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Public transport accessibility in metropolitan areas: A new approach incorporating population density

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ABSTRACT

Improving public transport accessibility can be considered an effective way of reducing the external costs and negative side effects of motorized commuting. Although there have been many studies conducted that have measured access levels to public transport stops/stations, there has been limited research on measuring accessibility that integrates population density within geographical areas. This study develops a new measure that considers public transport service frequency and population density as an important distributional indicator. A public transport accessibility index (PTAI) is formulated for quantifying accessibility within local areas in metropolitan Melbourne, Australia. A public transport network model is applied to identify the service coverage of public transport modes using a Geographical Information System (GIS). A consistent method is introduced for evaluating public transport accessibility for different levels of analysis, from single elements, including public mode stops to network analysis. The Victorian Integrated Survey of Travel and Activity (VISTA) is used to evaluate the index and examine the association between commuting trips undertaken by public transport and the level of accessibility within the Melbourne metropolitan region. Furthermore, the new index is compared with two existing approaches using the VISTA dataset. Key findings indicate that the PTAI had a stronger association whilst showing more use of public transport in areas with higher values of the PTAI.

1. Introduction

Shifting from private motorized vehicles to public transportation, walking and cycling can increase the sustainability of transportation and consequently, improve the environment, economics and public health (Elias and Shiftan, 2012). A well-organized public transportation system is capable of increasing the level of mobility in cities. Hence, a user-friendly public transportation system should consider accessibility to stops/stations, mobility of the system and connectivity to other transportation modes (Cheng and Chen, 2015). Providing efficient public transport in terms of accessibility is one of the main objectives of policy makers and planners in metropolitan areas throughout the world. In recent decades, sprawling land-use planning, automobile-oriented developments along with the increase in car ownership have encouraged people to spend more time traveling by automobiles. High levels of car dependency is not only affecting the quality of life but, critically threatening people's health. On the other hand, growing use of private motorization has resulted in critical issues such as traffic congestion and environmental impacts. Use of public transport is considered within the definition of active transport as it often involves some walking or cycling to get connected from origins to destination of trips (Taniguchi et al., 2013). In this regard, providing high levels of accessibility for public transport systems with good connectivity can promote active transport and sustainability. From a users' viewpoint, an effective public transport service can be defined as minimum in-vehicle travel time and waiting time (Ceder et al., 2009).

Transportation equity affects residents' economic as well as social opportunities (Wang and Chen, 2015; Cheng and Bertolini, 2013). In other words, transport problems may result in social exclusion as reported in several studies (Fransen et al., 2015; Priya and Uteng, 2009; Delmelle and Casas, 2012; Lucas, 2011). It has been shown that some suburban and regional areas in Australia are disadvantaged with respect to public transport where distance is a major barrier (Currie and Stanley, 2007). Australia has been categorized as a country with high car ownership (Lucas, 2012) with particular groups of people such as youth, seniors, low-income households and aboriginals encountering difficulties in accessing work, education and social or cultural activities (Lucas, 2012; Altman and Hinkson, 2007; Johnson et al., 2011).

This paper presents a review of previous research in this area. There have been numerous studies that have focused on measuring public transport accessibility. However, there has been limited work which has considered the distribution of population in measuring accessibility levels. We present a new index to measure public transport accessibility

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and describe its application to increase understanding public transport usage in metropolitan Melbourne, Australia. There is a need to incorporate different frequencies of public transport modes, public transport routes and population densities in measuring public transport accessibility. This paper defines an index that can be used classify levels of accessibility. The method has been applied to the Melbourne metropolitan area that is served by a public transport system that consists of train, tram and bus services. The following section provides background information. Section 3 introduces the methodology, which describes the computation of the index. Analysis and results of the application of the PTAI in the Melbourne region along with a comparison of the results between the new index and existing approaches are presented in Section 4. Section 5 discusses the results, while Section 6 summarizes the findings and outlines avenues for future research.

2. Public transport and accessibility measurements

Increasing accessibility to public services is a crucial area of transport policy and urban planning as well as being a key foundation of an integrated transport system (Wu and Hine, 2003). Poor public transport accessibility to education, jobs and health facilities (Hine and Mitchell, 2003) and inequity in transport provision (Langford et al., 2012) can have a large impact on vulnerable people within a society. Accessibility can be measured by the distance between a destination and public transport stops or by the length of a journey from an origin to a destination via public transportation (Weber, 2003; Cheng and Chen, 2015).

