THE FIRST/LAST MILE CONNECTION TO PUBLIC TRANSPORT

Christoffel Venter

Introduction

Interest is growing in the first and last mile of the public transport trip as an important component of the overall quality experienced by a public transport user. This reflects a growing appreciation of the public transport trip as inherently multi-modal, one where the effort and time required to access public transport from the origin of the trip, and to travel between the egress stop or station and the final destination, are seen as critical links in the trip chain. The first and last mile (1LM) connection is often the slowest, most unsafe, or most physically demanding part of the trip – especially where it involves walking in many walk-unfriendly cities – making it the weakest link that prevents large-scale shifts towards public transport.

Public transport operators and city authorities find it challenging to deal with the 1LM in a coherent and integrated way. The 1LM environment is complex, encompassing a variety of modes with widely varying characteristics. A diversity of role-players affect the quality of 1LM connections, including public and private transport operators, urban design, street infrastructure, and traffic safety professionals, raising the difficulty of co-ordinating between them. Individual public transport operators rarely have control over the 1LM portion of their service, making them dependent on other actors for delivering whole-trip service quality to passengers. Local authorities seldom focus on public transport in a holistic, multi-modal way.

The lack of attention to 1LM connections is partly because of an absence of tools for measuring, monitoring, and managing the quality of the 1LM environment in the context of the public transport system. Scholars have tended to focus on individual modes – for instance, a large body of work has evolved from the health and transport planning literatures on the relationships between the built environment, walkability, and walking behaviour (see also Chapter 23). Although a substantial part of this deals with walk access to public transport, there are no general methodologies for bringing the various modes into the same framework in order to explicitly capture the multi-modal nature of the 1LM problem (Phillips & Guttenplan, 2003). In addition, not enough is known about the needs and behaviour of the prospective public transport user regarding the 1LM part of their trip. A better understanding of 1LM issues will be useful for transport modelling, infrastructure planning, urban design, and the health research communities (Clifton & Muhs, 2012). And it will also help focus the attention of planners and implementers on 1LM issues as in themselves critical to the success of public transport.
This chapter aims to help fill this gap by briefly reviewing the literature relating to the first and last mile connection to public transport and presenting a framework for the integrated measurement of the quality of the 1LM environment. The review highlights factors that have been found to affect 1LM quality and major approaches to measuring these factors. The proposed integrated framework is briefly explained and illustrated using a case study from South Africa. The chapter concludes with research needs for the future.

The first and last mile of the public transport trip

The origins of the first and last mile idea lie in the “last-mile” concept in telecommunications and supply-chain management, where the last mile from hub to destination is the most challenging and costly from a logistical point of view. In public transport, the vast majority of 1LM trips have historically been made by walking (Jiang et al., 2012), but the number of other modes and services offering 1LM connectivity is growing. Bicycling is rising worldwide and is increasingly used for multi-modal trips, supported by the rise in cycle storage and bikeshare schemes at public transport stations (Liu et al., 2012; Wang & Liu, 2013). Newer forms of non-motorised transport, including e-scooters, personal mobility devices, e-bikes, and e-rickshaws, are proliferating, and although technologies and market models are still evolving, there is evidence that they could significantly alter the public transport experience by offering cheaper, faster, and more convenient access and egress options over larger distances (Kumar & Roy, 2019; Lesh, 2013), especially as a part of shared use schemes.

1LM trips are also increasingly served by other public transport modes as transport networks gain greater multi-modal integration (see also Chapter 6). This is reinforced by the shift in public transport service concepts over the last century in many parts of the world, which have de-emphasised traditional local public transport dating back to the street car, providing uniform, slow service while minimising walk distances to origins and destinations in favour of more commuter-oriented services with higher speeds and wider station spacings such as urban rail and bus rapid transit (BRT). The limited walking distances of users prevent such services from serving a majority of residents and jobs directly, especially in medium-density regions (Cervero, 1998). This makes the 1LM trip dependent on other modes like local buses and taxis and, especially in developing countries, a range of “intermediate” modes like cycle or motorised rickshaws and motorcycle taxis (Kumar & Roy, 2019).

