, with consequences in terms of loss of mobility and burden placed on their drivers (Davey, 2007; Musselwhite, 2017; Taylor & Tripodes, 2001).

Attributes of adequate urban transport systems are mainly adopted via accessibility, affordability, availability and acceptability. These synthetic categories combine all identified aspects of public transport need into four groups. Accessibility identifies with older people's ability to access the things required to meet their needs through services and activities available within a short distance, or subsequently, services and activities that can travel to them. Affordability relates to the possibilities of using transport and mobility systems within financial means, understanding the cost of travel can sometimes be a major barrier to the number of trips one may take. Availability corresponds to public transport facilities and whether they are within reachable distance of people's homes and destinations and service times and frequencies needed in relation to lifestyle. In turn, acceptability includes a wide range of issues including safety, driver attitude, information and transition support (McDonald et al., 2012; Shrestha et al., 2016; TRACY, 2013). The general requirements of public transport need for older people is listed in Table 4 and has been adapted from McDonald et al.'s (2012) GOAL research on public transport provision and associated facilities from the perspective of the need of the elderly.

Studies of mobility in later life have explored factors associated with need fulfilment (Luiu et al., 2018c; Ryan & Wretstrand, 2019). Luiu et al. (2018c) investigate factors preventing the use of alternative transport modes to using a passenger car by older people. They found in several European countries that almost half of journeys from the elderly were made by car with even a higher percentage in the USA, Canada and Australia. Various transport modes were analysed before conducting a logistic regression analysis of the relationships between different characteristics, circumstances and potential modalities – which saw five independent variables produce statistically significant results: cohabiting, perceived health condition, income, region of residence and gender. These results highlight the importance of having a larger choice and set modal satisfaction (Böcker et al., 2017; Nordbakke & Schwanen, 2015) and explore the unmet need for out-of-home activity as dependent on such factors as car availability (i.e., including self-perceived health), socio-demographics (i.e., gender, age and living situation), socioeconomic status (i.e., income), residential location and support from one's social network. Different studies found access to a personal car essential (Holley-Moore & Creighton, 2015; Luiu et al., 2018c; Musselwhite, 2011; Musselwhite & Haddad, 2018) Much less research has focused specifically on the relationship of unmet needs and the quality of public transport.

Towards a more sustainable transport, alternatives to physical movement should be also considered for older people. Parkhurst et al. (2014) presented a model of modes of connectivity which link corporeal mobility with three other forms of mobilities: virtual, potential and imaginative (i.e., an ideational form). Virtual mobility refers to the use of ICT to virtually visit any location out of home through internet-connected cameras. It also includes keeping in touch with family via video chat (e.g., Skype), online shopping and home delivery (e.g., takeout, groceries and telehealth). Potential mobility is the perceived ability to be able to go anywhere according to individual need (i.e., taking a trip when in reality it is not actually done). In turn, imaginary mobility is defined as "the ways in which people extend their sense of connectedness to, and meaningful engagement with, life activities that were previously addressed by corporeal mobility" (Parkhurst et al., 2014). These types of mobility do not replace physical movement but can assist in meeting some of the needs of the elderly when significant barriers restrict travel. Older people can be encouraged to reduce literal mobility in favour of ideational forms to make transport systems more sustainable. In all, these finding together with the other literature on transport need piece together a wide range of need-based research of how older people and their public transport requirements necessitate the many changes, mostly on the supply side, to health status, travel need and modal travel preference.

4.2. Defining innovation in the transport sector

A variety of definitions of innovation exist in the literature (i.e., scientific reports, business publications and popular press). Moreover, many disciplines are active in innovation research, including management studies, economics, entrepreneurship, psychology and sociology. Schumpeter (1942), referred to as the founder of the economic theory of innovation, regarded innovation as the economic impact of technological change and as the use of new combinations of existing productive forces to solve the problems of business. He saw innovation as consisting of one of five types of activity: creation of new products, new methods of production, new sources of supply, exploitation of new markets and new ways to organise business. From this standpoint, radical innovation creates major disruptive change, whereas incremental innovation continuously advances the process of change. Dating back to Schumpeter (1942), a number of different approaches have appeared. Carlson and Wilmot (2006) pointed out that innovation is the process that turns an idea into value for the customer and results in sustainable

Table 4
General requirements of public transport need for the elderly, adapted from McDonald et al. (2012).

Need	Activity	Travel requirement
Accessibility	Bus, tram	Kneeling facility, handrail, priority seating, information facility, provision of seating facilities, wheelchair space
	Bus, tram stop	Information about bus services (i.e., preferably real time information), audible announcement facility for visually impaired person, located at a visible place, well-lit bus stop, clean bus stop with protection from rain and sun, provision of seating facilities
	Bus, tram stop approach	Well maintained footpath leading to a bus stop, level or low gradient, good crossing facility (i.e., signalled crossing), traffic island for a road crossing to shorter distances, lower traffic speed
Affordability	–	Provision of concessionary fares, simple process of obtaining a pass, ease of use (i.e., showing it to the driver or machine reader), transferable and flexible tickets, simple fare structure
Availability	–	Services connecting residence to place of interest (e.g., shopping centres and medical services), demand responsive transport, point-to-point (e.g., home to destination and vice versa) convenience
Acceptability	Safety	Safe approaches to bus stop, safe crossing, safe bus stop location, priority seating, provision of grab rails
	Driver attitude	Good (i.e., positive) attitude towards older people, driving behaviour (i.e., pulling close to the kerb, waiting until passengers sit and smooth acceleration and deceleration), friendly and courteous, helpful and informative, assistance if needed
	Information	Provision of visual and audio announcement at bus stop, provision of route information displayed at bus stop, information with a large font and sufficient details, provision of help point out, easily understandable timetable, wheelchair accessibility of buses on a route
	Transition support	Travel information, travel training, travel awareness

