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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

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.

Keywords: Composite index, accessibility to stations, spatial analysis, rate of train station patronage, elderly

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 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 400m for bus stops and 800m for train stations, while for the origin it uses thresholds of 350m for bus stops and 750m 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 399m away are valuable but those 401m 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, service quality (in terms of speed, frequency, comfort), parking availability, and congestion. A list of potential factors influencing accessibility to train stations is provided in Table 1 and the variables specifically found to influence accessibility for the elderly are highlighted in bold. Travel distance and network connectivity are obvious determinants of accessibility. Further, as the physical condition of the elderly reduces in time relative to the rest of the population, they are more reliant on the staff and facilities available at the train stations; therefore, the service quality is particularly important. Moreover, given travel purposes for the elderly population, it is important to cater for shopping and offer recreation centres in the vicinity of train stations, in order to attract more elderly patrons to use train services. Besides these, access to the stations affects the choice of travel mode and stations and is related to the provision of particular services and facilities. For example, PnR users value parking bays as very important, while for bus users the frequency of bus services can be a determining factor.

Table 1: Factors that influence accessibility to train stations

Location of Study	Author	Focus of Study	Factors
Australia	Scheurer and Curtis (2007)	Urban and Regional Planning	**distance**, **travel time**, **travel cost**, **service quality**, opportunities, travel purpose
	Scheurer et al. (2008)	Urban Study	**public transport supply** and usage, population and dwelling density, amenity and functionality of the transit city
Worldwide	Genurs and Wee (2004)	Land-use and Transport	**land-use**, quality of transport services (e.g. travel time, travel cost, reliability, comfort), temporal consistency (time variation), and individual (e.g. personal needs)
	Halden et al. (2005)	Socially Disadvantaged Groups	**spatial** (e.g. ability to interchange between modes and network availability), **physical** (vehicle designs, kerb heights and topography), temporal (**transport system** and **service reliability**, **service frequency**, capacity etc.), financial (travel cost), environmental (lighting, amenity) and information (information whilst waiting)
	Litman (2011)	Transport Planning	**transit service quality**
	Litman (2012)	Transport Planning	mobility, **quantity** and **quality** of transport modes and services, user information, **integration**, parking, affordability, **land-use**, **network connectivity**

Note: The table contents are illustrative rather than exhaustive.

3. Data Collection

The study area of this research is the Perth Metropolitan area (Figure 1). Perth is the state capital of Western Australia and has a system of five radial train lines including the Armadale, Fremantle, Joondalup, Midland and Mandurah lines. There is also a spur line, Thornlie, which is off the Armadale line. The total length of the railway network is 168 km and comprises 69 train stations (Australian Department of Infrastructure and Transport, 2012).

The data used in this research were collected from two sources: government departments and field surveys. The secondary data include: land use, road networks, public transport networks, services, and patronage from the Department of Planning (DoP), Public Transport Authority (PTA) and the Department of Transport (DoT) in Western Australia. Field surveys were used to collect the trip information and attitudes of the elderly towards station facilities and service quality using two intercept surveys. The first intercept survey was conducted at seven train stations: Warwick, Greenwood, Murdoch, Warnbro, Midland, Cannington, and Claremont from 6:00AM to 6:00PM, July 31 and August 1, 2012 and collected 940 responses of which 122 were from the elderly users. A further 43 responses from elderly users were obtained on the 6th and 15th of March, and 8th and 10th of May, 2013, at three stations (Murdoch, Greenwood and Midland), to supplement the original 122 observations.

