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Spatial analysis of access to and accessibility surrounding train stations: a case study of accessibility for the elderly in Perth, Western Australia

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ABSTRACT

Approximately one-fifth of Perth's population is aged 60 or older. Projections suggest that this proportion will continue to increase as a result of the large number of children born after the World War II (1946–1964). Access to and accessibility around train stations for the aging population is and will become a more important issue as the elderly population continues to grow. The aim of the paper is to develop and apply a new measure of accessibility to train stations at a fine spatial scale, justified by the special circumstance of the elderly using a case study in Perth, Western Australia. Intercept surveys are used to collect data on factors affecting train station accessibility for patrons aged 60 years or older, at seven highly dispersed train stations. Overall accessibility is measured separately using a composite index based on three travel modes (walk-and-ride, park-and-ride and bus-and-ride). The results illustrate that key variables, such as distance from an origin to a station, walking or driving route directness, land-use diversity, service and facility quality, bus connection to train stations, all affect the accessibility to train stations for the elderly. This implies that improvements to these factors will improve accessibility for this population group.

1. Introduction

In Perth, Western Australia approximately one-fifth of the population is aged 60 or older (Australian Bureau of Statistics, 2011). It is reported that this aging population is unprecedented, ubiquitous and enduring. Projections suggest that this proportion will continue to increase as a result of a temporary, but significant, "baby boom" following the cessation of World War II. The cohort of individuals born between 1946 and 1964, also known as the "baby boomer generation", is wealthier, healthier and more involved in various activities than previous generations of the same age. This is expected to lead to higher requirements for public transport access and therefore measures need to be established or improved to enable elders' mobility.

Currently, studies in Western Australia specific to accessibility to train stations for the elderly are scarce, likely out-dated, and have considered them akin to the disabled (e.g., Ashford, 1981). However, while improving accessibility for those with disabilities may translate into improvements for the some of the elderly, it is not a complete solution for all. Studies in different cities around the world have identified that the elderly tend to rely more on private car than public transport and that land use plays a major role in shaping their travel patterns (Goulias et al., 2007; Rosenbloom, 2001; Schmöcker et al., 2008). However, many of the elderly will have to adjust their travel plans/arrangements due to their declining driving abilities and potential financial constraints, which are likely to become more restrictive the longer they are retired (Burkhardt, 1999). Therefore, public transport becomes a keystone for enabling mobility of this population group.

Improvements to the accessibility of train networks has been linked to increased usage (Schmöcker et al., 2008). Therefore, it is important to identify factors that are important for the elderly to ensure their needs are covered. When choosing a train station to board, the elderly may consider different factors compared to other age cohorts. For instance, walking distance when transferring to the train, seat availability at the train station and on the train, shelter availability and the presence of security staff may all be important to them, but these need to be properly quantified to best guide decision makers.

This paper aims to develop and apply a new spatial measure of accessibility to train stations, justified by the spatial circumstances

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of the elderly using as a case study Perth, Western Australia. Section 2 reviews the definition of accessibility and presents accessibility measures and factors affecting accessibility both for the general population and for the elderly. Section 3 presents the study area and data collection methods, whereas Section 4 focuses on the developed measure of accessibility to train station for the elderly. The results are explained based on a case study of Perth, Western Australia in Section 5. The paper ends with a summary of findings, contributions and a discussion of limitations and possible further developments.

2. Literature review

In general, accessibility can be defined as the ease of reaching valued destinations (El-Geneidy and Levinson, 2006). However, it is a broad and flexible concept that varies greatly depending on the research discipline and aim. Several researchers have defined it using a variety of ideas (Bertolini et al., 2005; Bhat et al., 2000; Burns and Golob, 1976; Chen et al., 2011; Ingram, 1971; Kwan et al., 2003; Lei and Church, 2010; Litman, 2012). However, there is not a single all-encompassing consensus-based definition that also accounts for all transport modes. Thus, in this paper, the working definition is the elderly's ease of reaching a train station by means of one or more transport modes (car, bus, walking, or by bike) and then enabling them to transfer and use the train services (e.g. Bus-and-Ride, BnR; Park-and-Ride, PnR; Kiss-and-Ride, KnR; Cycle and Ride, CnR; and Walk and Ride, WnR). The access also refers to the real or perceived costs (e.g. time, distance, or financial burden) and benefits (e.g. the level of services provided) when accessing the train station. This is a place-based accessibility definition that combines mode, spatial separation, and activity opportunities.

2.1. Accessibility measures

A large number of measures of accessibility have been proposed since Hansen first introduced the issue to spatial planning in 1959 (Dalvi and Martin, 1976; El-Geneidy and Levinson, 2006). Here, we provide a synthesis of these measures to provide context to the measures developed in this study.