profit for the enterprise. Similarly, O'Sullivan and Dooley (2009) give a more extensive definition in which "innovation is the process of making changes, large and small, radical and incremental, to products, processes, and services that results in the introduction of something new for the organisation that adds value to customers and contributes to the knowledge store of the organisation." They noticed that innovation can also be applied to services that makeup essential knowledge capital of organisations. The advantage of using this broad definition of innovation is that it encapsulates all types of innovation. It is also the main reason we adapted this definition to new solutions that improve mobility of older people in this review. A broad presentation of different concepts of innovation are given by Fagerberg (2006) and Salter and Alexy (2014).

Innovation measurement requires a unified definition to ensure that comparable data are collected for phenomena of interest. The Oslo Manual has been developed by the OECD and Eurostat to support the collection of statistically representative and internationally comparable data on innovation. The Oslo Manual's fourth edition provided a universal definition of innovation that is applicable to all sectors covered by the System of National Accounts. "An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD, 2018). Compared with previous editions, a major change to the definition of business innovation is a reduced list-based definition of four types of innovations (i.e., product, process, organisational and marketing) to two (i.e., product innovation and business process innovation). Business process innovation concern six different functions of a firm, where two functions relate to a firm's core activity of producing and delivering products for sale, while the other functions concern supporting operations (OECD, 2018).

Innovation in services is different from innovation in manufacturing essentially because services are characterised by intangibility, heterogeneity, perishability, increased customer interactivity and simultaneity between production and consumption (Randhawa & Scerri, 2015). Services are produced, delivered and consumed simultaneously making it harder to distinguish between service product innovation and service process innovation. This specificity of services is also characteristic for transport services. In most of cases, it is the manufacturing sector which stimulates innovation in transport, both product and process (e.g., new vehicles, novel infrastructure solutions and new ways of providing services), which are later adopted by service enterprises. Usually the first phase of innovation process in a service enterprise is adaptation of new technology, which brings advantages in terms of higher efficiency of functioning of a company, what results in improvement of quality and distribution of services. Afterwards, new transport services might emerge by finding relating applications in new areas and activities. The use of modern technology creates great potential. The adaptation of new ICT methods can forecast significant emphasis for older people with the implementation and organisational innovation of relating transport services.

Regardless of the various definitions used to define innovation, scholars widely agree that innovation comes in many forms. In transport, innovation has been discussed with different meanings attached. In some cases, it is still a synonym for technical innovation (Site, Filippi, & Giustiniani, 2011), whereas others notice a variety of innovation types (Edwards-Schachter, 2018; Hyard, 2013; Klasing Chen et al., 2014; Trott, 2017; Zawawi et al., 2016). Hyard (2013) classifies transport innovation into two different areas: technical and non-technical. Taking into account these types of innovation and necessary changes, considering the need of older people, we elucidate transport innovation into three key topics: vehicle and infrastructure as technical areas of innovation and organisational improvements (i.e., top-down government facilitation, societal incentives and bottom-up schemes) as non-technical.

4.3. Vehicle innovation

Due to the fact that transport is an important element of social life, the emphasis of making it easier to use vehicles, especially for older people, play an important part in transport innovation. Research conducted in this field concern many issues resulting from difficulties related to the mobility of elderly persons. Key solutions to vehicle innovation examine vehicle design (i.e., private cars, buses and rail vehicles) and vehicle adaptation (i.e., age-related impairments, driving problems, in-vehicle interventions and equipment assistance, flexible transport services (FTS) vehicle and taxi adjustments, facilitating access equipment and special types of vehicles for local mobility. Apart from pedestrian traffic, options that ensure the mobility for the elderly require the adaptation of vehicles due to various impairments (Luiu et al., 2018b). For older people, having difficulty walking (i.e., even to the bus stop) and cycling, driving is often the only option for independent mobility. Modern vehicle designers have predominantly focused their vehicle designs around young adult anthropometry and performance. This has meant that, more often than not, the ergonomic specifications of modern vehicles do not necessarily consider the need of the elderly (Eby & Molnar, 2013; Whelan et al., 2006). Dating back to 2001, an OECD working group identified a wide range of vehicle adaptations to best accommodate older driver's general functionality. It focused on age-related functional impairments that enable older drivers to maintain their mobility for longer (OECD, 2001). The vehicle adaptations include: (1) to allow better entry and exit for older occupants by way of alteration of the doorframe height, width of door aperture, seat height, door sill height, floor-well depth and provision of swivel seats; (2) to

Table 5
Age-related impairments, driving problems and in-vehicle interventions and equipment assistance, adapted from Whelan et al. (2006).

