



# The cost of equity: Assessing transit accessibility and social disparity using total travel cost



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## ABSTRACT

Social equity is increasingly incorporated as a long-term objective into urban transportation plans. Researchers use accessibility measures to assess equity issues, such as determining the amount of jobs reachable by marginalized groups within a defined travel time threshold and compare these measures across socioeconomic categories. However, allocating public transit resources in an equitable manner is not only related to travel time, but also related to the out-of-pocket cost of transit, which can represent a major barrier to accessibility for many disadvantaged groups. Therefore, this research proposes a set of new accessibility measures that incorporates both travel time and transit fares. It then applies those measures to determine whether people residing in socially disadvantaged neighborhoods in Montreal, Canada experience the same levels of transit accessibility as those living in other neighborhoods. Results are presented in terms of regional accessibility and trends by social indicator decile. Travel time accessibility measures estimate a higher number of jobs that can be reached compared to combined travel time and cost measures. However, the degree and impact of these measures varies across the social deciles. Compared to other groups in the region, residents of socially disadvantaged areas have more equitable accessibility to jobs using transit; this is reflected in smaller decreases in accessibility when fare costs are included. Generating new measures of accessibility combining travel time and transit fares provides more accurate measures that can be easily communicated by transportation planners and engineers to policy makers and the public since it translates accessibility measures to a dollar value.

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## 1. Introduction

Increasingly, social equity is incorporated as a long-term objective into urban transportation plans, although what is meant by ‘equity’ varies widely (Manauagh et al., 2015). Access to opportunities such as jobs and services is one of the main benefits of a transportation service such as public transit (Grengs, 2010; Jones and Lucas, 2012). Due to the central and peripheral nature of cities, not all residents benefit from similar levels of accessibility (Martens, 2012). Nevertheless, a fair distribution of transportation resources should provide commuters with various travel options to increase their access to

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opportunities, particularly to jobs; this is often not the case despite stated transport goals. Low-income and socially disadvantaged individuals are the most likely to be transit-dependent (Denmark, 1998; Dodson et al., 2007), and often face greater barriers to access their desired destinations (Lucas, 2012). To determine the level of opportunities residents in a region can reach, as well as to assess the spatial distribution of public transit service, typical research employs accessibility measures, which are measures of land use and transportation interaction (El-Geneidy et al., 2015; Foth et al., 2013). The simplest measure of accessibility and most commonly used is known as cumulative opportunities, where within a given time thresholds (usually 45 or 60 min) the number of opportunities that can be accessed using a specified mode is counted. By revealing the level of accessibility of socially disadvantaged neighborhoods, transport planners can evaluate the vertical or horizontal equity of transport benefits spatially.

To date, transportation equity studies have focused on travel time as a constraint on accessibility. However, financial access to transit is also crucial. For low-income populations, transit fares present a barrier to accessibility, since fares can consume a large share of individuals' budget (Carruthers et al., 2005). Job accessibility research that ignores transit fares may overestimate job accessibility, particularly for low-income riders. It is accordingly important to take the monetary aspect of commuting into account when examining accessibility.

The present study assesses the level of accessibility to jobs using public transit for people residing in socially disadvantaged neighborhoods in Montreal region compared to those living in other neighborhoods. In particular, we account for hourly wages and transit fares as important constraints on accessibility, in the context of a complex fare structure involving 14 different schemes. This methodology can benefit transportation planning agencies aiming to promote transit equity based on transit service supply and fare structure. Also the generated measure can be communicated easily to policy makers and the public as it will be either in a dollar value or travel time.

This paper is organized in five sections. The first section provides an overview of the literature on accessibility and equity issues in transportation. Next, the Montreal study context is presented, followed by a description of the data and methodology used to generate and assess the accessibility measures in relation to social equity. Results are analyzed spatially for the different accessibility measures. Finally, the results are discussed and the recommendations and conclusions of the study are presented.

## 2. Literature review

### 2.1. What is accessibility?

Accessibility is a measure of potential opportunities (Hansen, 1959). A simple measure of accessibility is the cumulative opportunity measure, which counts the number of opportunities that are reachable from a given location within a specified travel duration or travel distance when using a particular travel mode (Geurs and van Wee, 2004; Vickerman, 1974). While this measure is simple to calculate and understand, it evaluates all destinations equally, does not differentiate travel times except that they are above or below a threshold, and does not account for travelers' perceptions of time (Ben-Akiva and Lerman, 1979). The gravity-based measure of accessibility, on the other hand, discounts the attractiveness of the destinations by the cost of travelling. Typically, these costs are defined by the time or distance a person has to travel (Geurs and van Wee, 2004; Handy, 1994; Hansen, 1959; Owen and Levinson, 2014; Vickerman, 1974). The main disadvantage of the gravity-based measure, however is that its results are harder to communicate and interpret (Geurs and van Wee, 2004; Owen and Levinson, 2014). Importantly, gravity and cumulative accessibility measures are highly correlated, allowing their interchangeable use as necessary (El-Geneidy et al., 2011; El-Geneidy and Levinson, 2006). Hence, cumulative opportunity is used in this study.

### 2.2. Accessibility and equity

Measuring accessibility by public transportation is important to evaluate the distribution of services in a region based on equity (Foth et al., 2013). However, what constitutes an equitable distribution is difficult to define due to varying social norms and moral judgments (van Wee and Geurs, 2011). Two main types of equity are generally evaluated in transportation planning: horizontal equity and vertical equity. Horizontal equity refers to the uniform distribution of benefits and costs among individuals within a group. Based on egalitarian theories, it avoids favoring one individual or group over another. Most studies of horizontal equity look into spatial distribution of transportation impacts. However, with regard to public transit, some groups are more likely require such service, namely low-income populations that are transit-dependent (Pucher and Renne, 2003; Sanchez et al., 2004) as they cannot afford owning a car. According to Krumholz and Forester (1990), a fair distribution of resources provides a greater variety of options to those with the least. This relates to vertical equity, which considers the distribution of benefits between groups, and compares the benefits across socio-economic groups, e.g. the well-off with marginalized and vulnerable populations. In the case of transportation, potentially disadvantaged populations include low-income and unemployed people as well as minorities (Denmark, 1998; Dodson et al., 2007).

One way to investigate vertical equity issues in transportation is to assess the effectiveness of the service provided by transit agencies among different stratified socioeconomic groups by using accessibility as an indicator of the benefits provided by the land use and transportation system in a region. Recently, Riccardi et al. (2015) studied transit accessibility in Perth, Australia, and found that socially disadvantaged groups comprising of elderly people, low-income households

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