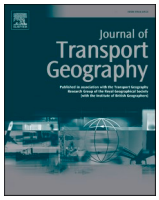
Journal of Transport Geography 103 (2022) 103408

Contents lists available at ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo



Critical review

Accessibility by public transport for older adults: A systematic review

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ARTICLE INFO

Keywords:
Accessibility
Older adults
Seniors
Systematic review

ABSTRACT

Accessibility, the ease of reaching destinations through a transport network, holds great potential to help foster equitable and sustainable cities. Though equity analyses are often considered in accessibility studies, only recently have researchers begun to consider older adults' access to destinations. In the context of an aging population, this paper presents a systematic review of the literature on older adults' accessibility using public transport. Our comprehensive review identifies articles focused on older adults' access to destinations via public transport published since 2000 ($n = 16$). Quality assessments indicate that this work has little risk of selection bias but could improve when it comes to study design. The ways in which accessibility are measured vary greatly across papers, with regards not just to accessibility metrics, but also the type of destinations used, public transport modes considered, and the ways in which older people are conceptualized. This makes it difficult to draw conclusions across studies on older adults' accessibility. Therefore, we call for more research on older adults' accessibility that engages with critical gerontology and age-friendly city frameworks. Doing so should involve centering the voices and experiences of older people into public transport accessibility research by, for instance, asking them which destinations should be considered and which thresholds should be used. In practice, this can be achieved through an experience-based co-design research approach or by actively reaching out to older people through other methods such as surveys, interviews, or focus groups.

1. Introduction

Population projections estimate that the global proportion of adults aged 60 and older will nearly double between 2015 and 2050 (World Health Organization, 2021). Many sectors will be impacted by this global population aging, including transport and land use planning. In fact, older adults exhibit different travel behaviours than other segments of the population. For instance, as people age they tend to make fewer (Moniruzzaman et al., 2013; Spinney et al., 2009) and shorter (Moniruzzaman et al., 2013; Wasfi and Levinson, 2007) trips. Further, past research has found that one third of older adults report unmet travel needs (Luiu et al., 2017). Leisure trips, including visiting friends and family, is the most commonly reported type of trip that goes unfulfilled (Luiu et al., 2017).

The most common travel mode for older adults is the car (Wasfi and Levinson, 2007), however, planning healthy aging around the car may be unwise (Musselwhite and Shergold, 2013). Though private vehicles may seem like the most convenient option for older adults because of their ability to provide mobility over great distances with little physical effort when compared to more active options such as walking, cycling, or public transport, many older adults begin to regulate their driving, or even stop driving completely, when health problems arise (Musselwhite and Shergold, 2013). Driving cessation is associated with many negative outcomes including reductions in quality of life, decreases in participation in activities outside of the home, and poor mental health outcomes (Musselwhite and Shergold, 2013; Qin et al., 2020). Therefore, maintaining independent mobility as one ages is an important policy priority.

Public transit is a low-cost and environmentally friendly travel mode that provides independent mobility and therefore may be able to support the mobility needs of the aging population. Because of public transport's potential to meet older adults' mobility needs, it is important that we ensure it is accessible to older riders of all abilities *and* accessible to older riders by providing access to their desired destinations. Research

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https://doi.org/10.1016/j.jtrangeo.2022.103408
Received 7 December 2021; Received in revised form 11 July 2022; Accepted 13 July 2022
Available online 20 July 2022

examining how accessible public transit is to people with differing abilities is on the rise. For instance, a recent literature review on public transport access for people using mobility devices identified twenty-six articles on the topic (Unsworth et al., 2019). They found that ramp access and user experiences have been well studied, though gaps remain in our knowledge of the barriers identified through people's actual experience.

There is, of course, another conceptualization of accessibility that is common in the transport and land use planning literature: accessibility as the ease of reaching destinations with a specific mode of transport. This concept of accessibility has been applied in transport planning since the 1950s (Hansen, 1959), though the field has since evolved through technological and computing advances that have enabled the generation of more complex measures (El-Geneidy and Levinson, 2021). Though barriers still exist when it comes to applying accessibility in practice (Handy, 2020), a large body of research examines accessibility (Geurs and van Eck, 2003; Geurs and Van Wee, 2004; O'Sullivan et al., 2000), and a branch of this work considers accessibility alongside equity. For instance, accessibility has been used to conduct social equity assessments (Allen and Farber, 2019, 2020; Cui et al., 2020; Deboosere and El-Geneidy, 2018; Van Wee and Geurs, 2011), for example studies have measured access to health care (Boisjoly et al., 2020), amongst low-income residents (Allen and Farber, 2019), and to compare accessibility levels for people with disabilities (Grisé et al., 2019).