In more car-oriented environments, the private vehicle plays an important role in serving the 1LM trip, especially to and from rail stations in suburban areas (Cervero, 2001). This is promoted by the provision of large parking lots at stations, which is often seen as a critical way of enlarging public transport catchments. However, the environmental costs of serving 1LM trips primarily with automobiles are significant; the emissions associated with the cold start and hot evaporative soak (which is not eliminated) may well negate the benefits of patronising rail in the first place (Cervero, 2001; Hoehne & Chester, 2017). Thus, one of the primary goals of Transit Oriented Development (TOD) around rail stations is to shift the 1LM mode from private cars to more sustainable modes.

Advances in vehicle, communications, and computational technologies hold promise for radically changing the manner in which 1LM trips are served while carving out a much greater role for the private sector (Canales et al., 2017). Transportation network companies offering mobility-on-demand services are already serving significant numbers of 1LM trips (Shaheen & Chan, 2016), although there is concern that they may divert entire trips away from public transport (Clewlow & Mishra, 2017). Simulation studies of flexible on-demand
shuttles (also referred to as microtransit) serving an access/egress function to higher-capacity bus routes concentrated on the heaviest volume corridors suggest that these services can be scaled to deliver significant benefits in terms of extending the catchment area of public transport to include those not traditionally part of a service area, reducing costs of feeder bus services and parking infrastructure, reducing overall travel times, and reducing private vehicle use (Shaheen & Chan, 2016; Zellner et al., 2016). The long-term environmental impacts are still unclear and will largely depend on the rate of adoption of cleaner vehicles and fuels within these shared fleets.

Wang et al. (2019) and Boarnet et al. (2017) argue that improving 1LM access could improve equity by enhancing regionwide accessibility to employment among excluded populations; Zuo et al. (2020) argue the same for enhanced use of bicycles for 1LM trips to public transport. Other authors have cautioned against the exclusionary effects that new technologies might have against those with limited access to bank accounts and smartphones (Yan et al., 2019).

The 1LM landscape in cities is likely to change significantly in coming years and to grow in complexity. The implications for users, public transport operators, and cities are hard to predict. Knowledge of what users want from the 1LM experience, and how it affects their travel behaviour, is already substantial, as the next section shows. Yet it will need to evolve to take account of this new landscape.

Factors affecting the quality of the first and last mile connection

The literature shows that the quality of the 1LM environment is systematically affected by a number of factors and that these can be measured. A wide variety of different approaches have been adopted, depending on the mode, context, and purpose of the analysis.

Access distance

Walk catchments are particularly important for urban public transport systems, as walking is the main access mode for most public transport trips (Jiang et al., 2012). A number of studies have examined the distances that people are willing to walk to stops and stations. Conventional wisdom in public transport planning holds that the primary walk catchment of public transport is 400 m (a quarter mile). This is based on a synthesis of studies between the 1960s and 1980s on how the propensity to walk decreases with distance to the stop, showing that 75% to 80% of passengers walk 400 m or less to a local stop (Kittleson & Associates Inc. et al., 2013) (see Figure 22.1). At an average walking speed of 5km/h, this translates to a 5-minute walk.

In the last decade, a renewed research interest in walking as a mode has produced new evidence on walk distances to public transport. Van Soest et al. (2020) provide a recent overview of this evidence and find that there is much larger variation in people’s willingness to walk to public transport than previously assumed. Morency et al. (2011) found in Montreal that about half of passengers walked more than 400 m to public transport, while in the Bay Area, the average distance to rapid rail was 800 m (Agrawal et al., 2008). A major source of variation relates to the mode that is being accessed: walk distances to rapid transit like rail have been found to be about double that for local bus (Agrawal et al., 2008; Guerra et al., 2012; Morency et al., 2011). The same seems to apply to BRT, although much fewer studies have focused on BRT than rail as a main mode (Jiang et al., 2012). The reasons for this are not clear, but it is likely related to the generally higher levels of service and longer distances of rail and BRT trips, indicating that
perhaps acceptable walking distances should be investigated as proportions of people’s total trip length rather than as absolute distances.