Age-related impairments	Driving problems	In-vehicle interventions and equipment assistance
Increased reaction time, difficulty dividing attention between tasks	Difficulty driving in unfamiliar or congested areas	Navigation and route guidance
Deteriorating vision, particularly at night	Difficulty seeing pedestrians and other objects at night, reading signs	Night vision enhancement, in-vehicle signs
Difficulty judging speed and distance	Failure to perceive conflicting vehicles, crashes at intersections and junctions	Collision warning, automated lane changing
Difficulty perceiving and analysing situations	Failure to comply with yield signs, traffic signals and rail crossings, slow to appreciate hazards, difficulty in complex traffic manoeuvres, such as lane changing and merging	In-vehicle signs and warnings, intelligent cruise control, automated lane changing and merging
Difficulty turning head/neck, reduced peripheral vision	Failure to notice obstacles while manoeuvring and reversing, lane excursion, difficulty merging and lane changes	Blind spot and obstacle detection, rear collision warning, automated lane keeping, changing and merging
More prone to fatigue	Getting tired on long journeys	Intelligent cruise control, automated lane following
General effects of ageing	Concerns over inability to cope with a breakdown, driving to unfamiliar places, at night, in heavy traffic.	Emergency callout (i.e., mayday), vehicle condition monitoring
Some impairments vary in severity from day-to-day (e.g., tiredness)	Concern over fitness to drive	Driver condition monitoring (e.g., alcohol ignition interlock device)

alter driving features by making driving easier (i.e., power steering, automatic transmission and easier adjustment of the seat, steering wheel and mirrors); and (3) to use specific adaptive equipment such as a steering wheel knob and special mirrors. Further design improvements advocated older, fragile occupants install handhold and support for assistance in entering and exiting the vehicle. Car seat adjusters has been another issue. Many cars are now equipped with power-operated seats, many of which store the preferred seat position and adjustment in memory. In order to identify the potential usefulness of in-vehicle intervention and equipment for older drivers, known impairments and associated problems drivers tend to develop with age, with possible intervention and equipment, should be examined (Table 5). As such, passenger car advanced technology systems have been on the rise with increased safety and mobility by adding age-related features geared toward the elderly (Akiyama et al., 2001; Eby et al., 2009; Eby & Molnar, 2013). However, it is worth noting the financial aspect, especially regarding the acquisition of passenger cars adapted for an older person's need are usually more expensive. As such, this can pose a significant problem to the lower income strata of aged populations.

As implied, not all older people have access to a passenger car in their household or hold a driving license, in part due to health and psychological issues associated with ageing (Adler & Rottunda, 2006; Hakamies-Blomqvist & Peters, 2000; Luiu et al., 2017). Investigating alternative transport options – such as public transport, FTS and demand-responsive transport system (DRTS) (e.g., community transport and "dial-a-ride" service), motorised mobility scooter (MMS) and powered wheelchair – is fundamental (Wasfi et al., 2014). Researchers have investigated a number of difficulties encountered by older people with use of such vehicles by recommending design features that improve their situation. In order to make public transport more attractive, many countries have developed specific instructions to adapt vehicles and infrastructure for elderly need (Rahman et al., 2016). For bus transport, recommended dimensions include a raised bus boarding platform, curb height and gradient from curb height to bus step. The use of low-floor wheelchair accessible vehicles and the provision of clear bus stop signs as well as timetable information are specified. For on-street rail vehicles, use of low-floor transit vehicles with a platform height of 350 mm are recommended (Eby & Molnar, 2013; Wong et al., 2018). Within a European context, GOAL attributed bus design with smooth, step less entrances (i.e., with a low-floor and kneeling facility); handrails; priority seating facilities (i.e., in the front part); information facilities; wheelchair space (i.e., with stable, firm and slip-resistant surface); unobstructed aisles; bright and adequate lighting; well-illuminated, large, clear bus route numbers; and bus route numbers on the front, back and side (McDonald et al., 2013).

Literature suggests that the dissatisfaction with conventional (i.e., fixed route) public transport are similar in many developed countries within the elderly passenger group (Luiu et al., 2017; Shergold et al., 2015). If public policy, or innovative private activity, are aimed at attracting the elderly toward alternatives to private car usage, alternative transport must remain highly flexible. Within the domain of FTS vehicle size and usage should be specifically equipped depending on the number of passengers. Trained drivers should be allotted for special need customers. Studies show that replacement of a fixed route service with FTS in Hervey Bay, Australia resulted in a significant, positive improvement in use and usability of buses. This is supported by a doubling in the number of users over the studied period (Broome et al., 2012) in which changes, associated with the bus system, showed improvements in satisfaction (i.e., operating bus times, finding and understanding information, physical aspects of the bus and driver friendliness). In particular, the dedicated use of a low-floor bus may correlate with improved satisfaction with bus signage and moving on and around the bus, as newer lowered floor buses typically included additional considerations such as signage specific to disability guidelines and increased availability of hand rails.

