Chapter 17: Public transport equity outcomes through the lens of urban form

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Abstract

While transport research has traditionally focused on the movement of goods and people to solve mobility issues, researchers, planners, and policy-makers are increasingly interested in the integration of land use and transport systems in an effort to increase accessibility, thereby contributing to the well-being of individuals. Public transport plays a key role in providing access to opportunities, especially for vulnerable populations. In this context, a large body of literature has emerged to explore the benefits provided by public transport as well as their distribution across population groups. Whereas the provision of public transport services has wide and differentiated impacts across individuals and metropolitan regions in the short, medium, and long term, this chapter adopts a user-based perspective and focuses on the direct equity outcomes associated with the provision of public transport services through the lens of urban forms.

Keywords

Public transport equity; Accessibility; Measures of inequality; Car dependency; Social inclusion

Introduction

Transport research and practice has traditionally focused on the movement of goods and people to solve mobility issues. Recently, there has been a shift in the emphasis of the transport research and practice paradigm towards accessibility, the ease of reaching destinations, as it incorporates the movement with the land use, thereby contributing to the well-being of individuals in a

comprehensive manner. Within expanding metropolitan regions, public transport plays a key role in providing access to spatially dispersed opportunities, especially for vulnerable populations. In this context, a large body of literature has emerged to explore and measure the benefits provided by public transport as well as their distribution across population groups.

This chapter first discusses the emergence of social concerns related to public transport and urban form, and presents the benefits associated with the provision of public transport services from a user-based perspective. The second section briefly discusses the theoretical perspectives behind transport equity, while the third section critically assesses the different indicators and approaches used to measure equity in public transport, while accounting for the urban form. Concluding remarks are provided at the end of this chapter to shed light on the avenues and challenges for fostering the integration of equity goals into land use and transport planning.

Urban form, public transport and social equity

Post-war urban structure, public transport and poverty

The consequences of the lack of public transport for vulnerable populations, closely tied with the significant modifications of the urban land use structures, were addressed in research at the end of the 1960s in the US (Sanchez, 2008). The first studies published in academic journals (Kain & Meyer, 1970; Pignatar & Falcocch, 1969), together with similar reports, books and conference proceedings (Ornati, Whittaker, & Solomon, 1969), emerged in the context of increasing concerns about issues of race, poverty and unemployment, and post-war urban structure changes (O'Regan & Quigley, 1998; Sanchez, 2008). Although poverty and unemployment were not new issues in the 1960s in the US, the lack of transport emerged as an important concern and was brought to light after the 1965 major civil rights riot in Los Angeles. While unemployment had so far been explained by traditional factors such as low levels of education, an investigatory body suggested that the conditions leading to the riot were largely due to the lack of geographical access to employment opportunities (O'Regan & Quigley, 1998). The post-war changes in urban structure and transport systems, although benefiting the majority, had led to a spatial mismatch between the location of low-income workers and low-income jobs (Kain & Meyer, 1970).

The specific role of public transport was central in the emerging studies on transport and poverty, as it was often the only travel option for low-income households in sprawling metropolitan regions

(Ornati et al., 1969). While overall household car ownership increased after World War II, reaching close to 80% in 1967 in the US, the level of car ownership was comparatively low for low-income households, on average below 50% (Kain & Meyer, 1970). Most studies at the time thus focused on public transport-dependent populations, usually low-income and minority households, and their public transport needs.

Public transport, employment and social inclusion

Employment outcomes

The car-oriented development that followed in the second half of the 19th century contributed to exacerbating urban sprawl. As a result, the distances between residential and employment areas is still nowadays an important barrier to access employment opportunities. As such, recent studies demonstrate that public transport still contributes to employment outcomes, especially among lower-income populations. In general, research has found that the lack of available transport options to reach employment opportunities constitutes a major barrier to obtaining and keeping a job (Andersson, Haltiwanger, Kutzbach, Pollakowski, & Weinberg, 2014; Cebollada, 2009; Ihlanfeldt & Sjoquist, 1998; UK Social Exclusion Unit, 2003). For example, in the UK, 40% of job-seekers stated that transport (either the lack of a car or the lack of public transport services) was a crucial obstacle to finding a job (UK Social Exclusion Unit, 2003). Another study found through interviews with unemployed individuals in Barcelona, Spain that the lack of reliable transport and high commuting times and costs contributed to missed job opportunities (Cebollada, 2009).