Mode issues might be confounded with other attributes of the public transport service and with built environment factors that vary systematically with the mode. For instance, the function of the station plays a role: research in Jinan, China, has shown that average walk distances to terminal BRT stations are more than double those to other stations (Jiang et al., 2012). Mulley et al. (2018) found people willing to walk longer to more frequent services, everything else being equal. In terms of built environment factors, good micro-level walkability expands acceptable walking distances (Dill, 2003; Park et al., 2015), as do macro-level land use variables like density and land use mix (Cervero, 2001; Saelens & Handy, 2008). Most research on the relationships between the built environment and walking has focused on walking propensity rather than walking distances per se. This research is discussed in the next section.

Journey-related factors also affect the willingness to walk, including trip purpose, time of day, and trip length (Krygsman et al., 2004; Park & Kang, 2008). Although most studies focus on the home side of the multi-modal trip, there is some evidence that public transport users are willing to walk longer distances on the activity part of their trip than on the home side (Krygsman et al., 2004).

Of course, if other modes are used for the 1LM trip, access distances could dramatically change. For instance, bicycle access to commuter rail typically peaks at 1.6 to 2 km in the United States (Park & Kang, 2008) and 1.5 to 3.5 km in the Netherlands (Keijer & Rietveld, 2000), with slightly shorter distances to access bus stops (Hochmair, 2015). Vuchic (2017) suggests that catchment distances double for Kiss & Ride modes (which could include taxis and e-hailing) as compared to walking, and then doubles again for Park and Ride, but cautions that this can vary widely depending on local conditions.

All of this suggests that flexible catchment area definitions are needed and that service areas around public transport stops and stations vary based on the service offered as well as attributes of the people and places served (El-Geneidy et al., 2014; Jiang et al., 2012).

Figure 22.1 Range of walking distances to bus stops from empirical studies

Source: Based on: Kittleson & Associates Inc. et al., 2013
Walking environment

There is a continuously growing base of research that consistently reveals associations between walking behaviour and the built environment (Ewing & Cervero, 2001; Saelens & Handy, 2008). The bulk of this literature has examined walking in general, while an increasing number of studies have looked specifically at walking access to public transport. Three main methodological thrusts have been the use of perception surveys to examine preferences and behaviours around walkability of the built environment (e.g. Adkins et al., 2012; Agrawal et al., 2008), the estimation of walking mode choice models to study the role of built environment and other factors on walking (e.g. Loutzenheiser, 1997; Meng et al., 2016; Park et al., 2015), and the development of walkability assessment tools for use in evaluation and design (e.g. Frank et al., 2010; Khisty, 1994). The intention is not to review this large body of literature here; the interested reader can see Talen and Koschinsky (2013) and Grasser et al. (2013) for recent reviews in the land use/transport and health literatures, respectively.

Initial studies of the role of the built environment focused on macro-level land use variables and showed that factors such as land use mix and diversity, residential density, and the presence of retail influence people’s willingness to walk to public transport (Cervero, 2001). Micro-scale design factors of the pedestrian environment were found to be secondary to macroscopic ones (Saelens & Handy, 2008). However, multiple recent studies have found solid evidence that micro-scale factors are equally important; these include street design (e.g. street connectivity, setbacks, and parking), pedestrian infrastructure (presence and condition of sidewalks, safe street crossings, conflicts with driveways), and aesthetic factors (e.g. buffers, benches, and shading). Safety from crime has also been found to be important (Tilahun et al., 2016) – in some cases second only to walking distance (Agrawal et al., 2008). There is also a correlation with personal factors such as gender: Kim et al. (2007) find, for instance, that security is more important for women than for men.

Walkability indices have become popular as ways of capturing some or all of these factors in a single composite measure and have been used for evaluation, defining benchmarks, and prioritising and budgeting remedial actions (Khisty, 1994). Typical measures such as the walkability index developed by Frank et al. (2010) use a multicriteria rating to weight the different environmental factors. Other indices such as Walkscore use walking distances to points of interest to construct a gravity-based measure of access to opportunities (Carr et al., 2010). Some indices convert their results into a pedestrian level of service (LOS) indicator (on a scale between A [best] and F [worst]) to be compatible with traffic engineering practice. Validation studies have found some walkability indices correlate well with physical activity levels, mode choices, and obesity levels (Glazier et al., 2012; Manaugh & El-Geneidy, 2011).