Paratransit vehicles comprise of an extensive range of public and private transport services that provide demand-responsive shared rides on a door-to-door basis, often referred to as "dial-a-ride" (Wasfi et al., 2014). Typically, small minibuses, taxis or private cars are used. Paratransit is particularly appropriate for areas where demand is low, either due to low population density (i.e., rural areas) or because clientele is restricted to a small minority of the population size. Taxi services using standard vehicles should have a body design that facilitates older passenger entry and exit. In addition, a person in a wheelchair should be able to board and get off using an access ramp that is controlled by the driver. Preferably the location of the seats in the rear of a minivan are to be close to the door to enable disabled passengers to enter the vehicle and then move easily within the compartment. Respectively, in the United Kingdom, a new regulation requiring some wheelchair-accessible taxicabs to be on-call has led to the adaptation of London's taxi system. In Sweden, a larger minivan, called "TaxiRider", has been developed. Its rear compartment, which is full low-floor, provides space for five to seven passengers who can move in a nearly upright position (i.e., 1.80 m) to reach their seats (Akiyama et al., 2001).

Another option that can help older people maintain independent travel, at least for short trips are MMS and powered wheelchairs. These special types of vehicles can be used to provide local mobility to those with disabilities. They offer tremendous mobility advantages for disabled people; however, lack of physical infrastructure often makes them unsuitable for widespread use. Interestingly, alternative transport options such as MMS provide an independent travel mode that can augment mobility at a time when ageing and related health conditions may affect capacity to drive, use public transport or walk. In Australia, MMS users (i.e., scooters) are classified as pedestrians and are permitted to be on the footpath (Johnson et al., 2013). Older MMS users have reported being satisfied with the 10 km/h speed limit (Somenahalli, 2015) with a number of MMS being able to travel over 35 km on a single charge – depending on battery configuration. Finally, it is worth noting that cycling is another option for mobility. The proportion of older people cycling is less than younger groups. Often older people are not use to or able to cycle; however, it has been documented that more elderly people are starting to cycle as a leisure activity. Cycling is especially important in small towns, where facilities are close by, easy and safe to reach. A beneficial addition to cycling is the electric bicycle which can be operated with less exertion and may be ideal for local trips when the weather permits and safe routes are available (Behrens et al., 2004; McDonald et al., 2013).

Smart solutions in smart vehicles is another important vehicle innovation. Since, vehicles and especially passenger cars are becoming important personal places. Elderly drivers that show signs of decreased driving ability – due to a decline in perception (e.g., vision and hearing), cognitive response time (e.g., motor skills coordination), cognitive memory and attention and physical strength and dexterity (Rhiu et al., 2015) – can be abetted as a result of this technology. Smart technologies used in passenger cars are particularly helpful in mitigating elderly driver's functional decline and avoid behaviour by assisting them with their driving activities, increasing road safety. Also, one should consider the dissemination of solutions introduced in new vehicles such as lane following warnings, image enhancement (e.g., night vision), image features prevention recognition, warning systems and smart speed limiters (i.e., speed measurement, auto braking and pedestrian detection). All these assistant smart technologies, in conjunction with relating transport infrastructure innovation, will improve the safety and comfort of travelling for older people.

4.4. Infrastructure innovation

Literature that links transport infrastructure and innovative solutions for elderly people is vast. Exploratory research highlights three dimensions: (1) specific technical infrastructural adjustments (i.e., distinct solutions for drivers, pedestrians (including the disabled and

wheelchair users) and cyclists (e.g., infrastructure for slow modes)); (2) recommendations and guidelines (e.g., for policymakers, transport engineers and urban planners); and (3) specific solutions for rural areas. First, in terms of driver need in regard to road design and infrastructural features, it is well documented that certain tasks are particularly difficult for older drivers, including: reading traffic signs, crossing intersections, turning at intersections, following road markings and responding to traffic signals (Eby et al., 2009). In addition, the literature identifies solutions in which specific relevance for older drivers is documented (Alonso et al., 2011; Figueroa et al., 2014). Some key examples include lighting at intersections, pavement marking at intersections, number of left-turn lanes at an intersection (i.e., right-turns for countries that drive on the left), width of travel lanes, concrete lane guides (i.e., raised channelisation) for turns at intersections and size of traffic signals at intersections. These technical infrastructure adjustments (i.e., advancement in infrastructure and infrastructure design) play an important role in bettering older driver's experience and making roads safer for all.

