Cities 90 (2019) 88–99

Contents lists available at ScienceDirect

Cities

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

Justice in public transport systems: A comparative study of Auckland, Brisbane, Perth and Vancouver

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ARTICLE INFO

Keywords:
Justice
Public transport
Accessibility
Equity

ABSTRACT

Although the concept of social justice seems to be ubiquitous in most transportation plans, methods adopted to evaluate transit systems have little engagement with political theories to define justice. Without a proper definition, transport planners will be unable to design transit systems that achieve justice. The present study proposes a combination of sufficientarianism and egalitarianism principles to define justice in transit. Based on this framework 1) access to public transport is a right, 2) public transport should provide a minimum accessibility, 3) public transport should benefit the less well-off groups, and 4) a just distribution has to be spatially evaluated. The framework proposes a method that can be used to measure and compare justice in transit systems. The framework is applied to four case study cities, Auckland, Brisbane, Perth, and Vancouver. The results show that Auckland's transit system performs well relative to the other three case study cities by accounting for people and providing a minimum access to jobs. However, Auckland's transit services fail in the just distribution as it favours more affluent neighbourhoods. This issue is more severe in Brisbane's and Perth's transit systems. Vancouver, on the other hand, provides a better service for low-income neighbourhoods. This study contributes to the field of justice in transit by providing a clearly defined framework which can be adopted to analyse a city's transit system and compare it with other cities. It is expected to assist practitioners in obtaining insights that can inform policy decisions.

1. Introduction

Transit services inevitably yield costs and benefits which vary across different communities within an urban area. Disadvantages in transit services have a direct impact on the livelihood of communities and can contribute to social exclusion. As such, recent studies on transport equity (Di Ciommo & Shiftan, 2017) focused on the distribution of benefits and its impact on the transport disadvantaged communities. From a theoretical perspective, the distributive justice theories have a well-established normative foundation and a small but expanding publications which explore its implication in transportation planning (Davoudi & Brooks, 2014; Khisty, 1996; Lucas, Van Wee, & Maat, 2016; Martens, 2016; Mullen et al., 2014; Van Wee & Roeser, 2013). It is well-known that accessibility to basic needs is a human right. Theories on justice have been used to determine accessibility measures for evaluating the basic capability of different transport groups (Di Ciommo & Shiftan, 2017). A well-planned transit system can meet the basic needs for different groups of users. However, literature on transport equity has revealed that many transit systems do not benefit captive users by providing long wait times, poor connectivity, and unreliable services (Currie, 2010). This is due to the limited ability of transportation planners to assess justice of a transit system. The specific implication of theories on justice in transit planning is relatively unexplored. The present study addresses this knowledge gap.

The current frameworks used in practice are often limited in engagement with the philosophical literature on justice (Currie, 2010; Foth, Manaugh, & El-Geneidy, 2013; Geurs, Boon, & Van Wee, 2009; Jones & Lucas, 2012; Levinson, 2010; Litman, 2015; Pucher, 1981). To the authors' knowledge, there is a lack of tools which assesses the outcomes of transit planning and policies with respect to political justice. Without a robust framework to assess justice, it is difficult to determine if transport policies will produce a just transit system. The aim of this research is to develop a framework to assess if the outcomes of transit plans provide riders with just services. The primary objective is to produce a framework that combines egalitarianism and sufficientarianism views of justice. The framework explores if a transit

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https://doi.org/10.1016/j.cities.2019.01.031
Received 29 May 2018; Received in revised form 29 November 2018; Accepted 19 January 2019
0264-2751/

system is accessible spatially and across income levels. The second objective is to investigate justice in the performance of a transit system. This framework can be used to compare transit systems among cities.

The next section of this paper is a summary of the relevant literature. It is followed by the research methodology. The results are then presented and it continues with a discussion of the findings. The paper concludes with the significance and originality of the proposed framework.

2. Literature review

2.1. Theory of justice

The political philosophy literature has long discussed the idea of justice. In the traditional practice of transportation planning, evaluation of transport plans is based on the utilitarian perspective of cost-benefit analysis. The utilitarian perspective addresses the issue of fairness in form of effective and efficient movement of people (Cervero, 2001; Shiftan et al., 2007). The libertarian perspective follows a similar path but instead of prioritising the well-being over individual rights, it gives priority to an individual's liberties. This prioritisation comes at the expense of the social welfare of the same communities (Kymlicka, 2002).

Traditional transport planning approaches have been criticised that they fail to measure justice. These criticisms can be found in both political left and right views. Marxists deny that a genuine progress toward justice can be made under capitalism (Fainstein, 2017, p. 135) because net effects of everyday operations and decision making tend to lead consistently to the redistribution of real income in favour of the rich (Soja, 2010, p. 48). On the other hand, the liberal understanding of justice mostly rely on incorporating the issue of justice under the current regime. Interestingly, both ideas, sometimes, come to similar conclusions in transportation justice, though from different ways of analysis. The notion of the right to the city is central to the left criticism of justice (Harvey, 2008; Lefèbvre, 1991; Soja, 2010). From the transportation perspective, the right to appropriation, which includes the right of inhabitants to physically access, occupy, and use urban space, is embedded in the right to the city (Capron, 2002; Isin & Wood, 1999; Lamb, 2002; Purcell, 2002; Salmon, 2001). Since transit system is a mean to provide access to public space, it should be available to everyone as a precondition for participation in urban life.

The liberal understanding of justice centres are around: a) Rawls' (1971) “Theory of Justice” which argues that policy settings should be based on how they affect the least fortunate and b) Human capability theory (Basta, 2016), as an extension to Rawls' theory, which explains freedom and opportunities available for individuals (Martha & Nussbaum, 2011). In the context of transportation, therefore, a minimum level of accessibility provided by a transit system is a capacity and should be provided to the most disadvantaged population of a city as a necessity for people to satisfy their needs.

Several recent studies consider how to include the concept of justice within transport policy settings. Martens, Golub, and Robinson (2012) explore principles for determining an ethical distribution. Even though Rawls' theory has been influential to transportation planning (Pereira, Schwanen, & Banister, 2017; Van Wee & Geurs, 2011), Martens does not find Rawls' idea useful because of its transcendental nature. Based on Walzer's (2008) sphere of justice theory, Martens recommends maximising average accessibility subject to a constraint on the maximum allowable range between the most and least well-off. Later, Martens (2016) expands his theory of justice in transportation based on Dworkin's theory on equality of resources. He concludes a fair transportation system provides all persons with a sufficient level of accessibility under most, but not all, circumstances. Similarly, Pereira et al. (2017) incorporates “sufficientarianism” perspective in transportation planning but combines it with Rawlsian “egalitarianism”. From Pereira's perspective, a just distribution of transportation benefits should take into account the minimum standards of accessibility and prioritise disadvantaged groups. Lucas et al. (2016) follow the same path using Gini coefficients and accessibility thresholds as the measures.

One of the key concerns here is that the transportation justice theories routinely ignore the inherently spatial dimension of the human condition (Dikec, 2001; Marcuse et al., 2009; Soja, 2010). Soja (2010), in seeking for spatial justice, expands the social justice theory by adding spatial dimension. Space is not, in Soja's view, an “empty void”, but instead is “filled with politics, ideology, and other forces shaping our lives”. Therefore, in the context of transit planning, the spatiality of distribution of accessibility is crucial when investigating the social justice in transit systems.

2.2. Transit accessibility

From a more classical point of view, accessibility can be understood as the ease of reaching desired destinations given a number of available opportunities and intrinsic impedance to the resources used to travel from the origin to the destination. Usually, opportunities are measured in terms of employment positions, and impedance in units of distance or time (Dalvi, 1978; Handy & Niemeier, 1997; Hansen, 1959). In the context of transit planning, the distinctively important benefit of a transit system is the accessibility it confers to persons (Dodson et al., 2016; Levine & Garb, 2002; Martens, 2016; Vigar, 1999). Transit accessibility, by linking to places and people, indicates the ability and freedom of choice (Talen, 2001). In this understanding of accessibility, the notion of the right to the city (Harvey, 2008; Lefèbvre, 1991) and the concept of human capabilities (Martha & Nussbaum, 2011; Sen, 2009) are closely allied.

During the last decade, a burgeoning body of research has addressed the issue of social indicators and transit accessibility (for a review of measures see: A. M. El-Geneidy & Levinson, 2006; Geurs & van Wee, 2004; Handy & Niemeier, 1997). In most of these studies, the positions of the advantaged and disadvantaged groups tend to go hand in hand with high levels of income and wealth and the spatial segregation is associated with the spatial mismatch between jobs and residents. Lojkine (1972), for example, argues that urban policies tend to increase distances between working-class jobs and housing, an issue potentially compounded by inequitable access to transportation systems. Harvey (1973) mentioned transport facilities as a need in terms of reaching other services and more importantly the job market. Ihlanfeldt and Sjoquist (2000) argued that history shows minority populations are most affected by job and housing discrimination. Åslund, Östh, and Zenou (2010) present a longitudinal analysis of accessibility and employment for refugees in Sweden. They found that refugees initially housed in locations with lower levels of accessibility (measured in terms of access to jobs) have lower levels of employment. From a social justice perspective, provision of access to jobs is the main principal function of transit.