Personal factors

Despite some conflicting findings, factors like income, age, gender, disability, race, household characteristics, and vehicle ownership have been found to affect walking behaviour (Manaugh & El-Geneidy, 2011; Van Soest et al., 2020). Earlier studies suggested these factors were dominant (e.g. Loutzenheiser, 1997), but as the accuracy with which environmental factors – particularly micro-scale design factors – are measured has improved, the dominance of personal over urban design and station area factors has subsided. Similar personal factors affect bicycling to public transport (Givoni & Rietveld, 2007), although gender gaps appear to be more pronounced (men are more likely to cycle than women) (Wang & Liu, 2013).

Cultural factors also play a role. There is evidence that commuters in developing countries such as China (Jiang et al., 2012) and South Africa (Behrens, 2004) are willing to tolerate longer
The first/last mile connection

walking distances to public transport, perhaps because of different expectations and generally lower values of time. Perceptions of walkability have also been shown to vary by socioeconomics; for instance, Gebel et al. (2009) showed that adults with low socioeconomic status, who are overweight, or walking with children are more likely to perceive a high-walkable neighbourhood as low-walkable.

Bicycle compatibility

As bicycling has gained popularity worldwide, so the number of studies have grown that examine bicycling access to public transport. Doolittle and Porter (1994) provide an early overview of the state of practice on the integration of bicycles and public transport, while Replogle (1993) points out that in Europe and Japan, bicycling has long played a key role to access rail and, to a lesser extent, bus services. Apart from cultural and historic reasons, this is attributable to “the great attention that has been given by local governments to making streets pedestrian and bicycle friendly” (Replogle, 1993, p. 76).

A variety of stress level and compatibility indices or LOS measures exist to measure the quality of the street environment for bicycle users. One of the more well-known is the bicycle compatibility index developed for the Federal Highway Administration (Harkey et al., 1998), which assesses factors like the presence and width of bike lanes or paved shoulders, parking lanes, the type of roadside development, and the volume and speed of adjacent traffic. This index is considered well validated and useful for general evaluation purposes (Phillips & Guttenplan, 2003) but does not focus specifically on 1LM issues. Similar land use variables appear to play a role in bicycle compatibility as in walkability, although European studies have found biking to rail stations to increase for more suburban environments (Martens, 2007). Also, biking appears less attractive as an egress mode (on the activity side of the trip) than an access mode (on the home side) (Givoni & Rietveld, 2007; Martens, 2007).

Travel time accessibility

The concept of accessibility to destinations has been used in a number of applications to include the speed and connectivity of the 1LM mode in the evaluation of public transport services. This makes behavioural sense, as accessibility to jobs (and presumably to other destinations) explains about four-fifths of public transport ridership (Owen & Levinson, 2015). Accessibility is measured in terms of the number of opportunities reachable by feeder service (e.g. walk or feeder bus) from stations in various lengths of time (Carr et al., 2010; Cheng & Agrawal, 2010). More complex approaches use gravity-based accessibility models (Chandra et al., 2013) or take temporal variations in service frequency into account to identify areas with poor spatial/temporal coverage (Liu et al., 2018; Transport for London, 2015).

These access measures go beyond mere 1LM distances or catchments in evaluating the quality of the 1LM service offer, highlighting the importance of the density and spatial distribution of origins and destinations within the public transport catchment as well as the speed and routing of the 1LM mode. However, they do not include the qualitative environmental factors of the 1LM that are also important in the assessment.

Multi-modal level of service techniques

The Transit Capacity and Quality of Service Manual (Kittleson & Associates Inc. et al., 2013) describes a standardised method for combining various qualitative and quantitative aspects of a
multi-modal public transport trip into a single measure, which is then expressed as a LOS rating. It is meant to evaluate the quality of service of each mode using a street, including public transport, from the user’s perspective. It includes factors such as the availability and quality of the public transport service itself (e.g., frequency, capacity, and reliability) but also includes some factors related to the pedestrian environment like street connectivity, grade, shelters, and pedestrian crossings. The factors are included as correction factors to a series of equations when calculating the public transport LOS score. They are calibrated on empirical studies of public transport user perceptions in the United States and as such are very difficult to validate or transfer to other parts of the world.