More specifically, some studies have found a negative relationship between access to public transport (or access to jobs using public transport) and unemployment. In the US, Sanchez (1999) found that access to public transport stops and access to jobs by public transport were significant determinants of employment in terms of the number of weeks and number of hours worked in Portland and Atlanta, US. Similarly, Kawabata (2003) showed that low-skilled workers were more likely to be employed, and to be employed full-time, if they had better accessibility to jobs by public transport in San Francisco, Los Angeles, and Boston, and the effect was greater for carless individuals. Similar conclusions have been drawn in the European context (Matas, Raymond, & Roig, 2010) and the South American context with respect to formal employment (Boisjoly, Moreno-Monroy, & El-Geneidy, 2017; Moreno-Monroy & Ramos, 2015). It is, however, difficult

to conclude causality of the relationship from these studies, as they are conducted at specific points in time.

Other studies have assessed changes in unemployment following variations in public transport services using a differences-in-differences method, in an attempt to disentangle the causality effect. In an assessment of unemployment rates in New York City before and after the Hurricane Sandy, Tyndall (2015) found that the interruption of the R Train resulted in greater increases in unemployment in areas affected by the R Train. Conversely, Sari (2015) assessed the impacts of a new tramway line in Bordeaux, France and found that areas close to the new tramway line had seen a greater decrease in unemployment than other areas in the region. These studies suggest that changes in public transport services may contribute to positive employment outcomes, with service improvements leading to greater employment rates. However, they did not assess whether individuals have improved their situation, or whether the changes in unemployment rates were due to movements of people.

To explore the effects of public transport services on individuals, Cervero, Sandoval, and Landis (2002) used employment data at the individual level in Alameda County, California. While they found that car ownership had the greatest impact on the odds of switching from welfare to work, they also found that, for individuals without a car, residing within walking distance of a public transport stop increased their odds of finding a job. By using individual data, this study shows that public transport can stimulate employment among unemployed people. Similarly, in a qualitative study conducted in Barcelona, individuals located in areas with low levels of public transport reported not obtaining a job because of the lack of access by public transport and the lack of car ownership (Cebollada, 2009).

Social inclusion

From a broader perspective, researchers are also concerned with transport-related social exclusion in the context of expanding metropolitan regions. This strand of research emerged in the early 2000s in the UK, when the government created a Social Exclusion Unit (SEU) to investigate poverty and unemployment. The SEU formally identified the links between transport, namely public transport, and social exclusion in 2003 (Currie, 2010). Accordingly, increasing attention was given to social exclusion by transport researchers.

Social exclusion can be defined as:

> *"a constraints-based process which causes individuals or groups not to participate in the normal activities of the society in which they are residents and has important spatial manifestations." (Preston & Rajé, 2007)*

While employment is an important component of social inclusion, the concept of social exclusion encompasses a wider set of attributes such as participation in cultural and leisure activities, political engagement and social networks (Currie & Delbosc, 2010). In the context of transport-related social exclusion, researchers emphasize that participation in society largely depends on the ability to access a diversity of opportunities, namely access to social capital, decision-making, education, health care and leisure facilities (Lucas, 2012; Preston, 2009; Preston & Rajé, 2007).

Within metropolitan regions which have developed on accommodating private cars, the ability to access these opportunities encompasses a strong spatial component, and accordingly, public transport can play an important role in fostering social inclusion. While the link between public transport and unemployment has been extensively investigated, less research has investigated other components of social inclusion. Using structural equation modelling in Victoria, Australia, Currie and Delbosc (2010) assessed the empirical relationship between public transport and social exclusion, measured as a composite indicator accounting for income, unemployment, political engagement, participation to activities and social support. They found that transport disadvantage, and more specifically public transport disadvantage, were positively associated with social exclusion. This study is, to our knowledge, one of the few studies to empirically test the relationship between social exclusion and public transport services.

Nevertheless, other studies have shed light on the contribution of public transport in accessing a diversity of opportunities and activities that are spatially distributed. For example, through interviews with bus riders in Melbourne, Australia, Loader and Stanley (2009) found that improved weekday services contributed to a greater participation of individuals in social and shopping activities. Clifton (2004) also found, through interviews with low-income households in Austin, Texas, that public transport played a key role for accessing food retails. Furthermore, in terms of health services, the SEU stated that a significant number of individuals (1.4 million) reported that they either missed, refused or decided not to get medical services because of transport problems (UK Social Exclusion Unit, 2003). While the SEU did not directly investigate the role of public

transport, the results suggest that improved public transport could support greater access to medical services.

Urban sprawl and forced car ownership

In addition to the social exclusion impacts associated with the lack of public transport, the dispersion of activities, together with the lack of public transport, can place a significant financial burden on low-income families. In cases where public transport does not efficiently connect origins and destinations, some households or individuals may opt for owning a car to ensure that they can access their activities. For low-income populations, the desire to access employment opportunities combined with the lack of adequate transport alternatives has been shown to be a major factor contributing to the acquisition of a car (Currie & Delbosc, 2011; Loader & Stanley, 2009; Potoglou & Kanaroglou, 2008). In these cases, while purchasing a car allows individuals to take part in their activities, it also places a significant financial burden on individuals or households (Boschmann & Kwan, 2008; Currie & Delbosc, 2011). Accordingly, the provision of adequate public transport services can contribute to reducing *forced car ownership*, as described by Currie and Delbosc (2011).