2.3. Measuring transit accessibility

There is a subtle difference between transit accessibility and the accessibilities provided by other transportation modes. The main difference of transit accessibility is in its schedule. While travel time to/from transport and in-vehicle time is common between car and transit, the real test of freedom in transit relies on its spontaneity. Frequency has a direct role in the provision of freedom in transit and is the crucial variable in meeting the accessibility desires, yet, as Walker (2011) argues, the frequency is oddly invisible. Transit must exist in both space and time thus it must run not just where we need it but also when we need it. Unless it does both, it does not exist for us at all.

This spontaneous nature of transit accessibility has made it more difficult to calculate. A large body of literature focuses specifically on measuring transit accessibility (O'Sullivan, Morrison, & Shearer, 2000). These studies often use isochrones for measuring transit accessibility.

An isochrone is a polygon showing the area that can be accessed using a transit system given a certain starting point. Two GIS tools commonly used to compute transit based isochrones. The first is the AddGTFStoNetwork developed by ESRI (Morgan, 2016). Examples of publications using this tool include Fransen et al. (2015) and Widener et al. (2015). The second is Open Trip Planner (OTP) developed in 2009 by TriMet, Oregon's transport agency (TriMet, 2009). Examples of publications using this tool include Boisjoly and El-Geneidy (2016), El-Geneidy and Levinson (2006), and Manaugh and El-Geneidy (2012). The Esri tool does not return access/egress time, wait-time, number of transfers, or walking between transfers, while the OTP tool allows restricting these parameters to limit the possible destinations, it still cannot provide the average wait time for a transit service. To overcome this limitation, studies tend to create isochrones for every few minutes of the analysis period and use the average accessibility which is computationally intensive and requires some programming skills.

2.4. Theory of proposed framework

The little conceptual clarity about what justice means in transit planning makes it difficult to obtain insights for informing policy decisions. Justice in utilitarian perspective (orange line in Fig. 1) is defined as maximum accessibility (utility) for everyone. However, the capitalist formulation, as Harvey (1973) describes, results in better service in reality for high-income urban areas. The sufficientarianism perspective (red line in Fig. 1), aims for a minimum accessibility. This view can be problematic because a transit service can improve the minimum accessibility but the real meaningful benefits could happen in high-income areas. According to Soja (2010) "service provision almost always favoured the wealthier residents even in the name of alleviating poverty". The Rawlsian egalitarianism perspective (blue line in Fig. 1) aims to provide better services for the least well-off population. The main objective is to balance the free market tendency to exclude these areas from accessing the opportunities a city provides. While, in this view, the "lowest" income groups can potentially benefit from a good service, the other relatively low-income groups are still at risk of transit inaccessibility.

To address this gap, an extension of Pereira et al. (2017) and Martens (2016) justice theories in transportation has been adopted for this paper. The combination of egalitarianism with sufficientarianism is a good match for a justice framework in transit planning (green line in Fig. 1) under four rules. First, the people's right to the city should not be violated or sacrificed by excluding them from transit services. Second, from the sufficientarianism perspective, a minimum level of accessibility and income has to be defined to identify low-accessible and low-income areas in a city that need to be prioritised for transit services. Following Martens (2016) this can be done through a just process of decision making. The combination of these two variables are also important to control for the self-selection issues. Third, from egalitarianism perspective, some level of inequality is inescapable, therefore, the provision of accessibility across entire distribution should benefit the least well-off groups and thereby mitigate morally arbitrary disadvantages that systematically reduce their accessibility levels (Lucas, 2012; Páez et al., 2010). Finally, following Soja (2010), a just distribution has to be spatially evaluated to identify the clusters of transit-deprived areas. This distribution of transit accessibility has to be analysed spatially at city or region level to factor in the integration of different services in a transit system.

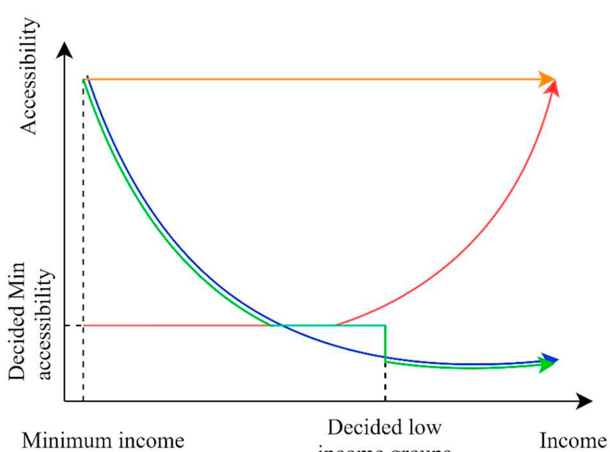

Fig. 1. Comparing the relationship between accessibility and income under different theoretical frameworks. Orange shows ideal equality where everyone has high accessibility. Blue shows egalitarianism views where low income received better accessibility. Red shows sufficientarianism views where the focus is only on provision of a minimum level of accessibility. Green shows the proposed combined egalitarianism and sufficientarianism views. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The proposed framework extends Rawls transcendental theory by the Sen's (2006) comparative approach to justice. The focus of this paper is on ranking the distribution of transit services for being less or more just rather than defining the perfect just arrangements. Moreover, the proposed framework contrast from Rawls by giving the same priorities to all transit-deprived "low-income and low-accessible" areas. The main objective is to ensure that a transit service provides a better accessibility to aforementioned priority areas. The proposed framework also extends Martens sufficientarianism perspective by adding the travel time dimension. The acceptable travel time by transit should be decided through a democratic and just process of decision making along with the minimum levels of accessibility and income. The proposed framework also contrasts from non-spatial indicators such as the Gini Index which is widely used for evaluation distribution of transit accessibility (Lucas et al., 2016).

3. Background of case study cities

Auckland is competing internationally to attract investments, skilled people, and businesses. However, growing social and infrastructure inequalities have contributed to Auckland's economic underperformance and adversely affected its international competitiveness (Auckland Council, 2012). To evaluate the performance of Auckland's transit system, it was compared to three other cities: Brisbane, Perth and Vancouver. All four cities have similar urban morphological periods for a comparative study. This comparison can potentially help Auckland to learn from transit systems in other similar cities. The case study cities have > 1 million population, have open census and transit data, have a recent (after 2011) downloadable transportation plan, and have considered the issues of social justice in their planning policies (Auckland Council, 2012; Brisbane City Council, 2008; State of Western Australia, 2011; Vancouver City Council, 2012).

One of the issues in a comparative study is the consistency of data. To enable a consistent comparison between cities, only the continuous urban areas for each city were analysed. This excludes a relatively small number of people living in rural areas and satellite cities. The analysis has been done based on Open Street Map (OSM) data by delineating densely clustered arrangements of the street network. Fig. 3 shows the map of transit services by mode and urban limits in the case study cities. Table 1 includes a summary of key statistics based on the continuous urban areas for each city.

Three high-level features of these cities urban forms and transport networks are noted. First, Auckland has the lowest population and the smallest urban footprint in these four cities. Brisbane/SEQ's is twice as large, Vancouver's is 70% larger, and Perth's is 25% larger. As a result, Auckland simply has fewer jobs to reach, and smaller average distances to travel to reach them. Second, despite the fact that all these cities are known for decades of low-density car-oriented development,

Table 1
Summary statistics for case study cities.
Source: Auckland 2013 census (Statistics New Zealand, 2013), Australia 2016 census (Australian Bureau of Statistics, 2011), and Canada 2011 census (Canada Statistics, 2011).

City	Population (millions)	Jobs (1000s)	Land area (km^2)	Service-km	Service-hours	Service-km per km^2	Service-hours per km^2	Transit mode share
Auckland	1.35	528	15960	306607	8138	19	0.51	7.4%
Brisbane/SEQ	2.71	1178	41951	1643591	12727	39	0.30	13.5%
Perth	1.70	723	25999	507622	9689	20	0.37	11.6%
Vancouver	2.32	1001	18014	735413	12507	41	0.69	14.08%

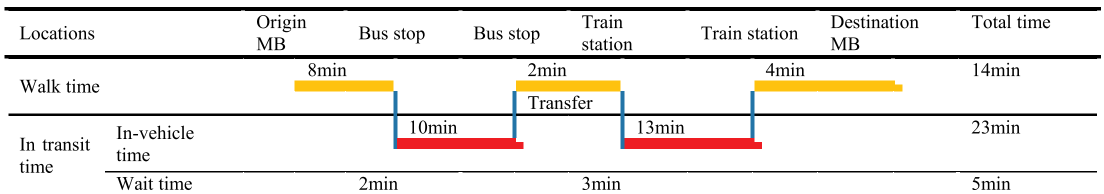

Fig. 2. Hypothetical 42 minute journey between two TAZs.

population densities vary considerably between them. Vancouver has the highest population-weighted density (82 people per hectare), while Perth has the lowest (29 people per hectare). This is important as a city's compactness can affect transit ridership and accessibility. Third, different cities offer different levels of transit services per square kilometre. Auckland and Perth have relatively 'sparse' networks, with an average of 19 and 20 transit service kilometres per km^2. The two other cities have around twice as much transit services per km^2. This is important as the quantity and quality of services influences accessibility outcomes.