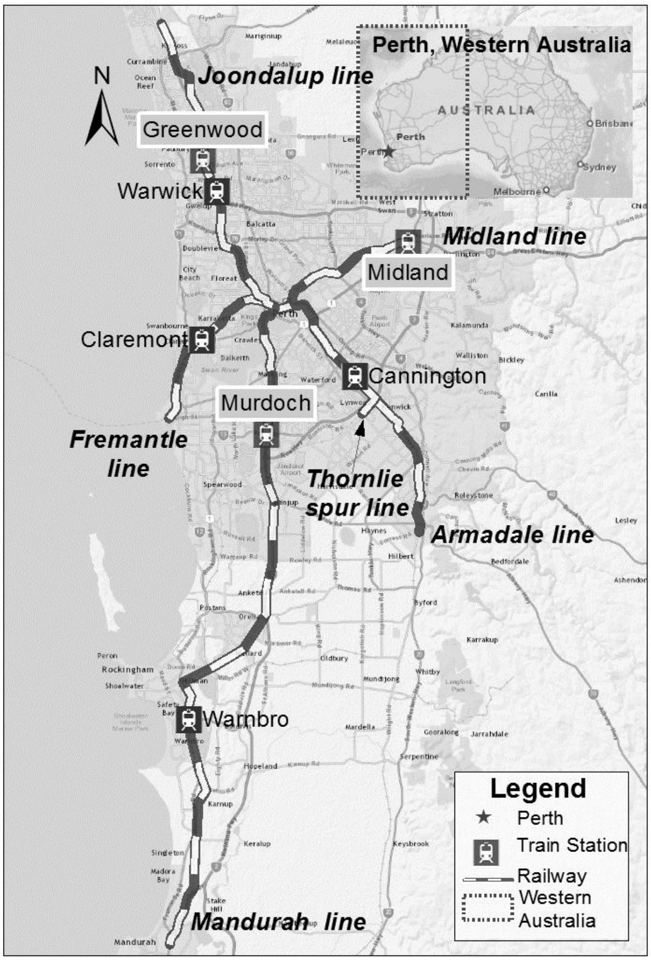

Figure 1: Study Area (Esri, 2010)

4. Methods

Three steps of analysis were taken to understand accessibility for the elderly to a railway station (Figure 2). The first step aimed to identify the elderly respondents' most favoured and least favoured stations using the rate of rail station patronage. Next, the variables affecting railway station patronage were investigated. Finally, based on these variables, accessibility indices were developed to measure and map their accessibility to train stations at a census district level for WnR, and PnR and at a street block level for BnR.

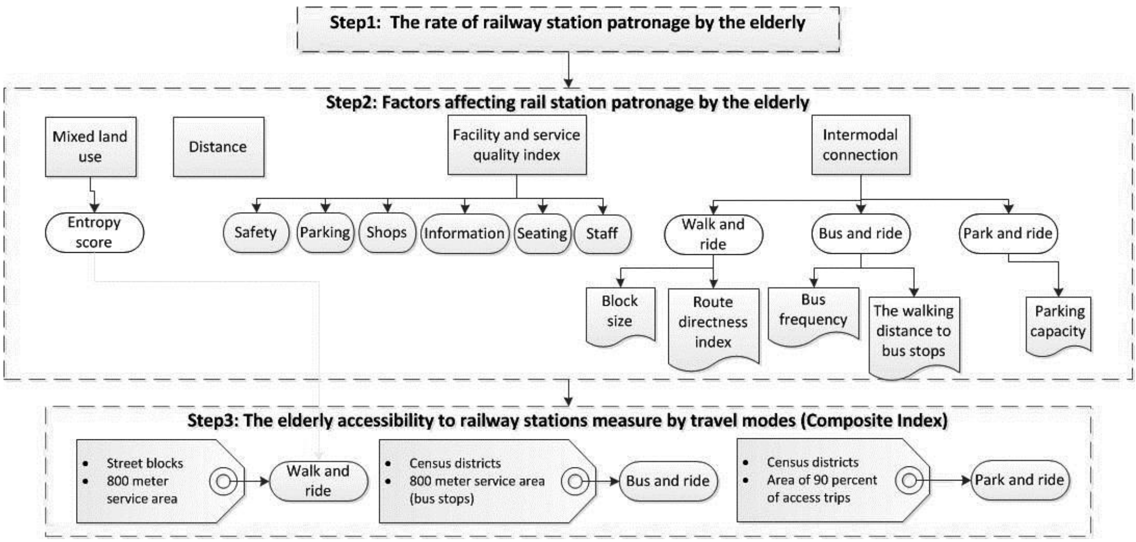

Figure 2: The Framework for Measuring Elderly Accessibility to Train Stations

4.1 Rate of Elderly Patronage

The first step of this study was to identify which stations potentially have a lower or higher rate of patronage compared to others, which can be defined as:

$$R_{pi} = \frac{P_{esi}/P_{tsi}}{P_{eci}/P_{tci}} \quad (1)$$

where:
R_{pi} is the rate of the elderly's patronage at train station i;
P_{esi} is the number of the surveyed elderly at train station i ;
P_{tsi} is the total number of respondents at train station i;
P_{eci} is the number of elderly living inside of the catchment area of train station i; and
P_{tci} is the total population living inside the catchment area of train station i.