Principles behind transport equity

As shown above, especially in the context of urban sprawl, the provision of public transport services has been seen to have broad impacts on an individuals' quality of life, and some populations are more likely to suffer from the consequences of a lack of adequate public transport options. Equity issues are thus inherent to land use and transport planning, and more specifically, to the provision of public transport services. While transport planning agencies are increasingly concerned with such issues (Golub & Martens, 2014; Manaugh, Badami, & El-Geneidy, 2015), there is a lack of guidance on how to define and assess equity in the distribution of transport investments across a metropolitan region (Golub & Martens, 2014; Lucas & Jones, 2012; Pereira, Schwanen, & Banister, 2017).

Two questions arise when attempting to define and measure transport equity, as discussed by Pereira et al. (2017). The first one relates to what should be measured to evaluate the quality of the service provided from a social perspective. The second one is concerned with what constitutes a fair distribution of the service in a region. In this section, these two questions are briefly discussed

before addressing, in the next section, the specific indicators and approaches used to evaluate equity in public transport services.

In recent years, transport researchers have reviewed various theories of justice to discuss the distribution of benefits and burdens of transport systems. With respect to the question of what should be measured, researchers draw from Rawls' theory of justice and argue that accessibility, broadly understood as the level of access to opportunities, should be considered to assess the distribution of benefits provided by transport systems (Lucas, van Wee, & Maat, 2016; Martens, 2016; Martens, Golub, & Robinson, 2012; Pereira et al., 2017; van Wee & Geurs, 2011). In other words, the literature suggests that transport planners and policy-makers wishing to consider equity in the distribution of transport benefits should be primarily concerned with the level of accessibility provided to individuals**.** This is in line with the empirical studies discussed in the previous section which have shown the importance of public transport accessibility for social inclusion. The notion of accessibility is especially relevant as it links the provision of transport services and infrastructures with the urban form in which they are implemented.

With respect to what should be considered a fair distribution of services, researchers build on egalitarian and sufficientarianism theories to derive two principles of justice. The first is that a sufficient or basic level of accessibility should be provided to all individuals (Lucas et al., 2016; Martens, 2016; van Wee & Geurs, 2011). In the context of land use and transport planning, Preston and Rajé (2007) argue the lack of access to opportunities, rather than the lack of opportunities, is of concern. Overall, researchers tend to agree that a minimum level of accessibility to some key destinations should be ensured, and that this threshold should be defined to allow individuals to meet their basic needs and participate in society. This is far from being a simple task, as is discussed in the next section.

The second principle of justice discussed in the context of transport refers to the equality of distribution. While this could suggest that the benefits of transport systems should be equally distributed to all individuals, researchers emphasize that what matters is equality of opportunities. Since individuals inevitably have unequal opportunities in a society, given internal and external constraints, egalitarian theories suggest that an unequal distribution of transport benefits should be considered to minimize inequality of opportunities (Martens, 2016; Pereira et al., 2017). It is argued that individuals more likely to have limited opportunities due to financial, cultural,

physical, situational (e.g.: lack of access to information) or cognitive constraints, should be provided with higher levels of accessibility (Lucas et al., 2016; Martens, 2016; Pereira et al., 2017). More specifically, researchers refer to the *maximin* principle, suggesting that policies should maximize the level of access of the worst-off (Lucas et al., 2016; Pereira et al., 2017). In addition to the *maximin* principle, Martens et al. (2012) argue that a maximum gap in access levels should also be taken into account.

In sum, there is an agreement that a fair distribution of transport benefits should consider the distribution of access to opportunities. Furthermore, the principles of justice highlighted by transport researchers suggest that: i) a minimum level of access should be provided to all individuals, and ii) the level of access of disadvantaged populations should be maximized relative to the rest of the population to foster equity of opportunities.

Measuring public transport equity

As discussed above, public transport is a key component for overcoming spatial barriers to social inclusion. It is accordingly essential to be able to measure the benefits provided by public transport to the different population groups in order to support equitable land use and transport systems. Against this background, researchers have proposed a variety of approaches to measure public transport performance from an equity perspective. The main approaches are summarized in Figure 17.1.