The analysis of transit services in the case study cities show that transit is mostly utilised in the morning peak period. Therefore, this study focuses on transit-based job accessibility in morning peak (from 7 to 9 am) as a proxy to measure fairness in transit services. The focus of this study on transit-based job accessibility in the morning peak does not mean that access to other city's spaces and opportunities – such as education and health – and transit's off-peak and evening peak services are not important. On the contrary, in a functioning transit system, trade-offs should provide the best possible services for a maximum range of opportunities. The main reason is simplification due to the limitation of resources available.

4. Method and data

This section introduces the data used to analyse the case studies by adopting the framework.

4.1. Accessibility framework

The proposed accessibility framework adopts the cumulative-opportunity, or potential, approach and sums the number of essential destinations reachable within certain times by transit (Wachs & Kumagai, 1973; El-Geneidy & Levinson, 2006). This measure is particularly useful in describing how well transportation networks perform in relation to the distribution of destinations. Despite the advantages of running on open data and open source software, this method faces two important limitations. First, it is sensitive to assumptions such as the size of Traffic Analysis Zone (TAZ). Second, it does not take competition effects into account (Geurs & van Wee, 2004). The proposed framework can be used to compare transit systems by selecting cities with similar urban characteristics.

A cumulative-opportunity accessibility measure is used for each TAZ by summing the total number of destinations (jobs) reachable by transit. It is intuitive that jobs that are located "near" are more accessible than jobs located "far". However, accessibility depends greatly on travel cost which can vary for different people. Transit fares play an important role, and people differently value each trip legs (access, waiting, in-vehicle, transfer, and egress time). Ideally, the connection between two TAZs should be monetised by considering all these factors. The contextual nature of the monetising factors, however, can complicate the accessibility analysis and jeopardise the objective of this research for its applicability in different jurisdictions. Studies show a strong linear relationship between travel time and travel cost (e.g. Mathisen, 2006, p. 5), therefore travel time has been used as a proxy for travel cost to demonstrate the simple use of the proposed framework. Moreover, the distance decay function fuzzifies the edges of accessibility isochrone minimising the potential issues. This assumption does not preclude the modelling techniques to utilised more advance travel costs. More advanced travel cost functions can be most useful when comparing different scenarios in the same context.

Different range of acceptable distance to jobs can result in different levels of accessibilities, therefore, various accessibilities have been calculated based on varying the travel times from 20 to 60 min. It is generally agreed that the reduction in accessibility levels by distance do not follow a linear shape. Studies show that s-shape distance decay function performs better in transit accessibility analysis (Bocarejo & Oviedo, 2012; Halás, Klapka, & Kladivo, 2014). The accessibility available to each TAZ is defined by the Eq. (1), the distance decay function.

$$A_i = \sum_{j=1}^{N} \frac{1}{(1 + \exp(\beta_1(t_{ij} - \beta_2)))} E_j \tag{1}$$

where, A_i is the total accessibility available to TAZ_i, E_j is the number of jobs available in TAZ_j, the parameter β_1 controls the steepness at which $f(t_{ij};\beta)$ decays with t_{ij} and β_2 defines the mid-point, that is, when $f(t_{ij};\beta) = 0.5$, this variable can change from 20 to 60 min. Fig. 2 illustrates the various travel time components for a hypothetical 42-minute journey between two centroids of TAZs based on an average walking speed of 4.8 kph,[1] wait-time, and in-vehicle time. While the walking time and in-vehicle time are the same for a transit service, independent of the time of the trip, the wait time can be different depending on the journey's start time. Therefore, as noted by El-Geneidy et al. (2015), transit accessibility can vary for a fixed travel time. To address this

[1] Several studies (e.g., Bohannon, Andrews, & Thomas, 1996; Dewar, 1992; Knoblauch, Pietrucha, & Nitzburg, 2007) report average walk speeds between 4.51 and 5.43 km/h.

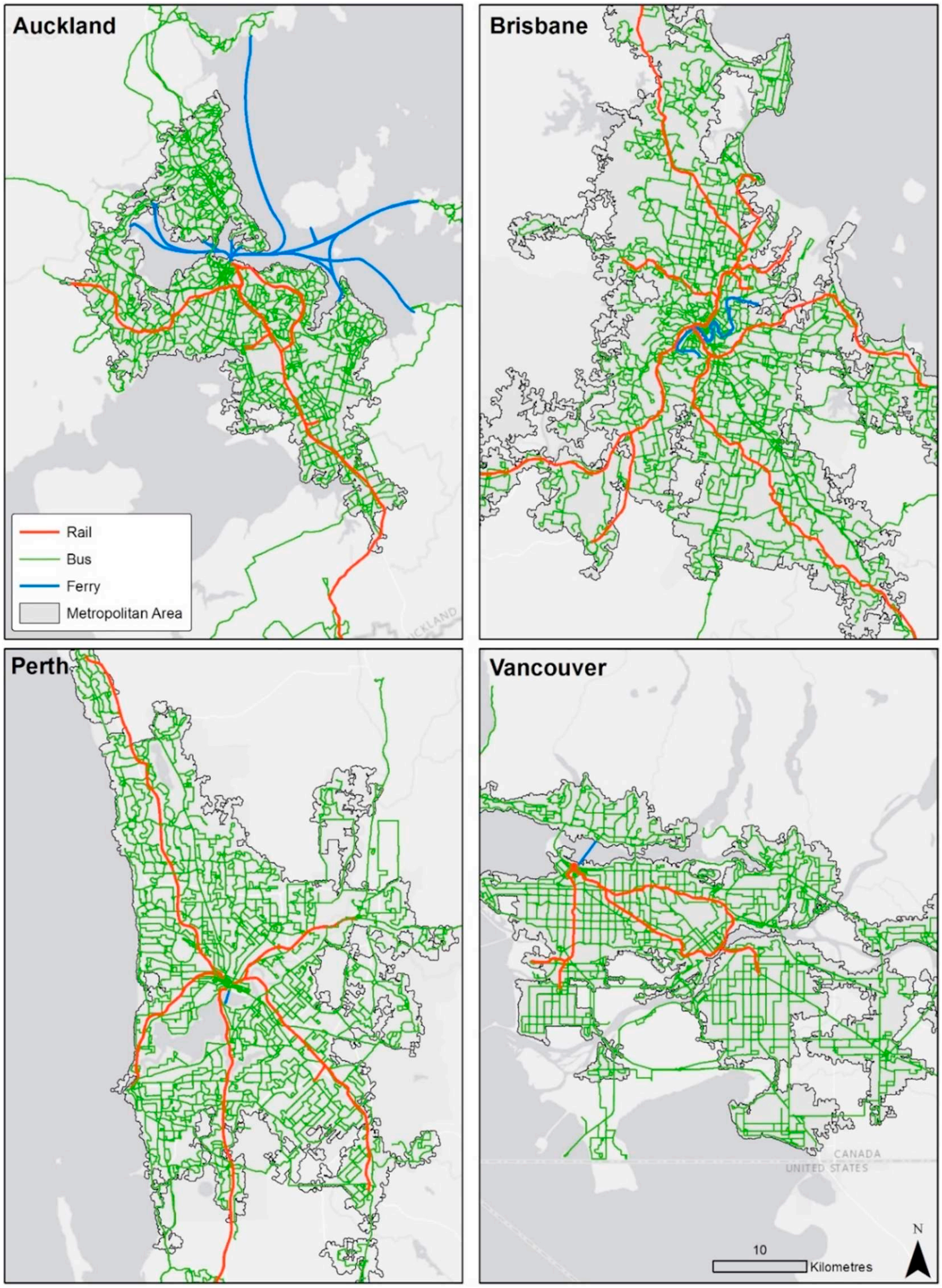

Fig. 3. Map of transit services in case study cities showing bus, rail, and ferry routes.

issue the wait time is replaced with half of the headway (based on the analysis period) for the transit services with the similar path. This method removes the randomness of the isochrones based on travel time start time which is more relevant and significantly reduces computation time.