In summary, the large and growing body of work examining factors affecting the quality of the 1LM environment has delivered significant insights into what people value and how to evaluate it. Because of the multitude of factors, large variations exist across and even within cities in both the quality of 1LM environments and in users’ expectations of them (El-Geneidy et al., 2014; Van Soest et al., 2020). These variations are likely very context and culture specific, related to pedestrian and cyclist behaviour, differences in perceptions, and different uses of street space (Jiang et al., 2012). This suggests that any efforts to measure the quality of the 1LM environment systematically must be flexible enough to reflect these differences yet rigorous enough to allow meaningful comparison across locales.

Towards a framework for measuring the quality of the first and last mile environment

This section presents some thoughts towards establishing a general framework for measuring the quality of the 1LM environment, building on the access-to-public transport literature. The point of departure is that a more precise measure is needed that acknowledges the specific nature of the 1LM environment, specifically its multi-modality and diversity, but that is robust enough to enable consistent measurement and comparison across different contexts to be useful for evaluation, benchmarking, and prioritisation. The section starts with a brief discussion of methodological issues, which are illustrated using data of the 1LM environment of the Gautrain urban rail system in the Tshwane-Johannesburg region in South Africa. More details are provided in Venter (2020).

Identification of first and last mile modes

The methodology needs to be generic enough to be adaptable to a variety of modes operating in a specific 1LM environment. The first challenge is to define what exactly is meant by the first and last mile. It should by definition include the very first and last component to/from the origin and destination, typically a walking link. But which other modes are to be included depends on the problem at hand: if the interest is in the 1LM to/from a rail system, it might include local buses and taxis serving rail stations. If the interest is in the 1LM connection of that local bus system, it might only include the walking mode between bus stops and origins/destinations. It follows that even within the same geographic area, the definition of 1LM might vary depending on the goal of the analysis, which is important to clarify at the outset. The 1LM evaluation methodology should ideally allow multiple modes to be assessed within the same framework for the sake of comprehensiveness and comparability.

The selected modes should also take into account differences between the access and egress side of public transport trips. As an illustration, Figure 22.2 shows the access and egress modes of a sample of rail passengers of the Gautrain rail system, based on passenger surveys at the two
terminal stations. Modal asymmetry is clear: walking and feeder bus play a much larger role as last-mile modes for egress trips, while park-and-ride dominates for the first-mile trip to the station. In this case, walking and feeder bus were chosen as 1LM modes for analysis.

Delimiting the service area and identifying routes

Two approaches are possible to determine the 1LM area of interest: either a discrete distance band can be defined around each station or stop to delimit the service area, or the spatial coverage of 1LM trips can be identified directly through surveys or direct observation, regardless of distance travelled to/from the station. As discussed previously, no consensus exists among practitioners or researchers regarding a uniform standard for, nor uniform approach to estimating, catchment area size (Jiang et al., 2012). The more flexible second approach seems preferable, as it reflects the actual travel patterns of passengers. Agrawal et al. (2008) and Jiang et al. (2012) have demonstrated the feasibility of identifying 1LM routes by asking passengers to trace the route of their walk trips on a map, which then become the basis of the 1LM evaluation. If the costs of conducting local surveys are prohibitive, it is suggested that the expert knowledge of people familiar with the area, together with geographic information system mapping of points of interest, could supplement or replace passenger surveys. Further research is needed on cost-effective ways of using various data sources to identify 1LM routes.

The proposed procedure delivers a set of routes along which 1LM trips take place, together with a set of origins and destinations that are the non-public transport end of the 1LM trip. It is thus a route-based, rather than an area-based, measure. If a single 1LM measure is calculated for all the routes serving a particular station or set of stations, then it might be preferable to weight the different routes according to the importance of the route. This could potentially be done using the number of origins/destinations served by a route or the number of people using a given route.