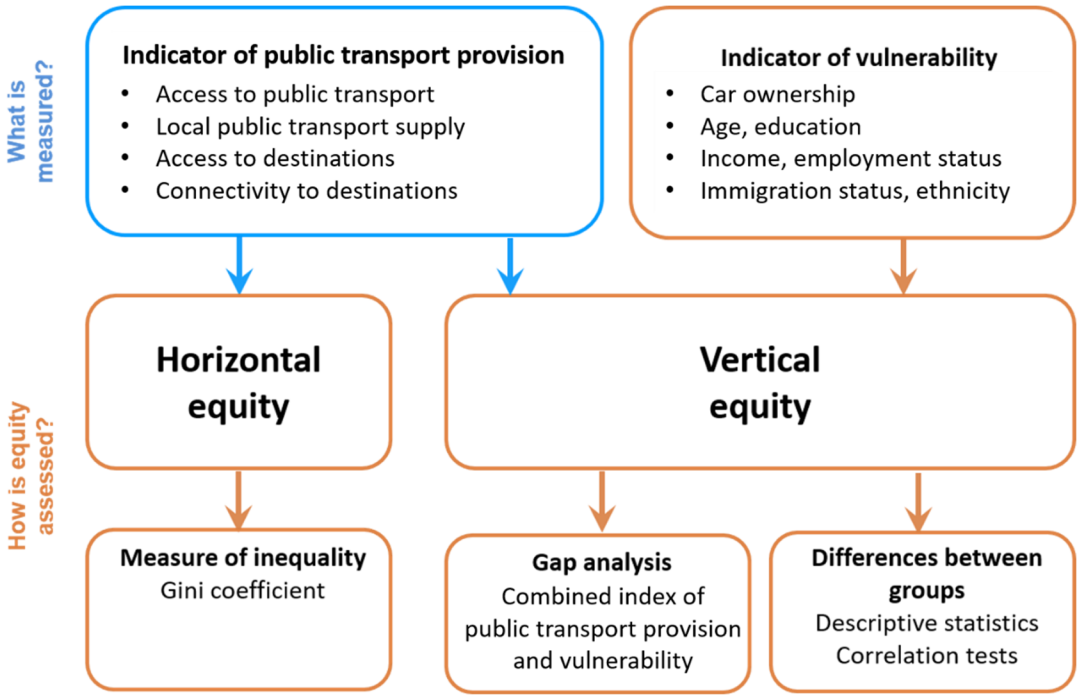

Figure 17.1: Indicators and methods to assess equity in the distribution of public transport services

What is measured?

Starting with the question of what should be measured, a review of the literature reveals four indicators that are typically generated to measure the provision of public transport services from an equity standpoint (see Figure 17.1): access to public transport, local public transport supply, access to destinations and connectivity to destinations.

Access to public transport and local public transport supply

Access to public transport is the simplest measure and typically counts the number of individuals or opportunities that are within a specific distance of a public transport stop (Blair, Hine, & Bukhari, 2013; Delmelle & Casas, 2012; Grengs, 2001). Such a measure is easy to operationalize and to communicate and is accordingly often used by public transport authorities as a measure of public transport coverage (LTA, 2013; Metrolinx, 2008). While such measures are relevant in assessing the spatial coverage of public transport services across a region, they do not consider the quality of the service, although some studies categorize the access on the basis of the frequency of the routes (Blair et al., 2013) or the destinations they serve (Grengs, 2001). Furthermore, such objective measures dot not consider individuals' perceptions, which may vary across individuals

and land use contexts, as shown in a previous study (Curl, Nelson, & Anable, 2015). They have nonetheless been shown to be associated with positive outcomes in terms employment and social inclusion, as discussed above.

To address this limitation, a common approach to measuring the distribution of public transport services in a region is to assess the level of service provided in an area, based on the detailed characteristics of the service. For example, Jiao and Dillivan (2013) developed a composite public transport supply index that counts the number of public transport stops (bus or rail) in a block group, the frequency of service at each stop (during weekday service) and the total number of routes in each block group, to represent the level of service provided to the residents of each block. Similarly, Delbosc and Currie (2011) used an aggregated measure of service frequency at bus stops combined with the catchment area of the bus stops. A similar approach, first implemented by Transport for London, is now increasingly incorporated into practice, through the generation of Public Transport Accessibility Levels (PTAL) indices that consider walking time, service reliability, number of services and waiting time (Transport for London, 2010).

Overall, these types of measures offer a detailed assessment of the public transport service provided to every area in a region. They, however, do not directly address how these services are integrated with the rest of the network. For example, an area might be served by a frequent bus line, but this line might not be well connected to the rest of the network, or might connect with few destinations. Nevertheless, it is possible to assume that a high density of frequent public transport service is desirable, although it does not directly measure the ease of reaching destinations.