4.2. Census data

Census data is the main open data available for population and place of work. Despite the wide use of census data in accessibility research, this data has some important limitations. First, as measures of employment are derived from census journey to work data in Australia and New Zealand, excluding people working from homes and people who did not travel to work on the census day, they represent an undercount relative to other sources of data such as labour force surveys and payroll tax data. This is likely to influence the level of the estimates of the number of jobs that can be accessed from any given point. As census data provides the most detailed geographic information on the location of employment, it was used in spite of this limitation.

Second, in dense urban areas, a meshblock or dissemination block is

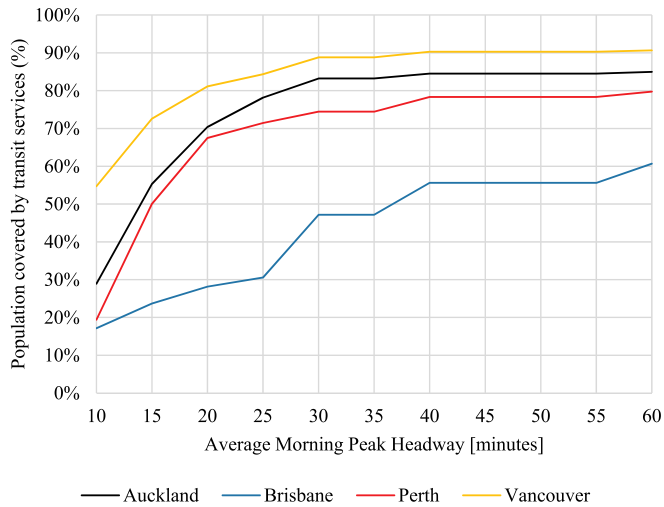

Fig. 4. Percentages of inaccessible areas in the case study city by travel times from 20 to 60 min.

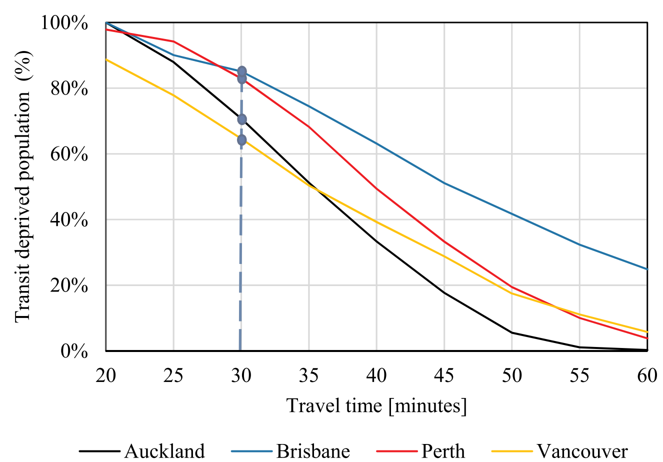

Fig. 5. Changes in transit-deprived population (percentile) for travel times from 20 to 60 min.

approximately equivalent to an urban block, but they tend to become larger in areas with lower population densities.[2] Meshblocks and dissemination blocks are roughly comparable in size between all countries. There is more variation in size among the area units, DZNs, and DAs that are used for employment data, but overall, the accessibility results are sensitive to boundary effects and the size of census zones. In order to make different levels of spatial aggregation of census data consistent and comparable, the finest grain census data is rescaled into 2 km^2 hexagon mesh (Hex). The rescale is calculated by the Eq. (2).

$$CV_i = \sum_{j=1}^{n} (P_{ij} \times CV_j) \tag{2}$$

where, CV_i is the census variable at the hexagon i, n is the numbers of census areas that intersects with hexagon i, P_{ij} is the proportion of the census area j that falls into the hexagon i, and CV_j is the census variable of the census area j.

[2] DZNs tend to be larger in areas with lower employment density. Consequently, DZNs tend to be smaller in city centres than in predominantly residential areas.

4.3. Disadvantaged groups

In a theoretical framework, the income is the basic metric for identifying the least-advantaged members of society. For this study, the disadvantages are measured using the median income of the census zones. The median income at census zones has been rescaled to Hex level based on the weighted average formula described by Eq. (3):

$$I_i = \frac{\sum_{j=1}^{n} (MI_j \times P_{ij} \times Pop_j)}{\sum_{j=1}^{n} (P_{ij} \times Pop_j)} \tag{3}$$

where I_i is the weighted average of median income at the hexagon i, n is the numbers of census areas that intersects with hexagon i, P_{ij} is the proportion of the census area j that falls into the hexagon i, MI_j is the median income of the census area j, and Pop_j is the population of the census area j. The concentrations of low-income households were checked for all the case study cities. Getis-Ord tests reject the null hypothesis of no clustering in the spatial distribution of the low-income population (p-value < 0.01), which is consistent with the segregation of households based on their income.

4.4. The relationship between income and transit accessibility

The final step is to statistically test the relationship between the level of income and the level of transit accessibility in case study cities. It is well known that transport and land use patterns have a mutual impact on each other (Páez & Scott, 2005). Therefore, the transit accessibility of one TAZ can be spatially affected by the neighbouring TAZs. As discussed rescaled census units into 2 km^2 hexagon mesh (Hex) has been used in this study as TAZs. To control for the spatial autocorrelation in the data, a spatial regression model is used.

In order to understand how transit accessibility responses to a change, a constant elasticity model has been used where the natural log of variables has been used. The baseline regression model at Hex level without the spatial autocorrelation control is described at Eq. (4).

$$log(A) = \beta_0 + \beta_1 log(Income) + \beta_2 log(PD) + \beta_3 log(Job) + \varepsilon_i \tag{4}$$

where, A is the level of PT accessibility, *Income* is the average household income, *PD* is the population density, and *Job* is the job density. The coefficients β_1 of $log(Income)$, for example, is the estimated elasticity of A with respect to *Income*. It implies that a 1% increase in income increases PT accessibility by β_1%. Similar interpretation goes for β_2 and β_3.

It is important to note that the focus on transit does not imply that all commuters actually use transit. Instead, the accessibility provided by transit to residents is measured based on the locations of their home and work, regardless of their actual selected mode. In this way, the potential benefit that the current system offers is measured. The spatial autocorrelation underlying the baseline regression model is based on the spatial lag regression which is the standard method in literature (Elhorst, 2010; LeSage, 2008). Two Hex are a neighbour in this model if they share a boundary.

4.5. Data sources

Several sources of data on existing transport networks, population and employment locations were used. First, Open Street Map (OSM) has been used to model walking network geometry (e.g. street segments, stairs, restrictions and shortcuts). Second, General Transit Feed Specification (GTFS) data is used to model travel times and distances on transit networks. A GTFS feed comprises of a series of text files, where each file models one particular aspect of the system (for full description see Google, 2015). This study uses GTFS data valid for Thursday 22 February 2018. Third, population and employment data has been sourced from national statistics agencies at a highly disaggregated geographic level. For Auckland, the Census 2013 data from the