In the context of global rapid population aging, this review focuses on older adults' accessibility to destinations using public transport. We focus on accessibility to destinations to complement Unsworth et al. (2019) review of public transport accessibility for people with mobility impairments, and public transport as this travel mode has the potential to provide older adults with independent mobility using alternative transport modes and reduce unmet travel needs. We use a systematic review strategy; in other words we complete an exhaustive search of the academic literature (published since 2000), perform quality assessments of the studies identified, and present a synthesis of the results (Grant and Booth, 2009). The paper concludes by putting forward a conceptual model and research agenda that calls for work on older adults' access to destinations that is grounded in critical gerontology and age-friendly city frameworks.

2. Methods

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA Statement). To be eligible, articles had to present a public transport accessibility analysis and have a focus on older adults. No restrictions on study design or on how older adults were considered were placed, however, only articles examining access to destinations via public transport were included. Papers that focused on access to transit, that did not measure public transport accessibility separately (e.g., combined car and bus), or that focused on accessibility for people with reduced mobility (universal access) were excluded. No geographic restrictions were placed, however, only papers written in English since 2000 were included. The time restriction was placed due to improvements in accessibility metrics (i.e., computing innovations) that took place since 2000. Further, only published papers from peer-reviewed journals were included (conference proceedings were excluded).

The search strategy was developed by the authorship team and searches were conducted in September 2021. Four academic databases were searched: Web of Science, Transport Research International Documentation (TRID), AgeLine, and Scopus. Trial searches were completed to ensure that pre-identified key papers were included in the final search. For the final search, titles, abstracts, and keywords were searched for synonyms of older adult and accessibility. Appendix A presents the full search strategy, including all terms.

Rayyan, an open-source literature review manager, was used to complete the screening of articles. Once all duplicates and articles without an author were removed, all remaining titles and abstracts were screened by two independent reviewers. Once all papers were screened, the authors met and resolved any conflicts though discussion. All papers selected underwent full text review whereby two authors read the full papers and decided whether they met the inclusion criteria. Again, once all papers were read the two authors met to compare decisions and all conflicts were resolved through discussion.

Once the final papers were selected, two reviewers completed data extraction forms using Excel. The questions guiding this synthesis were:

- How does this literature define older adults?
- What destinations are used in older adult public transport accessibility metrics? And
- How is accessibility measured in these papers?

The extracted elements can be found in Table 1.

Following recent calls to incorporate quality assessments in urban planning literature reviews (citation removed for anonymous review), the data extraction form also included a Risk of Bias Assessment. Rik of Bias Assessments provide guidance to rate each paper included in a literature review based on a number of factors. The tool used in this study is called the Risk of Bias Assessment for Urban Planning Studies and was developed by the authors. The four elements of the assessment are: representativeness of the sample, study design, analyses, and reporting bias. For instance, questions asked to assess study design include: *Did the authors use the appropriate methods?* And *Did the study use the appropriate data needed to answer the research question?* Each element also included a supporting statement where the reviewers could justify their responses to the guiding questions. The full tool is presented in Appendix B. Once both reviewers completed the extraction form for all papers, they compared their answers and resolved any differences in their excel sheets.

3. Results

The search identified 1465 papers, 912 of which were duplicates and 21 of which were automatically removed due to a lack of authorship information. After screening the remaining titles and abstracts, 85 papers were discussed for potential inclusion. After discussion, 33 were included in the full text review, 17 of which were excluded after reading the full text. This resulted in 16 papers included in the review (Fig. 1).

A summary of the papers included can be found in Table 2. Overall, this scholarship is very recent: all but one paper has been published in the past four years (since 2018). The most common setting for this research is the U.S.A. ($n = 5$ papers), followed by China ($n = 4$ papers), and Canada ($n = 3$ papers). Most studies focus on urban settings, though three papers consider more rural regions (Achuthan et al., 2010; Stentzel et al., 2016; Vrabková et al., 2021). Amongst studies set in urban areas, the urban boundary often varied. For instance, while most studies

Table 1
Elements extracted during the review.

Category	Extracted elements
Identifying information	Author's name; title of the paper; year of publication
Setting	Study setting, description of the setting
Research Design	Research question; study design; sample size; sample selection; characteristics of the population under study; age cut-off used to identify older adults; consideration of social factors besides age; presence of comparative groups; theoretical framework
Accessibility Measures	Accessibility measures; public transportation modes included; accessibility cut-off (if any); data used to measure accessibility; destinations or opportunities used
Results	Main results specific to older adults; unmet travel needs (if any); main results not specific to older adults; further equity considerations (if any)