Based on a review by Lei and Church (2010), public transport accessibility measures can be categorized into six main types. The first type of accessibility measure is based on travel time and distance (Murray et al., 1998; Matisziw et al., 2006; Polzin et al., 2002). This class deals with the physical access to public transport stops/stations. The second group includes approaches that measure travel times and costs (Wu and Murray, 2005; Liu and Zhu, 2004; O'Sullivan et al., 2000; Mazloumi et al., 2011). In this group, a user's ability to get to their destination is measured by taking into account the travel time or cost spent in the transportation network. The third group is integral accessibility that measures overall access related to a number of possible destinations (van Eck and De Jong, 1999; Wachs and Kumagai, 1973). These approaches measure general access in terms of distance and time for a selected location with respect to an activity type. The fourth category is based on the concept of time geography. This kind of measure is based on users' movement over space while their choice of activities is dependent on time (Kwan et al., 2003; Miller and Wu, 2000). The fifth type of measure is based on utility theory. In such approaches, users are considered as customers and public transport modes as a travel choice set (Rastogi and Rao, 2003; Koenig, 1980). The sixth category is called relative accessibility and assumes that a user's choice of travel is a function of cost (Li et al., 2015), time (Salonen and Toivonen, 2013), convenience and safety (Church and Marston, 2003). In a more general classification, existing accessibility measures can be categorized into three main groups, including access to public transport stops, duration of a journey by public transport and access to a destination via public transport modes (Mavoa et al., 2012; Lin et al., 2014). Most studies of accessibility have considered the physical level of access focusing on the proximity to public transport stops (Biba et al., 2010; Currie, 2010; Furth et al., 2007). Both access to public transport stops and travel time can be considered (Mavoa et al., 2012). In Auckland, New Zealand the potential access between land parcels and destinations via public transport was measured by introducing a public transit and walking accessibility index (PTWAI). This index allowed accessibility levels to be categorized based on travel time. Higher travel times indicate a lower level of accessibility.

A substantial body of research has assessed the relative quality of public transport services, especially in terms of accessibility (Orth et al., 2012; Fu and Xin, 2007). Previous studies have measured different aspects of public transport service levels such as accessibility, mobility, and connectivity. These studies have focused mainly on Geographic Information System (GIS)-based public transit networks (Tribby and Zandbergen, 2012; Mavoa et al., 2012). Among a series of methodological developments within this area, the PTAL (Public Transport Accessibility Level) is an approach developed in the UK which measures the level of accessibility. This approach is now a central part of many transport plans in both urban and rural contexts. The PTAL provides a rating scale comprising 6 levels of public transport accessibility which includes measures such as access walk time, service frequency and waiting time. This approach computes the level of access by public transport for points of interest (Wu and Hine, 2003; Currie, 2010).

A GIS-based land use and public transport accessibility index (LUPTAI) has been developed that is computed by utilizing GIS analysis techniques to measure accessibility based on both public transport travel time and walking distances (Yigitcanlar et al., 2007). This approach used an origin-based accessibility and destination-based GIS technique, and applied the index to two pilot studies in the Gold Coast, Australia. Their findings indicated that the LUPTAI could easily be applied to a range of different of land use categories.

'Needs-gap' is another approach that has been used to identify spatial gaps between the supply of public transport and the levels of needs for groups in Hobart, Australia. The supply index (SI) developed for metropolitan Melbourne is a more recent version of that approach (Currie, 2010; Currie, 2004). This research identified significant differences between levels of public transport service supply in outer and inner/middle areas in Melbourne. It also concluded that there are spatial concentrations of very high needs persons in the outer areas of Melbourne. This study used a combined measure of service frequency and access distance which was calculated for each census collector district (CCD). de Graaff et al. (2012), also argued that the distribution of employment and population affects urban form and travel patterns. Although in previous research access to public transport has been measured for specific population groups based on socioeconomic characteristics, including age, employment, car ownership, etc. (TfL, 2004), consideration of population density within spatial areas has been ignored. A major weakness of existing approaches is that they assign a level of accessibility to areas without considering the population distribution within those areas (Currie, 2010). In response, this study focuses on measuring access to public transport stops while considering population levels, along with walk time and service frequency.

3. Methodology

This study aims to develop an index for measuring the level of accessibility to public transport in Melbourne's 9510 Statistical Areas level 1 (SA1s),[1] the second smallest geographic area defined in the Australian Statistical Geography Standard. According to the Australian Government Department of Health and Ageing (Neighbourhood Planning and Design, 2009), the physical characteristics of neighbourhoods are accessible based on walkable catchments. This is generally defined as 5 to 10 min walking to/from public transport stops/stations. SA1 districts were found to have the closest conformity to walking catchments. In order to define the index two factors, a Weighted Equivalent Frequency (WEF) and the ratio of population density in SA1s and buffer areas (service areas of different public transport modes) are calculated. This work fits into Lei and Church's (2010) classification as it deals with physical access to the public transport stops/stations by considering walking time and service frequency. Furthermore, the work fits into the first category, access to public transport stops, of the more general three-way classification scheme developed by Mavoa et al. (2012). The methodology is developed for metropolitan Melbourne where areas with a denser public transport network and population show a higher access to all destinations nearby. The databases and study area, conceptual

[1] According to Australia Bureau of Statistics (ABS), the ABS structure of Melbourne region contains, 53,074 Mesh Blocks, 9510 Statistical Area Level 1 (SA1), 277 Statistical Area Level 2 (SA2), 42 Statistical Area Level 3 (SA3) and 12 Statistical Area Level 4 (SA4).