In the case of slow mode development there are a number of innovative noteworthy solutions. Technological innovation can now interlink with the green signal to match the time required for pedestrians to cross the road by tracking pedestrian movement through the use of infrared detectors and other devices (OECD, 2001). An example of such an ICT-based solution is the "Pedestrian User-Friendly INtelligent" (puffin) crossing, first introduced in the United Kingdom. The puffin crossing design is distinct in that lights that manage the pedestrians are on the same side of the road as the pedestrian user, rather than on the opposite side as in the older pelican crossing (Department for Transport, 2006). Another type of intelligent crossing device being developed includes the automated pedestrian detector which provide the means to detect the presence of a pedestrian as they approach the curb prior to crossing the road, indicating the walk signal without any action required on the part of the pedestrian. These detectors can be useful by increasing safety for slower pedestrians that require additional time to finish crossing (Hughes et al., 2000). In addition, infrastructural designs are being improved for disabled pedestrians and wheelchair users who require flush entry and exit points onto footpaths – especially when crossing intersections. For the blind and low-vision impaired, braille and sound-oriented systems can assist in manoeuvring footpaths, intersections and crossings. In terms infrastructure-based cycling research, most of it does not focus on older adults. Nonetheless, according to the Canadian study by Winters et al. (2015), factors that facilitate cycling must incorporate a broad scale of supportive infrastructure. Cycling infrastructure, especially in urban and peri-urban areas, is mostly compliant and transferable with MMS, electric scooter and electric bicycle usage. As such, in additional to just building cycling lanes adjacent to other vehicle lanes, additional cycling signage, bike-specific traffic lights, bicycle-only roads and pathways and bicycle repair stations are all important infrastructural advances in slow mode development.

Second, there is a wide range of practical implementation issues and differing kinds of guidelines for policymakers, transport engineers and urban planners alike in regard to older persons and their livelihood. The GOAL project (Alonso et al., 2013), in conjunction with the European Commission (Vlahogianni et al., 2015), put forth a number of policy recommendations, including: (1) guidelines for good practice in the design of infrastructure – based on findings out of the USA (Department of Transportation, 2001) and (2) guidelines for accessible transport design in North America, the United Kingdom and Hong Kong (Sze & Christensen, 2017). The ladder targets direct transport infrastructure design with "walkability in mind", aimed at best providing for older persons public transport usability (Beatty et al., 2016). An analysis of national-level documentation across Europe indicate a considerable amount of research focuses on addressing mobility-specific issues among older people's efficiency. Much of the findings are Western European-centric (Johnson et al., 2017). As such, a correlation can be made between more developed countries and a higher standard of regulation and infrastructural requirement in the designing of transportation networks, public transport and transportation implementation. This linkage infers that such guidelines not only assist with older persons ease of access but also in structuring safety, regulation and lifestyle – location-specific. There are still considerable differences not only between the levels of implemented accessibility policy in high- and low-income countries but also at the local or regional level as indicated by the example from Sweden (Hallgrimsdottir et al., 2016) and six Caribbean countries (Cloos et al., 2010). Additionally, it is worth mentioning, Levasseur et al.'s (2015) research on current knowledge on the associations or influence of the neighbourhood environment and social participation on mobility of elderly people partially reviewed this phenomenon. Mobility and social participation are found to both positively associate with infrastructural attributes, proximity to resources and recreational facilities and social support. Additional studies even confirmed that accessibility attributes connected with infrastructure determine the level of mobility of elderly people (i.e., to a greater extent than concessionary fares or other regulatory solutions) (Rye & Carreno, 2008). This signals useful policy recommendations related to land use planning and infrastructure, transportation and assistance with elderly-friendly development.

Third, special consideration of rural area infrastructure calls into question a number of network-relating factors, that being, the amount of rural road, public transport routing and vehicle access. Rural road networking is dependent on how well-developed the building of road is within a country. Relative to road network, the routing of public transport and vehicle access play secondary infrastructural roles. In the United Kingdom, for example, within specific rural areas it has been recorded older people do not have sufficient access to public transport and, as identified, only about 18% of those over 65 living in rural areas do not use public transport due to the fact that none is available compared to 2% of those living in urban areas (Holley-Moore & Creighton, 2015). Rural infrastructural innovation can play a critical part in expanding mobility options for elderly people. The issue of transport disadvantage in rural areas is particularly studied in Australia characterised by low-density development (Currie & Delbosc, 2010, 2017). Broderick (2018) reviewed existing and emerging technologies in the context of improving safety and infrastructure, access to transport and overcoming barriers in rural areas – stating that technology has been a key enabler in reducing transportation gaps and operational inefficiencies for older adults. From these finding we deduce a significant link between transport infrastructure and innovative solutions for the elderly as highly relevant in both urban, peri-urban and rural areas. Highlighted infrastructure design of public transport for older persons indicate varying levels of overarching control (i.e., through government regulation) as highly beneficial if it is citizenry-focused and oriented toward community needs (i.e., socially accepted at a societal scale).

4.5. Organisational innovation

One key factor the impact of ageing has on travel behaviour is its effect on the way organisational innovation is framed. Upgrading various modes or entire transport systems are not limited to a single technical breakthrough but rather attributed to the way a transport service is offered. Senior citizens are not as reluctant at adopting new technologies as it is commonly believed (Eggermont et al., 2006). Modern technology can be perceived as an enabler technology for older people to travel, leaving the need – and potential – for organisational change in terms of technical innovation a positive advancement. Innovative actions fall into three categories: top-down government facilitation (i.e., regulation and education), societal incentives (i.e., voluntary activities) and self-developed service providers catered via local community efforts (i.e., bottom-up schemes). As suggested by Su and Bell (2009), strategies to improve alternative transport options point toward the inclusion of new mobility services and promotion of

awareness. Another dimension, worth noting, are the differences between urban, peri-urban and rural environments, since rural areas experience, in general, significantly poorer transport accessibility – exacerbated by the elderly (Preston & Rajé, 2007). As such, organisational change in response to new technologies is predominately favoured in wealthier, urban communities (Velaga et al., 2012).