Access and connectivity to destinations

Since the ability to reach spatially dispersed opportunities depends on both the public transport supply and the land use in which it is implemented, researchers have developed more complex measures to specifically capture the ease of reaching destinations. Namely, location-based measures of accessibility to jobs are commonly used, counting the number of jobs that can be reached from a specific location in a given travel time or cost (Foth, Manaugh, & El-Geneidy, 2013; Golub & Martens, 2014; Grengs, 2010; Transport for London, 2006). For example, Foth et al. (2013) measured the number of jobs that can be reached within 45 minutes by public transport in an assessment of equity over time in Toronto, Canada, while Golub and Martens (2014)

compared the cumulative accessibility to jobs by car and by public transport in the San Francisco Bay Area. Such indicators are also used in planning processes. For example, in their long term transport plan, Transport for London included the changes in the number of jobs that can be accessed within 45 minutes of public transport as a central goal (Transport for London, 2006). While research has traditionally focused on employment opportunities, broader concerns have been introduced in equity studies, namely accessibility to food supply (Ferguson, Duthie, Unnikrishnan, & Waller, 2012), recreation sites (Delmelle & Casas, 2012) and health care services (Delmelle & Casas, 2012; Paez, Mercado, Farber, Morency, & Roorda, 2010). Such indicators are central in investigating the relationship between public transport, urban form and social inclusion.

Although accessibility measures are widely used because they consider both the land use and transport systems, these measures offer little information on the public transport network. As such, they typically do not account for characteristics such as the inconvenience of transfers, the number of options to reach the destinations and the capacity of vehicles and frequency of service. To overcome these shortcomings, some authors have developed indicators that account for both the detailed characteristics of the public transport network, and the location of opportunities (referred to in this chapter as connectivity to destinations) (Kaplan, Popoks, Prato, & Ceder, 2014; Welch & Mishra, 2013). Kaplan et al. (2014) developed a location-based accessibility metric, in which the travel time to destinations is calculated using a connectivity function and expressed in minutes. The function accounts for service reliability, smoothness of transfers, and trip components (waiting time, in-vehicle time). Connectivity is calculated using an algorithm that is composed of 11 attributes and represents a perceived value of time rather than the actual travel time. Although this measure better reflects the quality of service and the preference of users, it is more complex to operationalize.

How is equity assessed?

This section now turns to the question: How is equity assessed? Equity assessments of public transport supply can be divided in two main types (see Figure 17.1). The first one looks at horizontal equity, assessing the spatial distribution of public transport services across a region or a population. The second one is vertical equity, which focuses on the distribution of benefits across socio-economic groups.

Horizontal equity

In the context of transport, horizontal equity considers that all individuals should receive the same level of service. In recent years, researchers have attempted to quantify horizontal equity in a region using the Gini index which is a statistical measure of inequality commonly used in economics to assess income inequalities. The Gini index is based on the cumulative distribution of income (Lorenz curve) and indicates, for example, which proportion of the population has which proportion of the total income.

In the context of public transport equity, several researchers have calculated a Gini coefficient for different metropolitan regions, using an indicator of public transport supply on the y-axis, and the share of the population on the x-axis (Delbosc & Currie, 2011; Kaplan et al., 2014; Mortazavi & Akbarzadeh, 2017; Nahmias-Biran, Sharaby, & Shiftan, 2014; Ricciardi, Xia, & Currie, 2015; Welch & Mishra, 2013). For example, Delbosc and Currie (2011) measured the Gini index of the public transport system in Melbourne, Australia using a local public transport supply index on the y-axis, and the share of the population on the x-axis.

The Gini index is useful is providing a single quantitative indicator that is independent of scale and can be used to compare public transport distribution between metropolitan areas (Lucas et al., 2016), or for different scenarios (Mortazavi & Akbarzadeh, 2017). Many policy-makers are familiar with the Gini index, which makes it attractive and easy to communicate. This likely explains why many transport researchers have attempted to assess the public transport distribution using the Gini index. Yet, horizontal equity might not be a relevant goal in the context of social equity. While the Gini coefficient quantifies the equality in the distribution of public transport services, researchers have argued that an unequal distribution might be desirable if it ensures better access to opportunities for disadvantaged groups (see above). Yet, the Gini coefficient, or horizontal equity in general, does not differentiate between individuals and does not account for the personal characteristics that might affect individuals' levels of opportunities. Furthermore, the Gini coefficient does not consider the variations in land use structures. As such, metropolitan regions are inherently composed of various land use structures and the benefits of public transport services are necessarily unevenly distributed. For example, it is unrealistic to expect suburban residents to have the same level of accessibility to employment opportunities than central-city residents. Finally, the coefficient itself does not hold much information. Accordingly, while this

approach is increasingly used in research, the Gini coefficient does not appear to be an effective tool to include in public transport planning practice to evaluate social equity.