Attributes for assessment

The walkability literature has proven that the environmental quality of an area can be “unpacked” into its components (Adkins et al., 2012) for purposes of evaluation. The component factors
affecting 1LM quality for a particular area need to be selected according to the modes under consideration and local conditions. The selection can draw on the research described previously but needs to be tailored for each place, perhaps using local surveys and expert experience. In the Gautrain case, the researchers used a combination of global and local research to select the 19 quality attributes listed in Table 22.1. The chosen attributes emphasise micro-level design factors of the walking environment and bus infrastructure, while macro-level land use factors such as density and access to opportunities are incorporated indirectly through distance and time measures of the 1LM trip.

The quality of routes can be assessed using a variety of tools, including Google Street View images, audits, user questionnaires, and checklists (Aghaabbasi et al., 2017). The purpose is to provide a rating against each of the previous factors for each route, link (e.g. sidewalk section), or node (e.g. intersection). Audits are the most common, as they can reliably be conducted by trained auditors (Adkins et al., 2012; Agrawal et al., 2008), as long as care is taken to ensure consistency and reliability (Clifton et al., 2007). In the case of Gautrain, trained volunteers assessed each route on foot, scoring each element against the previous attributes on a scale

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**Table 22.1 Categories, attributes, and user-derived weights included in first/last mile quality assessment of Gautrain, South Africa**

<table>
<thead>
<tr>
<th>Broad category of first/last mile attributes</th>
<th>Specific attributes</th>
<th>Importance weighting derived from user surveys</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety from crime while waiting for and walking to buses</strong></td>
<td>o CCTV monitoring</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>o Visible security and police</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>o Emergency call box</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>o Lighting quality at sidewalks and bus stops</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Comfort of waiting areas</strong></td>
<td>o Overhead shelter (rain and sun)</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>o Resting facilities</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>o Wi-Fi provision at waiting areas</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Ease of finding information</strong></td>
<td>o Info on bus delays and arrivals</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>o Alternate route information</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Safety from traffic accidents while waiting and walking</strong></td>
<td>o Safe road crossing</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>o Safe place to walk and wait for buses</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Sidewalk comfort and quality</strong></td>
<td>o Walkways wide and obstruction free</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>o Clean and pleasant street environment</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>o Walkways flat, even, and neat</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Time and distance of access trip</strong></td>
<td>o Short walking distance to/from bus stop</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>o Short waiting time for bus</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>o Short travel time to station</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Cost (fare) of access trip</strong></td>
<td>o Cost of feeder trip</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>o Pay point machines at bus stops</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

Source: Venter, 2020
between –2 and +2, with a score of 0 being fixed as the minimum acceptable level of quality. For instance, the attribute *walkway width and obstructions* received a score of +2 if the walkway was at least 1.8 m wide and obstacle free, 0 if it was 1.2 m at its narrowest point (the minimum width prescribed in South Africa (Department of Transport, 2014), and –2 if it was less than 1.2 m wide or had obstacles like street furniture. A total of 129 1LM routes around ten rail stations were assessed, covering 350 km of walk routes. Figure 22.3 shows an example of attribute scores for the 1LM environment of two stations. It is clear that, while considerable heterogeneity exists across the factors, categories like comfort of waiting areas (bus stops) and time/distance and cost score consistently lower. This is especially so in the more suburban station environments.

*Figure 22.3* Audit scores for two example Gautrain stations
Incorporation of local attitudes regarding relative importance of attributes

In order to reflect user needs, the score of each attribute was weighted with an importance weight derived from user surveys. Various techniques have been used to examine the relative weighting of attributes, including analytical network processes of experts’ opinions (Naharudin et al., 2017), correlation analysis (e.g. Ji & Gao, 2010), and importance rating surveys (e.g. Aghaabbasi et al., 2017; Agrawal et al., 2008). In the Gautrain case, an intercept survey was used to obtain importance ratings from a sample of 250 rail and BRT users. The sample was slightly skewed towards younger users but provided fairly representative data. The results shown in Figure 22.4 suggest that passengers have a very clear ranking of 1LM attributes. Safety from crime is considered the most important by far, followed by the cost of the access trip. The dominance of personal safety concerns mirrors findings in the United States (Agrawal et al., 2008; Tilahun et al., 2016). The concern with cost is novel, as it has not been included in walkability research, but is clearly important where public or private for-hire modes enter the 1LM scene, especially so in low-income communities. Sidewalk quality and comfort is the least important issue to this group of South African users, unlike typical findings elsewhere (Aghaabbasi et al., 2017; Agrawal et al., 2008).