In terms of government sponsored organisational innovation, ageing populations especially require proper organisation and adaptability to best meet their needs. Some organisational innovation can only be completed by way of authorised, legal action. For example, in the USA existing legislation, through the Americans with Disabilities Act of 1990, ensures people with impairments have, among other, equal access to the means of transportation. A related federal, legally-binding statute is the Fixing America's Surface Transportation Act which facilitates pilot-oriented programmes to fund innovative projects and improve coordination of services for the transportation disadvantaged (Ettelman et al., 2017). A key limitation to any legally enforced organisational innovation is its prohibitive cost. Moreover, the role of government to provide mobility as a service (MaaS), includes carpooling and car-sharing schemes easily usable by the elderly (Li & Voege, 2017). Governments, with advancements in internet speed (i.e., broadband and fibre optics), have integrated data as well as on-the-fly data processing to revert from one-time actions to mass, multi-level coordination. Harmonisation between government agencies and jurisdictions have implemented elderly-friendly transport policies and resources, accordingly (Ryser & Halseth, 2012). Government intervention can also be pin-pointed to desired elderly requirements (e.g., full and accurate travel information). However, new mobile applications are often not older person-compliant due to a lack of understanding, interface complexity or simply due to the small font on smartphones or similar device (Hounsell et al., 2016). One solution to this problem has been reported by the Transport Innovation Deployment for Europe (TIDE) project in which authorities specifically organised tenders to develop applications dedicated with specifications for older users (TIDE, 2013). The TIDE project proved to be a useful legislative starting point in incorporating Europe's elderly with ICT and relating application-based transformation. In an effort to attain a TIDE-friendly approach, local authorities empowered special mobility services dedicated to older transport user requisites. Special transport services for people with disabilities supplement regular fixed services with public transit-oriented ones. This type of action is a DRTS which has been steadily becoming more aged-person responsive (Shrestha et al., 2016). Since older people are more reliant than others in their local neighbourhood, DRTS fulfils basic remodelling needs for local authorities when planning transport organisation. As such, walking and cycling can be an important alternative to travelling short distances for the elderly. Older people, however, may be more liable to injury if they fall or are involved in a collision as a pedestrian or cyclist. Local authorities should therefore ensure that roads, footpaths and other walkways are designed to be elderly-safe as well as properly maintained in order to prevent unnecessary falls and injuries (Cerin et al., 2014). A sound, implemented DRTS improves environmental features by effectively promoting the elderly a non-negative transport and community-oriented experience (Borst et al., 2009; Inoue et al., 2011).

In terms of retirement, reduced financial capability has been recorded; in turn, it forces a reduction in the use of private vehicles by emphasising alterative transport. In poorer societies, where private car ownership is limited it has been recognised that this can be transposed into full exclusion from public transport services. Organisational measures which can be used, to countermand this tendency, is reduced fare for the elderly and bus buddy-support initiatives. Fare subsidies are a long established, efficient tool to combat transport exclusion and attract the elderly to use public transport (Morlok et al., 1971). Modern technology integrates multi-mode discounts on electronic and free transit passes as well as reimbursement schemes (Blythe, 2004). Implementation of smart card or smartphone payments as well as electronic tickets in mobile devices accompany new transport options and reduce information confusion among elderly transport users. As such, it also reduces the number of activities involved in travelling (e.g., queuing to purchase tickets) (Gorris et al., 2011). Another emerging innovation is the use of autonomous vehicles. This development could also implement a discounted funding scheme that target older people unable to drive themselves (Anderson et al., 2014). New mobility options could facilitate this change (Dickerson et al., 2019). Development of autonomous cars could be utilised by local authorities organising rural transport based on this novel idea (Broderick, 2018). In rural systems, cars may be often a more economical way of transport than DRTS public bus services, even though DRTS still remains as the main transport activity enhancer. Organisational innovation for older people will also need to incorporate long distances to bus stops, poor pedestrian accessibility and inadequate shelters are barriers to bus use. Flexible route bus transport poses an opportunity to overcome these barriers (Broome et al., 2012). Ride-hailing services, not very well-known among the general rural elderly, may be another cost-effective travel option (Vivoda et al., 2018) frequently used by urban elderly (Mitra et al., 2019). Companies like Uber offer special services to seniors who need extra assistance where drivers are trained to help riders get in and out of vehicles and accommodate folding wheelchairs, walkers and scooters (Edelen, 2018). In selected localisations, programmes are being tested in which seniors can get discounted or free of charge rides on Uber or Lyft rides due to city support (Blodgett et al., 2017). A relating emerging scheme, from these companies, include non-emergency medical transport of the elderly paid from area residents' monthly bills (Powers et al., 2016). As such, financial concern plays a significant role in developing organisational innovation since it, more often than not, is often an issue in this age group.