Vertical equity

Researchers tend to agree that a focus on disadvantaged populations should be considered to assess social equity in the provision of public transport services and support equitable land use and transport systems. Most of the studies frame their work in terms of equity (e.g.: (Ferguson et al., 2012; Foth et al., 2013; Kaplan et al., 2014) or social exclusion (e.g: (Currie et al., 2009; Engels & Liu, 2011), and to a lesser extent in terms of environmental justice (Fruin & Sriraj, 2005). While these studies use different concepts, their approaches are highly similar: they investigate the socio-spatial distribution of public transport services, with a focus on disadvantaged groups. Social equity is hence, implicitly or explicitly, assessed based on vertical equity in these studies.

Vertical equity can be defined in transport planning as providing greater benefits to the populations that are potentially the most in need, referred to as vulnerable or disadvantaged populations in this chapter (Stanley & Lucas, 2008). This is in line with the theoretical perspectives discussed above. From an egalitarian perspective, providing equal access to opportunities does not mean equal service: it means that populations that are more likely to experience barriers to accessing opportunities should be prioritized. This is also desirable from a sufficientarianism standpoint, since these populations are considered at risk of having insufficient levels of access.

From a broad perspective, socio-economic disadvantage plays a role in constraining access to opportunities. For example, low-income individuals and recent immigrants might face greater constraints in terms of home and work locations and opportunities. As discussed above, low-income individuals, low-skilled workers, elderly and minority groups are more likely to suffer from the lack of adequate public transport. Accordingly, many studies include socio-economic factors such as income, unemployment, immigration status and ethnicity to identify vulnerable populations (Clifton, 2004; Currie, 2010; Delmelle & Casas, 2012; Foth et al., 2013; Jaramillo, Lizarraga, & Luis Grindlay, 2012; Kawabata, 2003). Furthermore, from a public transport perspective, populations that do not have access to a car or that are unable to drive are more likely to face greater accessibility barriers and to depend on public transport to access their destinations. Accordingly, several studies include factors such as car ownership and age to capture this dependency (Currie, 2004; Hensher & Chen, 2011; Ricciardi et al., 2015). Other studies identify

populations that are more likely to depend on public transport based on socio-economic characteristics such as income and unemployment (Blumenberg & Ong, 2001; Blumenberg & Pierce, 2017; Engels & Liu, 2011; Ricciardi et al., 2015). In many cases, studies acknowledge that public transport-related vulnerability or needs are the results of a combination of factors, and accordingly develop a composite index (Foth et al., 2013; Jaramillo et al., 2012; Jiao & Dillivan, 2013).

As illustrated in Figure 17.1, vertical equity studies typically use a vulnerability indicator in addition to a public transport provision indicator. Vertical equity studies can be classified in two groups (see Figure 17.1).

The first approach (differences between groups) consists in comparing the level of service provided to different socio-economic neighbourhoods. Most commonly, the relative level of service (or change of service) provided to different socio-economic groups is assessed, typically based on areas such as census tracts or traffic analysis zones (TAZ). To do so, many studies group areas based on their socio-economic conditions or vulnerability level, and compare the level of public transport provision across these groups (Bocarejo & Oviedo, 2012; Delbosc & Currie, 2011; Delmelle & Casas, 2012; Foth et al., 2013; Grengs, 2001; Welch, 2013). For example, Foth et al. (2013) group census tracts into ten socio-economic decile, and calculate the average accessibility change from 2000 to 2010 in Toronto, Canada for each socio-economic decile. Such an approach provides descriptive statistics and can be used to identify which groups benefit the most from the current or projected public transport network as a function of the land use in which they are implemented. A similar method consists in calculating the correlation between the level of vulnerability and the level of public transport supply of each geographic unit (Grengs, 2001; Mortazavi & Akbarzadeh, 2017). From a vertical equity standpoint, high vulnerability should be positively correlated with high levels of public transport service. Using this approach, Mortazavi and Akbarzadeh (2017) quantified the vertical equity of projected public transport improvements by calculating a Spearman's rank correlation coefficient, based on the Traffic Analysis Zone (TAZ) ranking in terms of needs (vulnerability) and supply (public transport provision). Each TAZ is given a rank from 1 to X (total number of TAZs) for its level of need and its levels of supply. The two rankings are then subtracted from one another to obtain a ranking difference score for each TAZ. Using these differences, the authors then calculated and compared the Spearman's rank

correlation coefficient for three scenarios. As is the case with the Gini coefficient, this approach provides a value that can be directly compared across scenarios, or across metropolitan areas, but by taking into account the principle of vertical equity. By providing a comparable measure, this approach could be highly valuable for planners and decision-makers. There are, however, very few studies using such approach. Further studies could accordingly test this approach in different contexts, and with different public transport supply indicators, to assess its empirical and theoretical soundness. The comparison of the provision of service across socio-economic neighbourhoods contributes to assessing the level of service provided to vulnerable populations compared to the rest of the population. From a theoretical perspective, this is useful to pursue that *maximin* principle of justice, which consists in maximizing the level of accessibility of the worst-off. However, as will be discussed later, these studies do not provide guidelines or insights on what should be considered a fair distribution. For example, most studies conclude on which groups benefit the most without discussing which discrepancy would be desirable.