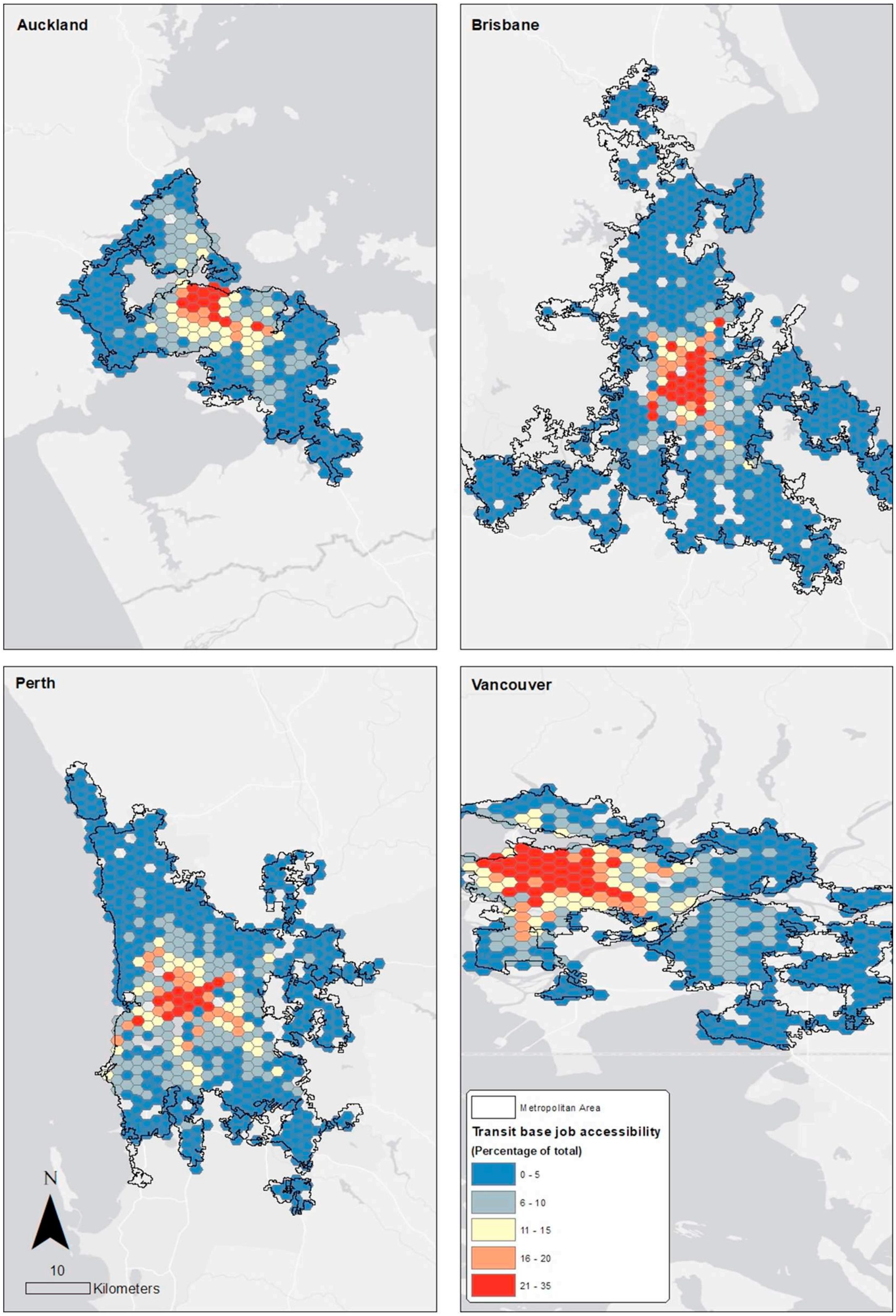

Fig. 6. Transit based job accessibility based on distance decay function for 30-minute travel time. The areas in dark red show the areas with the highest percentage of jobs accessible to them and areas in dark blue show the areas with the lowest percentage of total jobs accessible to them. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

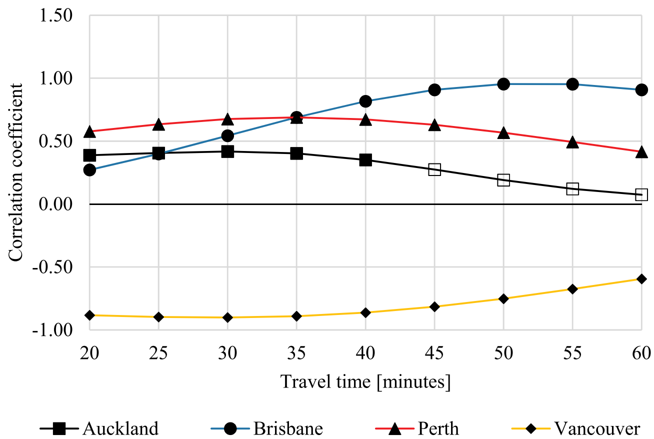

Fig. 7. Coefficients changes for different travel times in the case study cities. Solid markers indicate statistically significant coefficients (sig < 0.05).

Statistics New Zealand at the meshblock (MB)[3] level for population and employment is used. In Perth and Brisbane, population data is available at the meshblock (MB)[4] level and the employment data is available at Destination Zone (DZN)[5] level from the Australia 2011 census. In Vancouver, 2011 census population data is available at Dissemination Block (DB) level and employment data from the 2011 National Household Survey is available at Dissemination Area (DA)[6] level.

5. Results and discussion

The analysis in this paper reflects the justice rules discussed in Section 2.4. Under this framework, four rules are introduced to evaluate justice in a transit network. These rules are not absolute which means they are valid only in a comparative study. In other words, no transit system is perfectly just, they can be comparatively more or less just. The following sections present a proper quantitative analysis for each rule and the interpretations of their results.

5.1. Rule 1 – the right to access transit

The first rule of justice in a transit system is to include all urban inhabitants or as Lefebvre describes “citadins”. The orange line in Fig. 1 represents this ideal situation where everyone equally enjoys high accessibility in a city. In reality, however, no cost-effective mass transit system can provide high accessibility to all opportunities. As discussed in Section 2.4, following Lefebvre notion of the right to the city, the citadins have the right to physically access, occupy, and use the urban space. Therefore, in the context of transit planning, people's right to the city should not be violated or sacrificed by excluding them from transit services. This is the focus of the first rule of transit justice.

Fig. 4 shows the coverage area of the morning peak services for the case study cities based on 800-metre catchments around transit stops. Since a transit system cannot provide high frequency (low headway) services to all residents, the coverage of transit system increases as the headways of services increases. Vancouver performs best with the highest percentage of population coverage for all range of transit services (from 10 to 60 min headways) and Brisbane's coverage is the lowest. Even including the very low-frequency service of one service every hour, 40% of Brisbane's population do not have access to transit. This number for Perth, Auckland and Vancouver is 20%, 15% and 9% respectively. The areas with absolutely no transit services are obvious locations for planners to prioritise for transit investments but it is only the first step. The proposed investments are required to be alight with the remaining three justice rules.

5.2. Rule 2 – minimum transit accessibility

The second rule of justice in a transit system follows the sufficientarianism perspective to provide the residents with a minimum level of accessibility for a decent lifestyle. The red line presents this rule in Fig. 1. Only including people in transit (as described in the first rule of justice) is not useful unless the services take people to their desired destinations, which is the objective of the second rule of justice. As discussed, the minimum accessibility can be decided through a just and democratic process of decision making. In this paper, for ease of comparison, access to 10% of total jobs is used as a reference for minimum accessibility, however, this could be changed depending on the contextual political views.

The four maps for each of the study cities are shown in Fig. 6 illustrating a snapshot of access to jobs by transit within 30 min of travel time. Note that they are on the same scale, allowing for easy comparisons between each city. Based on this snapshot, 13% of Auckland's and Perth's urban area have access to > 10% of the jobs. This number for Brisbane and Vancouver is 8% and 19% respectively. While these numbers give some insights about the accessibility in the cities, it is limited in two important ways. First, this type of accessibility maps cannot easily illustrate overall average accessibility as it presents the areas and not the population living in those areas. Second, it is important to go beyond a fixed travel time because the level of accessibility can change dramatically for different of travel times.

Fig. 5 further synthesises these results, by plotting the percentile of people who have access to < 10% of jobs (vertical axis) to different transit journeys from 20 to 60 min (horizontal axis). In Vancouver, 65% of the city's population has access to < 10% of jobs by a 30-minute transit journey (shown by dashed line). This number increases to 71% for Auckland, 83% for Perth and 85% for Brisbane. Auckland performs better than all other case study cities for 40 min and higher travel times. The results show transit poverty is 6% for a 50-minute travel time in Auckland while it is 42% for Brisbane.

As discussed in Section 2.3, commonly, current analysis of sufficient transit accessibility focuses on a fixed travel time. By including a range of travel time from 20 to 60 min, sufficient accessibility cannot only be decided by the minimum level of access to jobs but also by the acceptable travel time envisaged to reach jobs. As it is shown in Fig. 5 the level of transit-deprived population is sensitive to what is decided as an acceptable travel time.

5.3. Rule 3 – better accessibility for low-income

The third rule of justice in a transit system follows egalitarianism to prioritise low-income neighbourhoods. The blue line presents this rule in Fig. 1. Under this rule, the investment for transit infrastructures should focus on improving the accessibility in low-income areas. This rule rectifies the potential flaw in the second rule of justice (sufficientarianism) where the investment under the name of improving low-income areas could mainly benefit the high-income areas. The relative percentage change between accessibility and income can be generated

[3] A meshblock is the smallest geographic unit for which Statistics New Zealand collects statistical data. Meshblocks vary in size, from part of a city block to large areas of rural land. Area units are slightly larger – in urban areas they generally cover part of a suburb.

[4] Mesh blocks are the smallest geographic region in the Australian Statistical Geography Standard (ASGS), and the smallest geographical unit for which Census data are available.

[5] The DZNs were developed by the individual state or territory governments' Transport authorities for the analysis of commuting patterns and the development of transport policy. DZNs are built from Mesh Blocks and aggregate to a subset of the ASGS regions.

[6] Dissemination area is a small area composed of one or more neighbouring dissemination blocks and is the smallest standard geographic area for which all census data are disseminated.