Education-based organisational innovation is primarily instructional. For some older people there can be a social stigma attached to the use of public transport which may deter them from using it. Such concerns can be addressed by travel training schemes which help install confidence and skills in individuals needed to travel on public transport (Smith et al., 2007). Training programmes aimed at elderly car drivers, with reduced reaction time and information processing, can be taught to change their driving habits and drive in a safer manner (Bédard et al., 2004; Charlton et al., 2003). Other education-based ideas include properly training and developing guidance for public transport drivers by enhancing awareness, understanding, behaviour and attitude of elderly passengers. Provision of seats and shelters is critical at bus stops typically frequented by the elderly and the culture of offering seats to the needy should be promoted (Wong et al., 2017). In addition, seats marking can be enhanced by modern educational platforms and electronic signalling, while anyone requiring additional assistance with modern communication services should be helped through government sponsored education aimed at e-inclusion (Obi et al., 2013). Education top-down government facilitation demands a responsive, participatory and active society.

At a societal level, organisational innovation for local passenger transport focuses on self-organisation via non-profit and voluntary groups. These entities can provide flexibility and demand responsiveness (Department for Transport, 2012). To best facilitate transport information and management, forum-oriented sharing among the elderly, through various means of ICT, have been proven to be useful (Neven et al., 2018). The development of ICT allows for live localisation. This can be, in turn, used to implement organisational solution-based employment (i.e., personal tutors and coaches) for the elderly or family members who can help elderly people route their way remotely and unobtrusively observe their behaviours online (Neven et al., 2017). Similarly, volunteers who use their personal vehicles to provide door-to-door service can use new ICT methods. For more than 40 years, a number of programmes have operated in the USA in which traditional leaflets and public meeting booklets have now been replaced with websites and mobile phone applications (Foreman et al., 2003).

Finally, there is innovative developments in terms of internet usage and generational-lag of technological understanding that is quickly closing. Contrary to some previous points where a proportion of the elderly may be ICT illiterate, service providers are now finding a growing number of older persons familiarising themselves with smartphone technology. These new elderlies will not require special simplified applications and will continue using applications they were using when they were younger. New computer literacy of the elderly means service providers are able to communicate with them using same electronic channels as with other customers. What is required is that information is given in an easy to find way and with larger print (Waara et al., 2013) or using special software which support those with loss of sight (Petrie et al., 1996). Service providers should also bear in mind that elderly persons have higher pre-journey information demand and booking applications should easily link travel routing information (Waara & Stahl, 2004). Other service provider adaptations may range from full replacement of a fixed route bus service with a flexible one (Patrick & Roseland, 2005), flex-route buses (e.g., telebus) (Broome et al., 2012) or bus buddy programmes (Cerenio & Soper, 1993). As noted, ride-hailing ICT-related services compliment the new elderly as smartphone literacy becomes age-indistinguishable. Organisational innovation in terms of ICT will most likely progress much faster in developed countries where there are higher living standards and bottom-up schemes are easier to instrument. The three identified approaches: regulatory measures, societal incentives and bottom-top schemes offer different potential for the elderly transport citizenry. While the regulatory approach ensures introduction of organisational innovation into a given area, they are not always a correct response to local needs. Community transport services evolving from local transport managers experiences are often much more effective. In a similar fashion the introduction of bottom-up organisational innovations allows for step-by-step development that is more successful than simple enforcement.

5. Recommendations for incorporating research gaps

To further developing the review, we have observed that most of the studies explore how transport innovation best facilitate mobility for the elderly, in which, surprisingly, there is a lack of investigation for the opposite (i.e., how and which new solutions may change older people's mobility patterns and then, eventually, influence future infrastructure development). For example, in rural areas where there is a gap in transport infrastructure the elderly can pay a heavy cost in terms of mobility if they cannot drive a personal vehicle or lack transport service modes. Strongly affected by demographic change of rural populations moving to urban centres, elderly persons may experience semi-abandonment in their rural communities. Implementing disruptive innovation (i.e., creating new rural services that upgrade or replace current transport systems) would facilitate mobility while calling into question the viability of contemporary transport systems, especially since infrastructure development traditionally is inflexible to rapid change and carries a long-life cycle. Hence, there is a vast amount of opportunity to develop positive and technologically advanced transport innovation for older people, including: government initiatives, local voluntary and non-profit support and community-oriented programmes. As a result, the importance of entrepreneurial development and the advantages, to date, that comes from a demand-based economic system should not be under stressed. Elderly persons living in such environments (e.g., developed countries) enjoy a higher standard of living and benefit from the most up-to-date innovative trends.

Apart from these opportunities, older people still face challenges and risks in regards to changing land use patterns. That is, the repercussion of building more intelligent transport infrastructure, at present, demands newer need-oriented and tech-savvy solutions. This change is most likely to be problematic for older populations – who may in the future become less familiarised as technology continually veers toward a human-tech merging. We found increased concerns in the reviewed literature regarding the challenge of revenue sources; first in terms of design and implementation and second maintenance. However, guidelines recommend the advancement of investment to bolster economic, social and political association between competing businesses and governance models. As the demand for transport infrastructure changes course, primary guidelines will need to focus on: (1) safety (e.g., use of autonomous cars may be risker with elderly and disabled persons), (2) cyberattack risk (i.e., elderly people are highly exposed) and (3) decrease between high- and low-income countries (i.e., at present, developed countries are experiencing the most benefits from elderly transport development). Proper transport planning guidelines should consider knowledge of past experience, existing circumstances and future-oriented goals. As such, our review identified commonly reported transport need as location-specific (i.e., in relation to spatial context) in which educative tools, information and clearing houses of innovative products will play an important part in overall transport need and innovation outcome. There is also a growing potential for non-transport innovation to influence transport need by including e-services that can reduce older people's mobility requirements as well as technical enhancements to walking, thus eliminating the use of mechanised transport options.