The second approach (gap analysis – see Figure 17.1) aims at identifying the gaps in the provision of public transport based on the needs of populations, or their vulnerability (Bocarejo & Oviedo, 2012; Currie, 2004, 2010; Currie et al., 2009; Engels & Liu, 2011; Ferguson et al., 2012; Jaramillo et al., 2012; Jiao & Dillivan, 2013; Mulley, Ma, Clifton, & Tanner, 2017; Welch, 2013). The gap approach focuses on areas with high vulnerability and low public transport services. This is relevant to identify specific areas that might be disadvantaged, as the differences between groups approach does not capture the disadvantage of each area. For example, low-income areas might have overall good accessibility, but it might be that some low-income areas situated in peripheral areas have very low levels of accessibility. This is especially relevant in the context of the suburbanization of poverty. To identify such areas, several studies generated a combined index of vulnerability and public transport supply. For example, Mortazavi and Akbarzadeh (2017) calculated a deficit index, based on the connectivity of the TAZ (public transport provision), and the proportion of carless households (vulnerability) in each TAZ. The deficit index is defined as the normalized vulnerability index of a TAZ, divided by its normalized index of connectivity. Similarly, Jiao and Dillivan (2013) developed a public transport discrepancy index by subtracting a public transport supply standardized score to a public transport demand standardized score, while other studies separately mapped the two indices for visual comparison (Currie, 2004, 2010; Jaramillo et al., 2012). The strength of these approaches resides in the spatial visualization and

quantification of the discrepancies between the needs and the provision for each geographic unit, which allows identifying areas in needs. This is helpful in addressing the principle of justice that stipulates that all individuals should have a basic level of accessibility to opportunities. As emphasized by Lucas et al. (2016), it is essential to focus on those individuals that are below the sufficient level, and the gap approach specifically identifies areas where individuals are most likely to experience such deficit.

In sum, this section presented various approaches to assessing vertical equity. These approaches are useful to guide decision-making for comparing scenarios and identifying areas in need of improvements. Ideally, equity assessments would combine some of these approaches to address both principles of justice: maximizing the level provided to the vulnerable populations and ensuring a minimum level of service, as done by Mortazavi and Akbarzadeh (2017). However, an important weakness of these studies is that they do not provide quantitative thresholds that could be used to set planning objectives. While in some cases, arbitrary thresholds are used as a proof of concept, they do not rest on any empirical or theoretical grounds.

Equity thresholds and targets

As highlighted by Pereira et al. (2017), the question of thresholds and targets has received very little attention in transport equity research, although there is a growing interest amongst land use and transport practitioners and decision-makers. While most studies agree that populations that are currently vulnerable should receive greater attention, there are little indications on what levels should be ensured, and what level of disparity should be considered fair. However, as emphasized by Manaugh et al. (2015), the measurement of social equity goals is essential to ensure that they receive greater attention in decision-making processes. Lucas (2012) also discusses the need to establish metrics guiding the provision of public transport for social inclusion, in order to promote the social inclusion agenda within metropolitan regions.

In line with this, a few researchers have recently worked on defining a minimum level of accessibility by public transport that should be provided to all individuals in a region. Building on sufficientarianism theories, researchers argue that the minimum level of service provided should allow individuals to meet their basic needs and to participate in society (Ferguson et al., 2012; Loader & Stanley, 2009). Yet, the definition of this threshold is highly context-dependent (Pereira et al., 2017). In this regard, Ferguson et al. (2012) argued that the threshold should be set with the

level of accessibility by car, which is considered as what is needed to meet the basic needs in a car-dependent society. This is especially relevant given car-dependency that characterizes many metropolitan regions. Following this approach, Golub and Martens (2014) developed the concept of *access poverty* based on modal equity. They generated an access ratio that represents the level of accessibility to jobs by public transport, relative to the level of accessibility to jobs by car. A ratio of 1 means that individuals using public transport have the same level of accessibility as individuals using a private vehicle, while a ratio below 1 reflects a lower level of accessibility by public transport. The authors set an *access poverty* threshold of 0.33, suggesting that areas with a ratio below this value are access impoverished. While the value is set arbitrarily in this study, the ratio approach is relevant to define a minimum level of public transport service in relation to job accessibility. Further empirical research could be conducted to explore, in different contexts and land use patterns, which ratio better reflects the minimum level of accessibility required from a sufficientarianism standpoint.