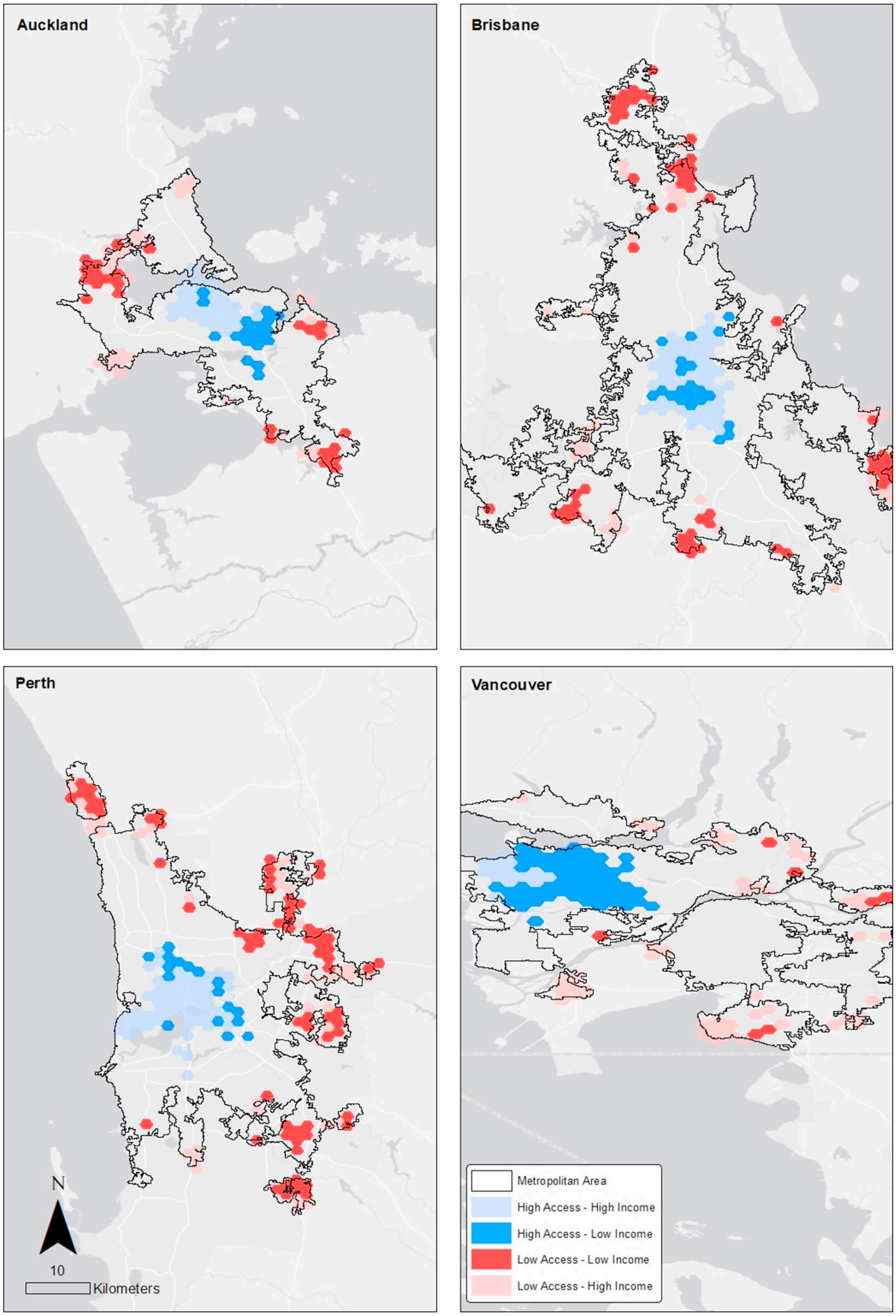

Fig. 8. Bivariate LISA based spatial clusters showing the local relation between household income and transit accessibility (sig < 0.05). (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

using a constant elasticity model. The positive coefficients of *log*(*Income*) implies that increase in income increases the level of accessibility, which is against the third rule of transit justice.

Fig. 7 shows the standardised coefficients of accessibility and income in Auckland and other case study cities for a range of travel times between 20 and 60 min. It is evident that Vancouver transit services benefit the low-income neighbourhoods contrary to Auckland, Brisbane, and Perth. Using the spatial lag model decreases the value and significance of the elasticities by factoring in the spatial autocorrelation, however, the general trend remains the same. Table 2 summarises coefficients for the regression analysis for 45 min travel time accessibilities. It shows that a 10% increase in income in Auckland, Brisbane

Table 2
The coefficients estimates of spatial lag model case study cities showing the relationship between 45-minute transit accessibility and median income.

Dependent variable: log(ratio)	Auckland	Brisbane	Perth	Vancouver
Intercept	0.621*** (0.933)	1.381*** (0.869)	3.649*** (0.791)	10.793*** (1.263)
Log(income)	0.057 (0.076)	0.274** (0.116)	0.087 (0.102)	−0.527*** (0.109)
Log(population density)	0.042*** (0.015)	0.083*** (0.029)	0.047** (0.023)	0.043** (0.021)
Log(employment density)	0.049*** (0.012)	0.310*** (0.032)	0.279*** (0.022)	0.239*** (0.024)
Rho (stpatial lag)	0.832	0.470	0.448	0.388
Number of observations	315	657	542	468
R2	0.783	0.608	0.668	0.614

Notes: Standard errors in parentheses, ***P < 0.01, **P < 0.05, *P < 0.1.

and Perth increases transit accessibility by 0.57%, 2.74%, and 0.87% respectively; this value is −5.52% for Vancouver (ceteris paribus).

The sensitivity to the defined travel time impacts the relationship between income and accessibility. As illustrated in Fig. 7, the trend of changes in coefficients over different travel times shows Auckland and Perth both provide better services for high income in shorter trips, but this coefficient reduces for longer trips. This means high-income people occupy prime locations near employment hubs but the suburbs further away from these hubs more or less receive a neutral service. On the contrary, Brisbane provides better services for high income and the coefficients even increase for longer travel times. Vancouver is the only city with a negative relationship between income and accessibility. Interestingly, transit services in Vancouver target low-income areas to provide high-quality services regardless of their location and distance to employment hubs. This has resulted in a negative coefficient meaning the high-income areas are receiving not as good services as the low-income areas. The coefficients, however, are less significant for longer trips. Generally, Auckland, Brisbane and Perth provide better service for high income while Vancouver's transit system targets the lower income areas.

5.4. Rule 4 – spatiality of a just distribution

The fourth rule of justice in a transit system is the spatiality of a just distribution. Even though the spatial factor has been included in the other three rules, it is important to specifically identify the priority areas for better transit services. Adding the spatial dimension combines and extends the previous three rules of transit justice. This combination is presented by the green line in Fig. 1. For a just transit system, areas with the combination of low accessibility and low-income should be prioritised for improvements. Prioritising these areas can fill the gaps that egalitarianism perspective on Rule 3 could potentially ignore and also factors in the self-selection issues.

The decision of drawing a line for minimum levels of income and accessibility is beyond the scope of this paper as fits into just processes and not outcomes. However, identifying the clusters of low-income and low-accessible areas can reveal areas for improvement for transport planners. This high/low classification of clusters is defined based on the mean of each variable.

Fig. 8 shows the bivariable cluster maps of the local relationship between income and accessibility levels for 30 minute travel time, significant at 95% level of confidence. Hex in dark red are high priority areas for transit investments. They show where low-income households cannot access the job market. These areas are important because they can generate a poverty cycle where inaccessibility can lead to unemployment and poverty, and poverty can prevent the residents from moving out of these areas.

While clusters of "low income-low accessibility" areas can be seen in all case study cities, Vancouver performs much better comparatively. The map for Brisbane and Perth shows clusters of low-income low-accessibility areas and similar for the eastern, southern and western areas in Auckland. These results are again sensitive to the travel time. As a general rule of thumb, the transit-deprived areas start to shrink by increasing the travel times, though with a different rate for each city.

6. Conclusion

Reducing the socio-spatial inequalities in a transit system is a challenge for many cities, and the priorities are not obvious sometimes. A review of the literature shows that the concept of justice is not clearly defined in transit planning. In this research, a framework is proposed to define transit justice. The aim of the proposed framework is to diagnose the problem of justice in a city's transit system and allow comparison among cities to assist policymakers in setting benchmarks for their transit system. Under the proposed framework, accessibility is understood as the distinct benefit of a transit system and a dialogue between the egalitarianism and the sufficientarianism perspectives is built to understand spatial distribution of accessibility. A just distribution, therefore, should be evaluated spatially to protect people's right, provide a minimum accessibility, and prioritise vulnerable groups.

The proposed framework advances the existing literature in four related areas. *First*, the framework extends and combines the existing egalitarianism with sufficientarianism theories of justice. Most importantly, it highlights the sensitivity of a just pattern to different travel times which is mostly overlooked in the literature. It is recommended that an acceptable travel time has to be decided through a democratic and just process of decision making. *Second*, this methodology is spatial therefore historical and temporal analysis of transit accessibility are extended by their spatial dimension. The case study cities, for example, involve 1667 zones combined. *Third*, the methodology is validated, in that, its conclusions are based on measures of statistical significance. *Fourth*, the method is flexible, as it can model a range of transit infrastructure. The method relies on open data commonly available in different cities allowing the results to be comparable between jurisdictions. Each of these aspects has been explored to some extent previously, however, the combination and its application to transit systems is novel.