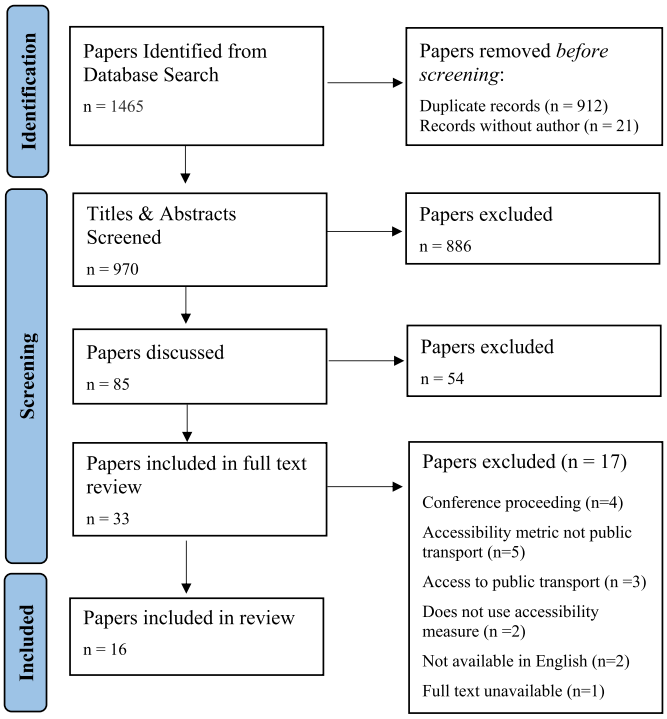

Fig. 1. PRISMA diagram.

considered the entire city or metropolitan area, Jin et al. (2018) focused on a section of a city (in both cases Northern Manhattan). Further, Mayaud et al. (2019a) compared older adults' accessibility by public transport across three cities in Cascadia while Park et al. (2021) examined accessibility to large parks in the 15 largest western cities of the United States. The use of other comparative groups was relatively common. Accessibility was compared across travel modes (Cheng et al., 2021; Choi et al., 2021), time (Cheng et al., 2021), or age (Guida and Carpentieri, 2021; Patel et al., 2019). Mayaud et al. (2019b) examined all three by comparing access to schools and healthcare facilities by car and public transit and walking for children and older adults (65+) in 2016 and 2022 (using projections).

In terms of key results, most papers identify areas of high and low accessibility (Chen et al., 2021; Choi et al., 2021; Li et al., 2021; Mayaud et al., 2019b; Ouyang et al., 2020; Patel et al., 2019; Ruan and Zhang, 2018; Stentzel et al., 2016). Because different contexts were considered, we cannot compare the specific areas/ neighbourhoods found to be of low or high accessibility. Further, no articles explicitly aimed to identify factors that correlate with areas of high or low accessibility within cities, such as built environment features, as part of the study's design, or in the reporting of the study's results. However, a trend identified in six papers is that areas outside of city centers have lower accessibility than more central parts of the city (Chen et al., 2021; Choi et al., 2021; Li et al., 2021; Mayaud et al., 2019b; Ouyang et al., 2020; Patel et al., 2019). In Li et al. (2021), a greater concentration of older adults also live outside the city centre. On a larger scale, Mayaud et al. (2019a) find that older adults enjoy higher accessibility in Vancouver than in Seattle or Portland.

Comparative accessibility analyses, by social factors, mode, or time, were also relatively common. For instance, three studies find evidence that older adults have lower accessibility to destinations than other segments of the population (Achuthan et al., 2010; Ermagun and Tilahun, 2020; Park et al., 2021). Additionally, Patel et al. (2019) identified class-based social inequalities indirectly when they found that private dental clinics are more accessible than public ones. Other comparative research included analyses of how accessibility varies over time and across modes. For instance, Vrabková et al. (2021) find that individual transport provides greater accessibility than public transport in the Czech Republic. In terms of temporal analyses, Cheng et al. (2021) find that older adults' accessibility decreases over time in Fuzhou, China while Guida and Carpentieri (2021) find that accessibility to healthcare decreased during the COVID-19 pandemic in Milan, Italy. Taken together, this very recent research, the bulk of which is set in urban and Western contexts, often identifies areas of high or low accessibility or identifies social inequalities in accessibility.

3.1. How are older adults defined?

The ways in which older adults were defined and considered varied greatly across the studies. The criteria almost always included an age range, but this age range varied considerably. Most papers studied used 65 years and older (n = 11; 69%) as the cut-off, but four used 60 years (Table 2). One study did not report what the population age-inclusion factors were. A further two papers examined differences across older adults: Patel et al. (2019) considered retirees (65+) and older adults (85+) and Guida and Carpentieri (2021) divided people three categories: people aged 65–69, 70–74 and 75 and over. Though few differences were identified across the older adult age categories in Guida and Carpentieri (2021), those aged 85+ were found to have lower accessibility than those aged 65+ in Patel et al. (2019).