Although not specific to public transport, Lucas et al. (2016) developed a measure of *minimal necessary accessibility*, which captures a set of socially relevant activities that can be reached under specific distance thresholds. Using this measure, the authors calculated the proportion of households, in a region, that reach a *minimal necessary accessibility*. Once again, the distance thresholds are set arbitrarily in this study. Qualitative and quantitative approaches could build on this study to investigate which thresholds are meaningful, as well as the type of opportunities that are judged socially relevant. This approach is relevant in broadening the scope of accessibility to opportunities other than jobs, and could be expanded to account for accessibility by public transport. Doing so could provide policy-makers with clear measures of equity, by defining the proportion of vulnerable individuals that are below the *minimal necessary accessibility*.

Finally, Loader and Stanley (2009) conducted interviews with public transport users to identify the minimum level of service required to participate in activities. By doing so, they identified specific weaknesses in the public transport service that limit individuals to participate in activities, namely infrequent service outside peak hours. This type of analysis is helpful in understanding how different aspects of the public transport service affect individuals' participation in activities, and should be conducted in parallel with quantitative studies to contribute to the definition of a minimum level of service.

While only a few studies have attempted to establish clear criteria, these studies suggest promising avenues to develop quantitative equity objectives to be included in public transport planning. Further research, qualitative and quantitative, should build on these approaches to develop and evaluate equity thresholds and guidelines supporting public transport planning and decision-making.

It is important to note that while most studies discussed here are conducted at the aggregated level, individual factors are also very important in influencing one's participation in activities and the level of accessibility they experience. This chapter focuses mostly on quantitative and aggregated approaches as tools to assess equity in public transport at a regional level. It is, however, essential to keep in mind that individual factors which may limit individuals in meeting their needs or accessing their desired destinations are not captured in such assessments. Furthermore, this chapters focuses on geographic constraints, but it is clear that other cultural, cognitive and social factors prevent individuals from accessing opportunities. Policies that account for discrepancies in mobility abilities and non-geographic constraints must also be considered although they fall outside the scope of this chapter.

Finally, it is important to note that this chapter addressed equity in the context of public transport specifically. Ensuring equitable access to opportunities, fostering social inclusion and promoting healthy mobility is nonetheless contingent on the variety of transport modes provided to individuals, as well as the design of the built environment and the distribution of opportunities. Accordingly, global approaches to transport equity are required. Nonetheless, the fair distribution of public transport services is an essential component of an overall equitable land use and transport system.

Conclusion

This chapter has emphasized that the provision of public transport, especially in the context of car-oriented metropolitan development, has broad impacts on individuals, and that issues of equity are inherent to public transport planning. While there are no clearly established guidelines to design equitable public transport systems, researchers have generated a variety of indicators to quantify the provision of public transport from a social equity perspective, namely local public transport supply, connectivity, access to destinations and connectivity to destinations. Using these

indicators, researchers have developed different approaches to evaluate equity in the provision of public transport taking into account the different factors affecting individuals' vulnerability.

The review of the literature identified promising approaches, as well as important gaps that need to be addressed to support the integration of equity goals in planning. With respect to the social outcomes of public transport, it is essential to further explore how the lack of public transport services affects vulnerable populations, especially with respect to social inclusion. As highlighted by Lucas and Jones (2012), the literature on this topic is still limited and the quantification of these issues remains a challenge. While many studies quantify the accessibility to a variety of services, more studies are needed to assess the impacts of the lack of access by public transport on social exclusion. Similarly, more research is needed to explore the direct causality between accessibility to jobs by public transport and unemployment, and to further explore the underlying causal mechanisms. Furthermore, future research should investigate how the different indicators are linked with social outcomes, and how they can be integrated into planning practice. The choice of a measure inevitably implies trade-offs, where simple measures are easier to generate and operationalize, but typically less theoretically and empirically sound. While researchers have placed a lot of effort in developing various indicators, more studies are needed to assess the usability of the different indicators in planning practice. Ideally, indicators should tend towards capturing all elements that affect individuals' ability to reach their destinations and should be empirically associated with social outcomes. The indicators should also be critically assessed in light of the data available and on the basis of their meaning to users, planners and policy-makers. Finally, it is essential to build on the equity assessment approaches discussed in this chapter to provide planners and policy-makers with meaningful equity targets to be included in planning processes.

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