This framework was applied to four cities, Auckland, Vancouver, Perth, and Brisbane. The findings showed that Auckland performs well to include residents and provide a minimum service, the overall trend in the distribution does not favour low-income areas. Auckland, Perth, and Brisbane provide a better service for short journeys, which benefit those who live in the prime locations close to major employment areas. Auckland and Perth show a reduction but still a positive relationship between accessibility and employment as the travel time increases, i.e. poor service but relatively less different for those with low-income (who typically live in the outskirts of the city). In Brisbane, however, this relationship increases continuously which can be interpreted as a sign of discrimination in transit services. Vancouver is an exception with a continuous negative relationship, meaning it provides a better service for low-income for both short and long journeys. In Auckland, the clusters of low-income and low-accessible (LL) zones in the east, south and more severely in west with poor accessibility indicate where improvement is required for the transit services. Perth and Brisbane seem to suffer the same issues but Vancouver does not show any clusters. In summary, a city that performs best in all four rules of justice can claim to have a just transit service. Based on the analysis results, Vancouver can be a role model for transit planning in Auckland.

Notwithstanding these advantages, the method is not without its limitations. A potential limitation is that the methodology does not include the demand for transit. This is not considered to be a fundamental problem for two reasons. First, this issue is common to most accessibility analyses as they consider potential rather than existing demand. Second, analysing existing transit demands requires access to ticketing data, with all of the associated confidentiality issues. For these reasons, it was considered reasonable to focus on measures of accessibility, rather than existing demand.

The idea of justice in transit systems unavoidably deal with normative discussions about "what is just?". The framework developed in this study can assist decision-makers to: (a) diagnose any issues related to justice in their transit system; (b) understand their priorities; and (c) find other transit systems to learn from. The type of data used to analyse the case study cities are usually freely available for other cities. The codes developed for this study are open source and can be downloaded from GitHub (link provided in Section 7). Therefore, all the graphs and maps presented in this study can be replicated for many cities around the world. It is expected that the developed framework will assist practitioners in obtaining insights that can inform policy decisions. This is a key step to start a democratic and just process to respond to issues of inequalities and discrimination. The paper encourages further research to develop the model by including other modes (such as cycling, and rideshare, as means to reach transit stops and stations), different time spans (such as all day, pm peak, and interpeak), and specific job categories (such as industrial, office, service jobs).

7. Open source link

https://github.com/saeidadli/TransitJustice.

References

Åslund, O., Östh, J., & Zenou, Y. (2010). How important is access to jobs? Old question—Improved answer. *Journal of Economic Geography, 10*(3), 389–422.

Auckland Council (2012). *Auckland plan.* Auckland: Auckland Council.

Australian Bureau of Statistics (2011). 2011 census. Retrieved from portal.abs.gov.au.

Basta, C. (2016). From justice in planning toward planning for justice: A capability approach. *Planning Theory, 15*(2), 190–212 (SAGE Publications Sage UK: London, England).

Bocarejo, J. P., & Oviedo, D. R. (2012). Transport accessibility and social inequities: A tool for identification of mobility needs and evaluation of transport investments. *Journal of Transport Geography, 24*, 142–154. https://doi.org/10.1016/j.jtrangeo.2011.12.004.

Bohannon, R. W., Andrews, A. W., & Thomas, M. W. (1996). Walking speed: Reference values and correlates for older adults. *The Journal of Orthopaedic and Sports Physical Therapy, 24*(2), 86–90. https://doi.org/10.2519/jospt.1996.24.2.86 (JOSPT, Inc. JOSPT, 1033 North Fairfax Street, Suite 304, Alexandria, VA 22134-1540).

Boisjoly, G., & El-Geneidy, A. (2016). Daily fluctuations in transit and job availability: A comparative assessment of time-sensitive accessibility measures. *Journal of Transport Geography, 52*, 73–81. https://doi.org/10.1016/j.jtrangeo.2016.03.004 (Elsevier B. V.).

Brisbane City Council (2008). *Brisbane City Council transport plan for Brisbane 2008–2026. Brisbane*.

Canada Statistics (2011). 2011 census. Retrieved from http://www.statcan.gc.ca/.

Capron, G. (2002). Accessibility for "modern urban public spaces" in Latin-American cities: Physical appearances and socio-spatial pertenencies. *A conference on rights to the city, Rome, May*.

Cervero, R. (2001). In Baltes P. B. B. T.-I. E. of the S. & B. S. (Ed.). *Transportation planning A2 - Smelser, Neil J* (pp. 15873–15878). Oxford: Pergamon. https://doi.org/10.1016/B0-08-043076-7/04452-1.

Currie, G. (2010). Quantifying spatial gaps in public transport supply based on social needs. *Journal of Transport Geography, 18*(1), 31–41 (Elsevier).

Dalvi, M. Q. (1978). Behavioural modelling, accessibility, mobility and need: Concepts and measurement. In D. A. Hensher, & P. R. Stopher (Eds.). *Behavioural travel modelling* (pp. 639–653). London: Croom Helm.

Davoudi, S., & Brooks, E. (2014). When does unequal become unfair? Judging claims of environmental injustice. *Environment and Planning A, 46*(11), 2686–2702 (SAGE Publications Sage UK: London, England).

Dewar, R. E. (1992). Driver and pedestrian characteristics. In J. Pline (Ed.). *Traffic engineering handbook*(4th ed.). Englewood Cliffs, N.J.: Prentice Hall.

Di Ciommo, F., & Shiftan, Y. (2017). Transport equity analysis. *Transport Reviews, 37*(2), 139–151.

Dikec, M. (2001). Justice and the spatial imagination. *Environment and Planning A, 33*(10), 1785–1806.

Dodson, J., et al. (2016). The social meaning of access: Lessons in transport governance from cities in developed countries. In M. Lönnroth, (Ed.). *Improving urban access: New approaches to funding transport investment*. Retrieved from https://books.google.co.nz/books?hl=en&lr=&id=whveCwAAQBAJ&oi=fnd&pg=PP1&dq=improving+urban+access,+new+approaches+to+funding+transport+investment&ots=M0pkAiq9S1&sig=nxo3r1gTGGzj3ddy9oaIpDvVcJ0#v=onepage&q=improving urban access%2C new approaches to fundi, Accessed date: 25 September 2017.

El-Geneidy, A., & Levinson, D. M. (2006). *Access to destinations: Development of accessibility measures*.

El-Geneidy, A., et al. (2015). Non-stop equity: Assessing daily intersections between transit accessibility and social disparity across the Greater Toronto and Hamilton Area (GTHA). *Environment and Planning. B, Planning & Design*. https://doi.org/10.1177/0265813515617659 (p. 0265813515617659, SAGE Publications).

Elhorst, J. P. (2010). Applied spatial econometrics: Raising the bar. *Spatial Economic Analysis, 5*(1), 9–28 (Taylor & Francis).

Fainstein, S. S. (2017). Urban planning and social justice. In M. Gunder, A. Madanipour, & V. Watson (Eds.). *The Routledge handbook of planning theory* (pp. 130–142). . Retrieved from https://books.google.co.nz/books?id=blsyDwAAQBAJ (Taylor & Francis) .

Foth, N., Manaugh, K., & El-Geneidy, A. M. (2013). Towards equitable transit: Examining transit accessibility and social need in Toronto, Canada, 1996–2006. *Journal of Transport Geography, 29*(0), 1–10. https://doi.org/10.1016/j.jtrangeo.2012.12.008.

Fransen, K., et al. (2015). Identifying public transport gaps using time-dependent accessibility levels. *Journal of Transport Geography, 48*, 176–187. https://doi.org/10.1016/j.jtrangeo.2015.09.008.

Geurs, K. T., Boon, W., & Van Wee, B. (2009). 'Social impacts of transport: Literature review and the state of the practice of transport appraisal in the Netherlands and the United Kingdom. *Transport Reviews, 29*(1), 69–90 (Taylor & Francis).

Geurs, K. T., & van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography, 12*(2), 127–140. https://doi.org/10.1016/j.jtrangeo.2003.10.005.

Google (2015). *What is GTFS?* Google. Retrieved from https://developers.google.com/transit/gtfs/.

Halás, M., Klapka, P., & Kladivo, P. (2014). Distance-decay functions for daily travel-to-work flows. *Journal of Transport Geography, 35*, 107–119 (Elsevier).

Handy, S. L., & Niemeier, D. A. (1997). Measuring accessibility: An exploration of issues and alternatives. *Environment and Planning A, 29*(7), 1175–1194. https://doi.org/10.1068/a291175 (SAGE Publications).