The numerator represents the percentage of surveyed elderly train users, whereas the denominator is the proportion of elderly residents in the catchment area. R_{pi} indicates whether the elderly could 'prefer' some stations more than others, i.e. the higher the value, the higher the patronage of the station. This ratio was used to target stations for study in order to focus on detailed attention to one high use and one low use station. This calculation was based on the 2012 survey data only.

4.2 Factors Affecting Accessibility for the Elderly

In this paper, accessibility to railway stations for the elderly was defined using the following indicators:

1. Ease in reaching a railway station
   a) Network connectivity - Route directness index (*d(r)*)
   b) Distance (*D)*
   c) Facility and service quality (*Q*)
2. Adjacent opportunities or activities

a) Mixed land use within 800m buffer around a railway station (*H*)
b) Intermodal connection
   i. The number of trips per hour that use the stop on a weekday between 9:00am and 4:00pm (*F(b)*)
   ii. PnR parking capacity at the station (*N(p)*)
   iii. PnR parking capacity outside of the station (*NO(p)*)

4.2.1 The route directness (d(r))

The route directness index is the ratio of network distance to straight-line distance between two locations (Guerra et al., 2012). An index closer to 1 indicates a more direct route. In other words, the network is more directly connected. The route directness can reflect how easy it is for the elderly to reach a train station from their origin of the trip. This is particularly relevant for walking. The route directness index was calculated separately for WnR, PnR and BnR. For WnR, the route directness index is calculated based on the local street network within an 800m buffer; for PnR and BnR, the route directness is based on the road network. The catchment area for PnR and WnR were determined by the area of 90% of all access trips. Google Direction API and ArcGIS were used to perform the calculations.

4.2.2 Mixed land use (H)

Previous research has revealed that land-use diversity and density play an important role in determining trip rates (Kockelman, 1997). Commuters would maximise their utility of the trip by making good use of opportunities around stations to improve their trip production rates (Ferdman et al., 2005; Rosenbloom, 2001). In this study, we assume that the diversity of land use around a station can increase the accessibility to the station, which was measured by an entropy score, known as the mixed land-use index (Brown et al., 2009). Besides the diversity of mixed land-use, the relative proximity of mixed-use development, such as neighbourhood shops can also encourage transit commuting (Rosenbloom, 2001). According to Cervero et al. (1995), *"If retail shops are within 300 feet, or several city blocks, from a dwelling unit, workers are more likely to commute by transit, foot or bicycle. Beyond this distance, however, mixed use activities appear to induce auto-commuting".* This paper investigated how land-use, specifically the presence of retail, education and training, health care and social assistance, and art and recreation services, shape the elderly transit travel behaviour. These land use types were mapped in an 800 m circle around a train station.

The mixed land use index (H) used in the paper is defined as (Frank et al., 2006):

$$H = -A / (\ln(N)) \tag{2}$$

$$A = \sum_{i=1}^{4} (b_i / a) \times \ln(b_i / a) \tag{3}$$

where:
b_1 = Area$_{\text{Education}}$;
b_2 = Area$_{\text{Entertainment/Recreational \&Cultural}}$;

b_3 = $\text{Area}_{\text{Health/Welfare \& Community Services}}$;
b_4 = $\text{Area}_{\text{CulturalShop/Retail}}$;
a = total square metres of land for all four land uses present in the 800m buffer; and
N = number of the four land uses where area > 0 m^2.