While some papers used a sample and extracted older adults based on age criteria (e.g., Chen et al. (2021)), others relied on census data to identify parts of the city with high proportions of older adults. For instance, Choi et al. (2021) calculated accessibility from what they identified as "aging communities" from census data (specifically, if 7% of the population was 65+, the neighbourhood was considered aging, if 14% was 65+, it was considered aged, and if 20% was 65+, it was considered super-aged). Others still did not use a sample or secondary data to identify their population, instead inclusion criteria were theoretical. For instance, some calculated accessibility across the city (with no special consideration for age) to destinations assumed to be important for older adults (e.g., Stentzel et al. (2016)). Another example of a paper where the older adult population was theoretically informed is Achuthan et al. (2010). This paper used a unique approach that combined both access to destinations and universal access for people with disabilities. Namely, they calculated door-to-door accessibility (i.e., including the walk ingress and egress to/from bus stops) via the bus network with no barriers (which represented younger people's accessibility) and compared that to accessibility measures where the ingress/ egress incorporates built environment barriers to people with limited mobility (e.g., crossings without dropped kerbs, dropped kerbs with gradients steeper than 5 degrees, pavement widths less than a metre, and a maximum walking distance set at 400 m). In sum, though all papers focused on aging populations, great variation exists across the existent literature in how older adults are defined, considered, and conceptualized.

3.2. What destinations are used?

Great variation exists in the destinations used in the accessibility metrics (Table 2). The most common type of destination used was healthcare facilities, but the type of facility varied widely. Some used more general health care destinations (e.g., Chen et al. (2021), Mayaud et al. (2019b), and Mayaud et al. (2019a) all used healthcare facilities), while others used very specific health care destinations (Ruan and Zhang (2018) used high order urban hospitals). At the times, the types of specific clinics included ranged even within papers, such as Stentzel et al. (2016)'s consideration of both general healthcare (medical clinics / general practitioner) and specific services (optometrist in the first and internists, ophthalmologists and urologists in the latter). A sub-set of papers examining health-destinations focused solely on dental care (Jin et al., 2018; Patel et al., 2019).

Another commonly used destination is greenspace. Though most

Table 2
Summary of approaches used in included papers.

Authors	Study location	Age	Type of accessibility	Public transport mode(s)	Accessibility threshold	Destinations
Achuthan et al. (2010)	St Albans, Hertfordshire, United Kingdom	65+	Cumulative opportunities measure	Bus	30-min + 400 m	Bus stops
Chen et al. (2021)	Nanjing, China	60+	Competition measure	Bus	30-min	Health care facilities
Choi et al. (2021)	Calgary, Canada	65+	Cumulative opportunities measure	Bus and LRT	10, 20, 30, 45, and 60 min	Hospitals, community health centers, community centers, public libraries, parks, grocery stores
Cheng et al. (2021)	Fuzhou, China	65+	Competition Measure	Bus and subway	Varies by mode	Urban green spaces
Ermagun and Tilahun (2020)	Chicago, United States	65+	Cumulative opportunities measure	Not specified	30-min	Jobs, parks, groceries, hospitals, schools, and libraries
Guida and Carpentieri (2021)	Milan, Italy	65+	Competition Measure	Bus and transit	NA	Primary health services
Jin et al. (2018)	Northern Manhattan, United States	65+	Cumulative opportunities measure	Bus and subway	30-min	Preventive screening and oral healthcare services
Li et al. (2021)	Philadelphia, United States	65+	Cumulative opportunities measure	Bus, trolley, subway	20, 30, 40-mins	Senior centers
Mayaud et al. (2019b)	Surrey, Canada	65+	Cumulative opportunities measure	Bus and rail	30-min	Healthcare facilities, schools
Mayaud et al. (2019a)	Vancouver, Canada, Seattle & Portland, United States	NR	Cumulative opportunities measure	Bus and rail	30-min + 400 m	Healthcare facilities (hospitals and clinics)
Ouyang et al. (2020)	Shanghai, China	60+	Cumulative opportunities measure	Not specified	30-min	Urban parks
Park et al. (2021)	15 cities in western United States	65+	Cumulative opportunities measure	Not specified for each city, but bus and rail included	60-min	Large parks (regional parks, state parks, and national forests and parks)
Patel et al. (2019)	Sydney, Australia	65+	Cumulative opportunities measure	Bus	Within 250- 500 m from bus stop that is within 50 km of General Post Office	Dental services
Ruan and Zhang (2018)	Xi'an City, China	60+	Competition Measure	Bus	NA	High order urban hospitals
Stentzel et al. (2016)	Vorpommern-Greifswald county, Germany	60+	Cumulative opportunities measure	Bus and train	<1 h, 1–2, 2–3, 3–4, 4-5hs, and not connected	GP- practices, internists, ophthalmologists and urologists
Vrabková et al. (2021)	All counties but Prague, Czech Republic	65+	Competition Measure	Bus and train	30, 60-mins	Selected residential and outpatient-clinic services