Network measures, rely on road network topology and are the first and simplest measures of accessibility. There are a large number of indices used to measure networks. For example, Porta et al. (2006) provide several network measures such as Ki (Degree of Node), $Lm(G)$ (number of stations), $Lt(G)$ (number of route segments), $Eg(G)$) (the global efficiency), and $El(G)$ (the local efficiency). Further, El-Geneidy and Levinson (2006) use the network size as an index and Dill (2004) apply street network density, connected node ratio, intersection density and link-node ratio as network indices. However, the gamma index (γ) and alpha index (α) developed by Garrison and Marble are regarded as popular measures of network connectivity (Garrison and Marble, 1965).

Spatial separation measures focus on the travel impediment or resistance, which can be measured in various ways, for example, shortest path travel distance and/or travel time (Scheurer and Curtis, 2007). Spatial separation is a widely accepted method, because: (1) the measures are simple and only take geographic spatial separation into account, thereby excluding other considerations such as socio-economic status, traveller's behaviour differences and location differences (Baradaran and Ramjerdi, 2001); (2) it has clear concept and is comparable over time (Australian Population and Migration Research Centre, n.d.). For example, the ABS (Australian Bureau of Statistics) uses Metro ARIA (Metropolitan Accessibility/Remoteness Index of Australia) as an accessibility index to indicate spatial separation. It is an index based on travel distance, with values ranging from 0 (high accessibility) to 15 (high remoteness).

Contour measures, also known as isochronic or cumulative opportunity measures, are travel cost-based (e.g. distance/time) contours and count the number of opportunities within each contour (Chen et al., 2011; El-Geneidy and Levinson, 2006; Mavoa et al., 2012; Scheurer and Curtis, 2007). The Department of Transport and Main Roads Queensland have developed the Land Use & Public Transport Accessibility Index (LUPTAI) based on this approach, where the threshold of the destination is 400 m for bus stops and 800 m for train stations, while for the origin it uses thresholds of 350 m for bus stops and 750 m for train stations. These are simple metrics to understand and calculate, but their thresholds are sometimes arbitrary and experimental. In addition, it uses crisp thresholds which suggest that, for example, opportunities 399 m away are valuable but those 401 m are not (El-Geneidy and Levinson, 2006). Alternatively, one can identify multiple contours and also take into account the time-of-day variability of accessibility, due to travel times changing with traffic or due to the opening and closing of stores (Chen et al., 2011).

Gravity measures are based on the social equivalent of Newton's law of gravity (Hansen, 1959). The gravity model includes two basic components: (1) attractiveness of a location (the numerator in the fraction); and (2) the travel cost (such as travel time or travel distance), representing the impedance and being the denominator in the fraction. A power function is usually considered, with parameters calibrated from data.

Random Utility Models (*RUM*) represent the amount of 'benefits' travellers obtain from travel (Ben-Akiva and Lerman, 1985). This has become more recently a popular measure (Cascetta, 2009; Diana, 2008; Fukuda and Yai, 2010; Golob and Beckmann, 1971). The basic assumption underlying it is that every individual is a rational decision-maker and she/he chooses an alternative providing the highest level of utility. The utility has a deterministic component, which can be calculated based on observed characteristics, and a stochastic error component/unobserved (Golob and Beckmann, 1971).

The competition or constraints-based measures incorporate the constraints of activities into accessibility measures from a regional perspective. For example, Joseph and Bantock (1982) take into account the availability of physicians, suggesting that in less heavily populated catchment areas physicians are more likely to be available because of less competition. To incorporate competition effects, Genurs and Wee (2004) summarised three different approaches: (1) dividing the opportunities by potential demand to incorporate the effects of competition; (2) using the quotient of opportunities; and (3) using balancing factors.

The composite measures not only combine two or more of the described measures (El-Geneidy and Levinson, 2006), but they are also measures that go beyond the scale of the six categories above. The advantage of this method is its flexibility and consistency. It uses simple linear combination rules to combine variables with different weightings. The weight represents a variable's influence on the total accessibility measure. Methods, such as the Analytical Hierarchy Process (AHP) (Saaty, 2008), and regression modelling methods (Johnson, 2001) are widely used to determinate the weight or the importance factor. This paper has adopted a composite measure approach.

2.2. Factors affecting accessibility

When dealing with factors that influence accessibility, people tend to rank proximity (i.e., the distance from point A to point B) as first or highest. However, a Dutch railway survey, for example, identified that less than half of the passengers chose their nearest train station (Debrezion et al., 2007). This indicates that although important, distance is not the only factor. Many other elements were identified and they often included travel cost, land use mix,