4.2.3 Facility and service quality (Q)

The facility and service quality of a train station was measured by 12 surveyed items. The elderly were asked to rate these items and their importance (weight) on a scale 1 to 7, where: 1 = Not at all important to 7 = Most important. A facility and service quality index Q_i was calculated using:

$$Q_i = \frac{\sum_{k=1}^{m}(\sum_{j=1}^{n}(q_{jki} \times w_{jki}))}{m \times n \times 7 \times 7} \quad (4)$$

where:
q_{jki} is the value of surveyed item *j* evaluated by the elderly respondent *k* at the station *i*;
w_{jki} is the weight of surveyed item *j* evaluated by the elderly respondent *k* at the station *i*;
m is the number of respondents *k* evaluating the item *j;*
n is the number of quality items*;* and
7 is the highest importance scale as well as the number of train stations where data was collected.

The higher the value of Q_i, the better the station is rated in terms of service quality.

4.2.4 Intermodal connection

Intermodal connection, also called "intermodality", is the connection between different transport modes or transport operators at a station (Akaike, 1974). Some common connections to railway stations are PnR, BnR, CnR, KnR and WnR. According to Shoup (1997), high levels of intermodal connections are associated with significant increases in railway station patronage. For this paper, we only focused on intermodal connections of PnR and BnR. The effect of PnR services on enhancing accessibility to railway stations has been thoroughly researched in the past. In this paper, we were interested in only one aspect related to PnR services: parking availability. For the WA elderly, they are *"entitled to travel for free on all Transperth services between 9.00am and 3.30pm Monday to Friday, all day Saturday and Sunday, as well as public holidays"* using a Smartcard (Transperth, n.d.). However, PnR parking lots are usually fully occupied before 7:30am in most stations. Therefore, it can negatively affect the accessibility to a railway station if they use PnR services.

Yet, according to Young (2008) and Burns and Golob (1976), a higher number of different bus lines connected to a station positively influences the station usage. The information about the number of bus lines with service to a station, bus frequencies and their intermodal integral times (namely, the time to change from a bus to a train) was used to measure bus and train interconnections.

As these factors are all in different units, in order to combine them into one index, the factors were scaled into five levels to make them comparable (see Table 2). The scaling strategy used was the equal interval and standard deviation. For travel distance (PnR), we converted the distance into the cumulative probability of the travel distance because the travel distances for PnR users are different for different stations (see Figure 3). For example, Midland station has a much larger PnR catchment area than others, due to its location at the end of the most Eastern line. The cumulative probability of the travel distance is consistent for all the stations and, therefore, more suitable for comparison purposes.

Table 2: The Standard for Scaling

	Land use mix	***Distance (WnR)***	***Distance (PnR cumulative probability)***	***Service quality***	***Route directness***
Very Good	0.8-1	0-200	0-20%	0.8-1	1-1.5
Good	0.6-0.8	201-400	20.1%-40%	0.6-0.8	1.51-2
Medium	0.4-0.6	401-600	40.1%-60%	0.4-0.6	2.01-2.5
Poor	0.2-0.4	601-800	60.1%-80%	0.2-0.4	2.51-3
Very Poor	0-0.2	>800	80.1%-100%	0-0.2	>3