studies focused on urban greenspace or parks (Cheng et al., 2021; Choi et al., 2021; Ermagun and Tilahun, 2020; Ouyang et al., 2020), Park et al. (2021) focuses on large (20 acres or more) federally, state, or locally owned parks in the Western United States. Other destinations used more than once included different types of community centers (Choi et al., 2021; Li et al., 2021; Vrabková et al., 2021); grocery stores, (Choi et al., 2021; Ermagun and Tilahun, 2020), public libraries, (Choi et al., 2021; Ermagun and Tilahun, 2020), and schools (Ermagun and Tilahun, 2020; Mayaud et al., 2019b). Some studies also combined different destinations, making comparison of results across contexts difficult.

Looking across the studies, it is clear that destinations used were often selected without a clear guiding theory or principle. Perhaps the destinations chosen were instead derived by data available or by the authors' assumptions regarding the importance of select destinations to older people. Regardless of why this is the case, the result is a lack of consistency in the destinations selected across studies making it hard to draw conclusions on older adults' accessibility by public transport across the literature.

3.3. How is accessibility measured?

Though all papers included in this study calculated older adults' access to destinations via public transport, great variation existed in how this was measured. Different transit modes were included depending on the study location. Buses were more frequently included ($n = 15$), however, at times studies focused on buses when other public transport options existed such as rail and metro (e.g., Chen et al. (2021)).

Two measures of accessibility are used in the studies: cumulative opportunities measure and competition-based measures. Cumulative opportunities measures, a tool which calculates the number of opportunities in a defined catchment based on travel time or distance, were most used ($n = 11$), the accessibility thresholds also varied considerably, though 30-min was most frequently used. Competition measures, a measure which incorporates provision and demand for destinations, were used in five papers (Table 2). These measures could be based off cumulative measures (e.g., Vrabková et al. (2021)) or gravity measures, a measure which incorporates a distance or travel time decay function to discount farther opportunities (e.g., Guida and Carpentieri (2021)).

Taken together, the accessibility thresholds and public transport modes used across the studies are highly variable, making it difficult to draw conclusions across the literature. The two accessibility measures used in the studies are considered rigorous tools. A benefit of cumulative opportunity measures is that they are easier to communicate to policy makers (El-Geneidy and Levinson, 2006). Competition measures seem to be most appropriate when resources are scarce, for example measuring

accessibility to hospital beds, and we therefore recommend this measure when resource scarcity is in question.

4. Risk of bias assessment

The score of each included paper following the Risk of Bias Assessment for Urban Planning Studies is shown in Table 3. Because research on accessibility tends to rely on large secondary data sources such as the census, the fact that all papers scored highly (i.e., 'low bias') on the selection bias domain was expected. Study Design, however, was the criteria where the largest number of papers scored poorly (3 scored 'high risk' while 9 scored 'medium risk') (Table 3). Here, the methods were often deemed appropriate, but the study design and data used was often not considered well suited to respond to the paper's research question. A key recurring flaw was the lack of explanation for why destinations were selected. For instance, one paper examined public transit accessibility (by bus) to bus stops(Achuthan et al., 2010) while another measured public transit accessibility to large parks (i.e., 20 acres or more) in cities in the Western Unites States (Park et al., 2021) – a destination one would not normally expect older adults to use transit to access. Other issues included destination data that was from a different year than General Transit Feed Specification (GTFS) data that was used to calculate the travel times by public transit, and when destinations just beyond urban boundaries were omitted.

The included studies scored higher when it came to the Analyses and Reporting Bias domains. For the Analyses domain, clearer explanation of the statistical and GIS methods used was needed in some papers alongside maps that follow cartographic rules (Achuthan et al., 2010; Jin et al., 2018; Vrabková et al., 2021). No papers scored 'high risk' on the Reporting Bias domain, though at times not all results were discussed in the paper (Achuthan et al., 2010; Ouyang et al., 2020). Taken together, this body of work can take steps to reduce bias in study design and does exceptionally well at having low selection bias.

Table 3
Quality assessment of included studies.