Hansen, W. G. (1959). How accessibility shapes land use. *Journal of the American Institute of Planners, 25*(2), 73–76. https://doi.org/10.1080/01944365908978307 (Taylor & Francis Group).

Harvey, D. (1973). *Social justice and the city.* University of Georgia Press. Retrieved from https://books.google.co.nz/books?id=VCwLi2nVmooC.

Harvey, D. (2008). The right to the city. *The City Reader, 6*, 23–40.

Ihlanfeldt, K. R., & Sjoquist, D. L. (2000). The geographic mismatch between jobs and housing. *The Atlanta paradox* (pp. 116–127). New York: Russell Sage Foundation.

Isin, E. F., & Wood, P. K. (1999). *Citizenship and identity.* Sage.

Jones, P., & Lucas, K. (2012). The social consequences of transport decision-making: Clarifying concepts, synthesising knowledge and assessing implications. *Journal of Transport Geography, 21*, 4–16. https://doi.org/10.1016/j.jtrangeo.2012.01.012.

Khisty, C. (1996). Operationalizing concepts of equity for public project investments. *Transportation Research Record: Journal of the Transportation Research Board, 1559*, 94–99 (Transportation Research Board of the National Academies).

Knoblauch, R., Pietrucha, M., & Nitzburg, M. (1996). Field studies of pedestrian walking speed and start-up time. *Transportation Research Record: Journal of the Transportation Research Board,* (1538), 27–38.

Kymlicka, W. (2002). *Contemporary political philosophy: An introduction.* Oxford: Oxford University Press.

Lamb, M. (2002). Vernacular practice and the emergence of policy: An analysis of trespassing on a Brooklyn golf course. *A conference on rights to the city, Rome, May*.

Lefèbvre, H. (1991). *The production of space.* Blackwell. Retrieved from http://books.google.co.nz/books?id=SIXcnIoa4MwC.

LeSage, J. P. (2008). An introduction to spatial econometrics. *Revue d'Économie Industrielle, 3*, 19–44 (De Boeck Supérieur).

Levine, J., & Garb, Y. (2002). Congestion pricing's conditional promise: Promotion of accessibility or mobility? *Transport Policy, 9*(3), 179–188. https://doi.org/10.1016/S0967-070X(02)00007-0 (Pergamon).

Levinson, D. (2010). Equity effects of road pricing: A review. *Transport Reviews, 30*(1), 33–57 (Taylor & Francis).

Litman, T. (2015). *Evaluating transportation equity.* Victoria Transport Policy.

Lojkine, J. (1972). La Politique urbaine dans la région parisienne: 1945–1972. Mouton (La Recherche urbaine). Retrieved from https://books.google.co.nz/books?id=S-8EAAAAMAAJ.

Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy, 20*, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013.

Lucas, K., Van Wee, B., & Maat, K. (2016). A method to evaluate equitable accessibility: Combining ethical theories and accessibility-based approaches. *Transportation, 43*(3), 473–490 (Springer).

Manaugh, K., & El-Geneidy, A. (2012). Who benefits from new transportation infrastructure? Using accessibility measures to evaluate social equity in transit provision. *Accessibility and transport planning: Challenges for Europe and North America* (pp. 1035–1053). Cheltenham, UK: Edward Elgar. Martens, K.

Marcuse, P., et al. (2009). *Searching for the just city: Debates in urban theory and practice.* Taylor & Francis (Questioning Cities). Retrieved from https://books.google.co.nz/books?id=YQ6UAgAAQBAJ.

Martens, K. (2016). *Transport justice: Designing fair transportation systems.* Routledge.

Martens, K., Golub, A., & Robinson, G. (2012). A justice-theoretic approach to the distribution of transportation benefits: Implications for transportation planning practice in the United States. *Transportation Research Part A: Policy and Practice, 46*(4), 684–695. https://doi.org/10.1016/j.tra.2012.01.004.

Martha, C., & Nussbaum, M. C. (2011). *Creating capabilities: The human development approach.* Cambridge, MA: Belknap Press of Harvard University Press.

Mathisen, T. A. (2006). *The relationship between travel distance and fares, time costs and generalized costs in passenger transport.* Norway: Bodø Graduate School of Business (Citeseer).

Morgan, M. (2016). Yay, transit! - Using GTFS data in ArcGIS network analyst. Retrieved from http://transit.melindamorang.com/, Accessed date: 29 December 2016.

Mullen, C., et al. (2014). Knowing their place on the roads: What would equality mean for walking and cycling? *Transportation Research Part A: Policy and Practice, 61*, 238–248 (Elsevier).

O'Sullivan, D., Morrison, A., & Shearer, J. (2000). Using desktop GIS for the investigation of accessibility by public transport: An isochrone approach. *International Journal of Geographical Information Science, 14*(1), 85–104. https://doi.org/10.1080/136588100240976.

Páez, A., & Scott, D. M. (2005). Spatial statistics for urban analysis: A review of techniques with examples. *GeoJournal, 61*(1), 53–67 (Springer).

Páez, A., et al. (2010). Relative accessibility deprivation indicators for urban settings: Definitions and application to food deserts in Montreal. *Urban Studies, 47*(7), 1415–1438. https://doi.org/10.1177/0042098009353626 (SAGE Publications Ltd).

Pereira, R. H. M., Schwanen, T., & Banister, D. (2017). Distributive justice and equity in transportation. *Transport Reviews, 37*(2), 170–191 (Taylor & Francis).

Pucher, J. (1981). Equity in transit finance: Distribution of transit subsidy benefits and costs among income classes. *Journal of the American Planning Association, 47*(4), 387–407 (Taylor & Francis).

Purcell, M. (2002). Excavating Lefebvre: The right to the city and its urban politics of the inhabitant. *GeoJournal, 58*(2–3), 99–108. https://doi.org/10.1023/B:GEJO.0000010829.62237.8f (Kluwer Academic Publishers).

Rawls, J. (1971). *A theory of justice.* Harvard University Press. Retrieved from https://books.google.com/books?id=kvpby7HtAe0C&pgis=1, Accessed date: 5 November 2015.

Salmon, S. (2001). The right to the city? Globalism, citizenship, and the struggle over urban space. *A conference on 97th annual meetings of the Association of American Geographers, New York, February*.

Sen, A. (2006). What do we want from a theory of justice? *The Journal of Philosophy, 103*(5), 215–238. Retrieved from http://www.jstor.org.ezproxy.auckland.ac.nz/stable/20619936 (Journal of Philosophy, Inc.) .

Sen, A. (2009). *The idea of justice.* Belknap Press of Harvard University Press.

Shiftan, Y., et al. (2007). *Transportation planning.* E-Elgar.

Soja, E. W. (2010). *Seeking spatial justice.* University of Minnesota Press. Retrieved from http://books.google.co.nz/books?id=NkfEeomy-IUC.

State of Western Australia (2011). Public transport for Perth in 2031. Perth. Retrieved from www.transport.wa.gov.au.

Statistics New Zealand (2013). Census 2013. www.stats.govt.nz. Retrieved from http://www.stats.govt.nz/Census/2013-census.aspx.

Talen, E. (2001). Access: Geographical. In N. J. Smelser, & P. B. Baltes (Eds.). *International encyclopedia of the social & behavioral sciences* (pp. 30–33). Elsevier.

TriMet (2009). TriMet - Trip planner, TransitTracker, service alerts. Retrieved from http://trimet.org/, Accessed date: 29 December 2016.

Van Wee, B., & Geurs, K. T. (2011). Discussing equity and social exclusion in accessibility evaluations. *European Journal of Transport and Infrastructure Research, 11*(4), 350–367 (Delft University of Technology).

Van Wee, B., & Roeser, S. (2013). Ethical theories and the cost–benefit analysis-based ex ante evaluation of transport policies and plans. *Transport Reviews, 33*(6), 743–760 (Taylor & Francis).

Vancouver City Council (2012). *Transportation 2040, plan as adopted by Vancouver City Council. Vancouver*.

Vigar, G. (1999). Transport for people: Accessibility, mobility and equity in transport planning. *Social town planning* (pp. 90–101). London: Routledge.

Wachs, M., & Kumagai, T. G. (1973). Physical accessibility as a social indicator. *Socio-Economic Planning Sciences, 7*(5), 437–456.

Walker, J. (2011). *Human transit: How clearer thinking about public transit can enrich our communities and our lives.* Island Press. Retrieved from http://books.google.co.nz/books?id=Y98oPkGTCKQC.

Walzer, M. (2008). *Spheres of justice: A defense of pluralism and equality.* Basic Books.

Widener, M. J., et al. (2015). Spatiotemporal accessibility to supermarkets using public transit: An interaction potential approach in Cincinnati, Ohio. *Journal of Transport Geography, 42*, 72–83. https://doi.org/10.1016/j.jtrangeo.2014.11.004.