Definition of summary indices

Indices summarising the audited quality of an individual 1LM route, subsets of routes, all routes serving a station, or all stations in a system can be calculated as the weighted average attribute score. Attribute weights were derived by converting results from the importance survey to weights that add up to 1.0, as shown in Table 22.1 for the Gautrain case. The results, still scaled between –2 and +2, can be compared to identify trends and concerns. Figure 22.5 shows, for example, the frequency distribution of weighted route scores for all Gautrain stations but separated by location type. It indicates, first, that the majority of 1LM environments perform

![Figure 22.4](https://example.com/figure22.4.png)  User survey: Percentage of respondents identifying a 1LM attribute as among top three most important
Conclusions and further research

As awareness grows of the importance of the 1LM as an integral part of the public transport journey, so does the need to better understand how it affects passengers’ (and prospective passengers’) behaviour. One potentially fruitful strand of research is to use qualitative techniques to explore intersections between demographics, modal experiences and options, and 1LM needs, such as in the work by Hickman and Vecia (2016) in London. It might lead to new insights into the equity and environmental impacts of various 1LM strategies in terms of their contribution to achieving sustainable transport goals. Evidence suggests that passengers’ 1LM needs and behaviours vary significantly across places and cultures; this variation needs to be better understood.

This is especially important as cities are standing on the cusp of major changes in 1LM offerings brought about by shared mobility, micromobility, and new market models, the implications of which are not yet understood. The majority of 1LM studies to date investigate rail as main mode; access to newer modes like bus rapid transit is understudied. Qualitative research should supplement quantitative studies exploring how these offerings are likely to change travel behaviour broadly, public transport mode choice specifically, and mobility in cities. While some visions of the future foresee new technologies drastically reducing the role of both walking and local bus operations in the 1LM environment, this is speculative and deserves critical analysis.

Behavioural studies need to be supported by better data collection of the 1LM trip. While the collection of walking and cycling data in travel surveys has improved, multi-modal trips are still often underreported (Clifton & Muhs, 2012), hampering our ability to characterise the...
1LM trip to/from public transport. Big data techniques using smart cards and in-vehicle navigation might exacerbate the problem, as these might miss the 1LM trip altogether.

Better techniques are also needed for assessing the quality of the 1LM trip using in-field or remote sources. The chapter described an audit-based technique that takes the subjective requirements of 1LM users into account when evaluating 1LM quality. The suggested framework is completely generic with regard to modes, catchment areas, attributes or factors, and how they should be weighted and may easily be customised to fit individual situations. It proposes a route-based rather than area-based approach for the evaluation of 1LM connections to specific public transport services. Its strength lies in its ability to reflect the multi-modal nature of the 1LM environment, as the attributes of any combination of 1LM modes may be included. It has been applied only to assess walking and feeder bus modes, but may easily be extended to include cycling, taxis, e-hailing, and park-and-ride. More research is needed on how to incorporate informal 1LM modes prevalent in developing countries, as it may be more difficult to identify 1LM routes and stops.

Potential difficulties that need further research arise when users of different 1LM modes attach different importance weights to attributes, which might well happen if 1LM modes serve different socioeconomic groups. Further research is also needed on how to properly reflect accessibility to opportunities as an attribute, as this is a critical aspect of the utility of 1LM regimes but only incorporated indirectly. Further work is needed to test the transferability and robustness of the technique to ensure that similar ratings in different places carry the same qualitative meaning, especially given the potential subjectivity that is introduced by the use of trained auditors for conducting the environmental ratings. It might also be useful to relate the scores explicitly to a standardised scale such as level of service ratings between A and F. Last, most research has focused on the first mile, or the access part of the public transport trip. Research shows that the last mile might be quite different in terms of its characteristics and user behaviour; future research should differentiate between first- and last-mile issues more explicitly.

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References


The first/last mile connection