Authors	Selection bias	Study design	Analyses	Reporting bias
Achuthan et al. (2010)	Low Risk	High Risk	Medium Risk	Medium Risk
Chen et al. (2021)	Low Risk	Low Risk	Low Risk	Low Risk
Choi et al. (2021)	Low Risk	Low Risk	Low Risk	Low Risk
Cheng et al. (2021)	Low Risk	Medium Risk	Low Risk	Low Risk
Ermagun and Tilahun (2020)	Low Risk	Medium Risk	Medium Risk	Low Risk
Guida and Carpentieri (2021)	Low Risk	Medium Risk	Low Risk	Low Risk
Jin et al. (2018)	Low Risk	High Risk	High Risk	Low Risk
Li et al. (2021)	Low Risk	Low Risk	Low Risk	Medium Risk
Mayaud et al. (2019b)	Low Risk	Medium Risk	Low Risk	Medium Risk
Mayaud et al. (2019a)	Low Risk	Low Risk	Low Risk	Low Risk
Ouyang et al. (2020)	Low Risk	High Risk	Medium Risk	Medium Risk
Park et al. (2021)	Low Risk	Medium Risk	Low Risk	Low Risk
Patel et al. (2019)	Low Risk	Medium Risk	Low Risk	Low Risk
Ruan and Zhang (2018)	Low Risk	Medium Risk	Low Risk	Medium Risk
Stentzel et al. (2016)	Low Risk	Medium Risk	Low Risk	Low Risk
Vrabková et al. (2021)	Low Risk	Medium Risk	Medium Risk	Low Risk

5. Discussion

In this review, we find great variation in the ways in which older adults' public transport accessibility is measured. The included studies use two accessibility metrics (cumulative and competition) to study access to a variety of destinations using different public transport modes – even the ways in which older adults are defined or considered varies greatly across papers. This variability in the literature makes it difficult to draw conclusions on how well public transport systems provide older adults with access to key destinations in various regions around the world. To reduce some of this variability, we call for research that addresses some of these methodological considerations. For instance, future research on public transport accessibility should consider all public transport modes that exist within the region under study. This is necessary to capture a complete picture of public transport accessibility. Considering different age categories amongst older people would also benefit future research. Finally, competition based accessibility metrics are most appropriate when measuring access to destinations that have scarce resources. In other cases, cumulative opportunity measures have the benefit of being easily interpretable by practitioners. In the context of population aging, incorporating seniors in equity analysis derived from accessibility measures will likely become increasingly important. Therefore, we use the remainder of this paper to put forth a framework for calculating accessibility metrics for older adults that engages with critical gerontology and age-friendly city frameworks.

In 2007, the World Health Organization (WHO) initiated the age-friendly cities model to advance the development of urban environments that support older people (World Health Organization, 2007). According to the World Health Organization (2007), an age-friendly city is a city that *"encourages active ageing by optimizing opportunities for health, participation, and security in order to enhance quality of life as people age"* (p. 1). The WHO model contains eight domains: Social participation; Communication and information; Civic participation and employment; Housing; Transportation; Community support and health services; Outdoor spaces and buildings; and Respect and social inclusion (Fig. 2). Further, a checklist tool (the Checklist of Essential Features of Age-Friendly Cities) was also developed to assist cities in becoming more age-friendly (World Health Organization, 2007).

The number of cities and communities engaged with age-friendly city

Fig. 2. WHO age-friendly cities framework.

frameworks surpassed 1000 in 2020 (World Health Organization, 2018). The approaches taken to foster age-friendly cities, however, vary widely, with some models focusing on physical infrastructure or age-friendly design and others focusing more on social aspects of the environment, such as relationships, participation, and inclusion (Buffel et al., 2012). Greater engagement of older people in the development of age-friendly urban environments has also been called for (Buffel et al., 2012). Currently, top-down approaches that engage primarily with policy-makers and assess environments against established criteria or checklists are more commonly used (Buffel et al., 2012).

Studies examining older adults' access to destinations have great potential to contribute to age-friendly cities. Indeed, accessibility brings together many of the eight age-friendly cities domains put forth by the WHO (Fig. 2). For instance, accessibility has the potential to bridge transport with access to housing, opportunities for civic participation and employment, community support and health services, and outdoor spaces and buildings. In turn, access to these opportunities can contribute to social participation which is associated with social inclusion. Given this opportunity, we call for more research on older adults' accessibility by that is grounded by age-friendly city frameworks. This research would measure accessibility to destinations embedded within the WHO framework, such as destinations related to civic participation (e.g., destinations with volunteer opportunities), community support (e.g., leisure centers, community centers, religious and spiritual organizations), health services (e.g., hospitals, clinics, rehabilitation centers), and outdoor spaces (e.g., parks, public squares).