Apart from these gaps, complementary future research could closely examine impairments, handicaps, mobility modes and barrier-related research. In piecing together an all-encompassing picture of transport innovation for older persons, complementary linkages could be further extended to incorporate medically-oriented research. We recommend future studies continue to focus on all fields of transport innovation and correlate significant socially-oriented data with elderly persons' rate of ICT knowledge. Current research that examines the role of technology in facilitating transport for the elderly and how it merges with transformative-based innovation (i.e., a deep-rooted will to live differently) will be an important development phase. Examples primarily focus on large-scale infrastructural developments and ICT integration. As such, emerging innovative ideas, more often than not, are high-tech ICT-oriented which offer the elderly future opportunities to easily utilise transport as well as provide for better service and access (e.g., connecting vehicle and mobility supplements and telehealth for rural areas). Other examples include "shared economy" research, in conjunction with MaaS, and vehicles shared by multiply passengers as notable advancements for elderly transport enlargement. At present, pilot operations where robots man information desks at airports and train stations can be found in many modern transport facilities and aid in easing the process of internally informing and moving passengers (e.g., Haneda Airport in Tokyo). As such, future enterprise is visionary and long-term focused. It has a disruptive innovative stance that dramatically can alter transport service and affect transport demand. For elderly people, this future state may include additional products and services where autonomous AI-oriented personal vehicles, taxis and self-driving UBER-like services become the norm (e.g., Singapore and Pittsburgh). Other activities, even a decade ago that may have seemed like science fiction, include flying drones, wheeled drones, flying taxis (e.g., tested in Dubai), self-driving air taxis and other innovative business models in AI show vast potential for elderly transport mobility and usability.

Finally, an internationalisation of the research is also recommended. We note that one main limitation of our review was that we examined only relevant English language literature. For example, a search for the Russian language term "пожилые + транспорт" (i.e., elderly + transport in English) for articles in transportation, planning and development, geography, psychology, safety research and economics in the Cyberleninka online repository – a search engine directed at scientific literature from Russian speaking countries – returned 19 publications. Transport scenarios in cities such as Moscow and Saint Petersburg are regularly used as study sites for relevant Russian speaking language articles, reviews and books that would indeed fit our criteria. Similarly, a search for Arabic, Chinese and Spanish language

scientific literature would have likely produced relevant publications from Africa, the Middle East, Asia, and Latin America.

6. Conclusion

On a global scale, it is evident that transport innovation for elderly people is country-specific with distinctive decision-making, policy and enforcement regulation. The majority of the literature is focalised in the USA, Canada, Australia, New Zealand, Japan, Hong Kong and Western Europe. These high-income countries far out-number the sparse or lack of the research in low-income ones. A huge gap in the research is information from all low-income countries. These perspectives and potential innovative, and perhaps low-cost, solutions are missing. We found increased concerns in the reviewed literature that indicate development and implementation of transport innovation for the elderly require economic resources and know-how. But guidelines exist and regularly recommend increased mobility as a primary feat. As a result, the continued contribution to society of the elderly, regardless of age, is commonly connected with policy development. Apart from geographic disparity, a large part of the reviewed literature is based on classical solutions and implementation (i.e., ex-post analysis), while far less focus is on future-oriented viewpoints. However, there is a number of comprehensive studies on disruptive innovation (i.e., ex-ante analysis) for elderly people in terms of autonomous car research, smartphone usage (i.e., by way of mobile application development and integration for elderly transport on demand) and educational awareness and training. Different perspectives that may play a vital part in the elderly transport revolution range from its current state-of-the-art and relating emerging innovations to future enterprise.

In terms of transport need, proper planning guidelines must attribute adequate urban transport systems via the implementation of accessibility, affordability, availability and acceptability (McDonald et al., 2012; Shrestha et al., 2016). The general requirements of public transport need for older people should provision and associated facilities from their perspective. General guidelines signal public transport facilities with adequate and acceptable levels of mobility correlate with an increase in public transport modality (Luiu et al., 2018a). This identified barrier of underdevelopment, especially in peri-urban and rural areas, is crucial to elderly mobility and independence at a societal level (Ellaway et al., 2003). As stated by Rabbitt et al. (2002), if most older drivers feel restricted after giving up driving, personal self-sufficiency must be properly engaged and holds as an important recommendation for any future transport design and system. This review highlighted three transport innovation-based topics: vehicle, infrastructure and organisational. After closely analysing them it becomes apparent that a slight overlap and messing of ideas work in unison. Findings indicate that implementing, incorporating, administering and promoting transport innovation for the elderly will require context-specific expertise, information and knowledge offered via an interdisciplinary array of sectors society-wide.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rtbm.2019.100381

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