This framing would require a deeper consideration of how accessibility studies are designed. Beginning with how older adults are defined, we believe a greater engagement with the critical gerontology literature is needed (Bernard and Scharf, 2007; Minkler, 1996; Minkler and Estes, 1999). The experience of aging is dynamic and highly variable. One does not suddenly experience aging upon their 65th birthday, instead aging is a process, and one that varies greatly across people and places. Guida and Carpentieri (2021) and Patel et al. (2019) begin to uncover a more nuanced examination of older adults' accessibility by categorizing older people into different groups based on age. Simply put: they acknowledge that the experience of a 65 year old will certainly differ than that of a 90 year old. Moving forward we recommend that scholars follow these authors by considering older adults' accessibility at different age groups. Even more nuance, however, can be attained. Take, for example, how there are both intrinsic and social processes that shape aging. Aging involves biological processes, but is also shaped by socioeconomic attributes, individual and societal attitudes toward aging – and even more external cultural, political, and economic forces (Antoninetti and Garrett, 2012). For instance, ageism, the existence of negative stereotypes that associate aging with decline in abilities and obsolescence, is a cultural force that impacts the experience of aging (Butler, 1969). When measuring accessibility by public transit for older adults, it is important to challenge one's assumptions about aging, old age, and older people. Centering the experiences of – and voices of – older people in our work is one way to achieve this.

For instance, biased assumptions about aging may have shaped the current literature's choice of destinations selected in their accessibility studies. Few of the papers included in this review justified why they selected the destinations they did. Those who focused on healthcare destinations, which comprised the most used destination, often stated these destinations were important to older adults. How they know this, however, is unclear. It seems this assumption may instead be based on ageist associations of older people with illness. Asking older adults themselves where they travel to on a regular basis – or where they wish to travel to more – would result in a new set of destinations that can be incorporated in accessibility calculations. This would result in accessibility calculations that more accurately reflect how age friendly a region is - based on the actual needs of people from that region. Though we found that this has yet to be done in research on older adults' public transport accessibility in this literature review, past research has asked older adults directly about their travel experiences (Davey, 2007; Loukaitou-Sideris et al., 2019; Ravensbergen et al., 2021). By doing so, this work has identified the ways in which transport systems (Loukaitou-Sideris et al., 2019), and specifically public transport (Ravensbergen et al., 2021) are not age-friendly, as well as identified the unmet travel needs of older people (Davey, 2007). Much of this work will include qualitative methods such as interviews or focus groups. Therefore, we recommend that future accessibility studies build off of this research approach that asks older people directly about the destinations they wish to access.

Even better still would be to center older adults' experiences by partnering with older adults themselves. For instance, the EMBOLDEN study uses an experience-based co-design research approach that brings together older adults, key stakeholders, and a team of interdisciplinary researchers. This approach results in research programs that better reflect the experiences and needs of older adults and result in recommendations for practice that are more aligned with existing policies and programs (for more information, please see: https://emboldenstudy.mcmaster.ca/). For public transport accessibility research, centering the voices of older people could be done through a similar research approach.

Less resource intensive approaches that still center older people's voices could also include travel surveys or qualitative methods (such as interviews or focus groups) that ask older people which destinations are important to them. Such methods could also help in identifying the appropriate threshold to be used when setting the cumulative opportunities measures of accessibility.

The WHO age-friendly cities framework may also theoretically inform older adults' public transport accessibility studies. Many of the domains contain key destinations for older adults (e.g., opportunities for civic participation and employment, community support and health services, and outdoor spaces and buildings). Further, if the focus is on public transport, a mode hailed for its potential to provide day-to-day independent mobility, we recommend using destinations that are visited on a weekly basis, rather than those rarely visited locations such as federal parks and high order hospitals, as this is theoretically more appropriate. Again, these studies could engage with age-friendly cities frameworks and still center the voices of older people by involving them in the research design or by actively reaching out to them through other research tools such as surveys, interviews, and focus groups.

6. Conclusion

In this systematic literature review, we complement Unsworth et al. (2019)'s review on public transport accessibility for people with disabilities by presenting a synthesis and quality assessment of the studies on older adults' access to destinations using public transport identified through a comprehensive search of the academic literature. After two reviewers scanned the titles, abstracts, and select full texts from the results of a systematic search of four academic databases, a total of sixteen articles were identified. The literature on older adults' accessibility by public transport is very recent, and varies greatly with regards to study design, and in particular how older adults are conceptualized, which destinations are used, and how accessibility is measured. This makes it difficult to draw conclusions on the status of accessibility by public transport for older adults in a general review. Our critical appraisal shows that this body of work is very rigorous when it comes to potential selection bias, but that there is room for improvement in the current studies' design.

Moving forward, we call for research on older adults' accessibility by public transport that considers all public transport modes in the region under study, that segments age into different categories to capture different experiences of aging, and that uses the more practice-oriented cumulative opportunities accessibility measures. Further, we call for more research that engages with age-friendly city frameworks and critical gerontology. We advocate for centering older adults' experiences

and voices in research design. This can be done through travel surveys or qualitative methods. Doing so would allow for accessibility calculations that use destinations and thresholds that older adults themselves believe are important. Not only do we believe this holds potential to strengthen the current literature by improving study design, doing so may also diminish ageist assumptions in research opening possibilities for studies that can truly contribute to age-friendly cities.

Acknowledgements

This research was funded by the Natural of Canada (NRC) project number AiP-023-1. The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

Appendix A: Full search of the academic databases.

Database	Full search	Results
Web of Science	TOPIC: ("aging" OR "aging" OR "older adult*" OR "older people" OR senior* OR "baby boomer*" OR elder* OR retired) AND TOPIC: ("public transport*" OR transit OR bus OR metro OR subway OR streetcar OR rail OR "train") AND TOPIC: (accessibility OR access)	631
TRID	Keywords = ("aging" OR "aging" OR "older adult*" OR "older people" OR senior* OR "baby boomer*" OR elder* OR retired) AND ("public transport*" OR transit OR bus OR metro OR subway OR streetcar OR rail OR "train") AND (accessibility OR access) OR title = ("aging" OR "aging" OR "older adult*" OR "older people" OR senior* OR "baby boomer*" OR elder* OR retired) AND ("public transport*" OR transit OR bus OR metro OR subway OR streetcar OR rail OR "train") AND (accessibility OR access)	18
Ageline	(TI (("aging" OR "aging" OR "older adult*" OR "older people" OR senior* OR "baby boomer*" OR elder* OR retired) OR AB (("aging" OR "aging" OR "older adult*" OR "older people" OR senior* OR "baby boomer*" OR elder* OR retired)) AND(AB (("public transport*" OR transit OR bus OR metro OR subway OR streetcar OR rail OR "train") OR TI (("public transport*" OR transit OR bus OR metro OR subway OR streetcar OR rail OR "train")) AND (((access OR accessibility)) OR TI ((access OR accessibility))	63
Scopus	TITLE-ABS-KEY (access OR accessibility) AND TITLE-ABS-KEY ("public transport*" OR transit OR bus OR metro OR subway OR streetcar OR rail OR "train") AND TITLE-ABS-KEY ("aging" OR "aging" OR "older adult*" OR "older people" OR senior* OR "baby boomer*" OR elder* OR retired)	753

Appendix B: Risk of bias assessment for urban planning studies.

Type of bias	Guiding questions	Criteria
Selection Bias	(Q1) Are the individuals selected to participate in the study likely to be representative of the target population? Very likely Somewhat likely Not likely Can't tell	*High Risk of Bias*: No comparison to general population and very small sample (under 100) *Medium risk*: Sample's socio-demographic characteristics are compared to the general population (e.g., through the census) and little discrepancy is identified OR 60% or more agreed to participate
	(Q2) What percentage of selected individuals agreed to participate?	*Low risk*: Sample's socio-demographic characteristics are compared to the general population (e.g., through the census) and some discrepancy is identified OR use multiple data sources, some of which are highly representative (e.g., the census) OR representative sampling strategy
Study Design	Is the study design appropriate for the research question? Very likely; Likely; Unlikely; Very unlikely Did the authors use the appropriate methods? Very likely; Likely; Unlikely; Very unlikely Did the study use the appropriate data needed to answer the research question? Very likely; Likely; Unlikely; Very unlikely	*High risk*: two (or more) questions score not likely OR three questions score somewhat likely or not likely *Medium risk*: One question score not likely OR two questions score somewhat likely or not likely *Low risk*: No questions score not likely and one or less score somewhat likely
Analyses	What kind of statistical methods, if any, is used?	*High risk*: less than three questions score: likely, very likely, Yes, Sort of, Yes, all, Yes, but only some, or NA
	Is this the most appropriate method? Very likely, Likely, Unlikely, Very unlikely, NA	*Medium risk*: All but one or two questions score either: likely, very likely, Yes, Sort of, Yes, all, Yes, but only some, or NA
	Are the statistics easy to read and understand? Yes, Sort of, No, NA	
	If the study includes a GIS component was it well explained? Yes, Sort of, No, NA	*Low risk*: All questions score either: likely, very likely, Yes, Sort of, Yes, all, Yes, but only some, or NA
	If the study includes maps do they follow the appropriate cartographic rules (scale bar, north arrow, easy to understand and to differentiate legend etc.)? Yes, all, Yes, but only some, No, NA	
	Are the graphics and tables clear? Yes, Sort of, No, NA	
Reporting Bias	Are all the results presented?	High risk: Not all models discussed in methods are presented in the results
	Yes, only some of the models discussed in the methods are presented	Medium risk: Results from all models from methods are presented, but only expected results reported in the results, discussion and conclusion
	Are all results discussed? Yes, mostly expected results are discussed Only expected results are discussed	Low risk: Results from all models from methods are presented and discussed

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