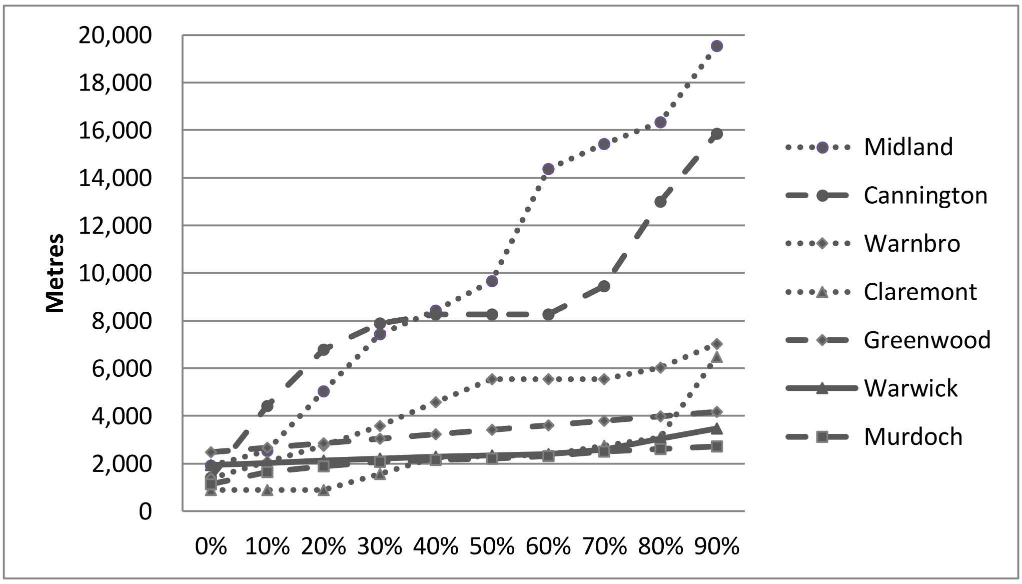

Figure 3: Cumulative Probability of the P&R Elderly's Travel Distances

Different variables may have differing importance with respect to measuring accessibility to train stations. The Analytic hierarchy process (AHP) method was used to organise and analyse these influences (Saaty, 2008). The elderly users were asked to evaluate these influences as the weight of factors for each travel mode using the AHP method. Because many elderly respondents had difficulties in understanding the AHP method (mainly because it was administered during a short period of time while they were waiting for the train), we used the stated importance (from 1-not very important to 7-extremely important) of variables for determining accessibility to the train station. Then the importance rating was converted into weights using the AHP method. The definition of other variables can be seen in the beginning of the Section 4.2.

- *Walk and Ride (WnR)*

Based on the literature and our survey, the catchment area for the WnR is around an 800m service area (Guerra et al., 2012). The catchment area was, then, subdivided into street blocks. The accessibility A_{ijwalk} to a train station j from each block i within the 800m buffer was estimated using the composite index:

$$A_{ijwalk} = W_{Q_{jwalk}} Q_{jwalk} + W_{H_j} H_j + W_{d(r)_{ij}} d(r)_{ij} + W_{D_{ij}} D_{ij} \tag{5}$$

where Q_{jwalk} is calculated based on the all the items in the facility and service quality survey except factors related to parking. W represents weights of the four variables.

- *Park and Ride (PnR)*

The catchment area for PnR was delineated by capturing 90% of access trips to a station j by the PnR mode with census district boundaries (Cervero et al., 1995). The accessibility to a station j from each census district i within the catchment area by the elderly was estimated by:

$$A_{ijPnR} = W_{N(p)_j} N(p)_j + W_{NO(p)_j} NO(p)_j + W_{Q_{jPnR}} Q_{jPnR} + W_{H_j} H_j + W_{d(r)_{ij}} d(r)_{ij} + W_{D_{ij}} D_{ij} \tag{6}$$

where:

Q_{jPnR} is calculated based on the all the items in the facility and service quality survey.

- *Bus and Ride (BnR)*

The BnR catchment area was described by an 800m service area buffer around bus stops, inside the area of 90% of access trips to a station j by the BnR mode. The accessibility to a station j from each census district i within the catchment area by the elderly A_{ijBnR} was estimated by:

$$A_{ijBnR} = W_{Q_{jBnR}} Q_{jBnR} + W_{H_j} H_j + W_{F(b)_{ij}} F(b)_{ij} + W_{D_{ikwalk}} D_{ikwalk} + W_{D_{kjbus}} D_{kjbus} \tag{7}$$

where Q_{jBnR} is calculated based on all the items in the facility and service quality survey except the items related to parking. D_{ikWalk} is the distance between a census district i and a bus stop k. D_{kjWalk} is the distance between a bus stop k and a train station j.

5. Results

Table 3 depicts the rate of rail station patronage by the elderly, based on the survey data. It shows that the Midland station has the highest patronage by elderly, whilst Greenwood station has the lowest. Because Midland station is located at the end of train line, it is reasonable to expect higher patronage for this station. For comparison purposes we also selected a station “in the middle”, Murdoch station, with the second highest patronage (Table 3). The three selected stations were compared from four perspectives: mixed land-use, distance, services/facilities of train station and inter-modal connection.

Table 3: The Rate of Train Station Patronage by the Elderly[1]

Station	P_{esi}	P_{tsi}	P_s(%)	P_{eci}	P_{tci}	P_c(%)	R_{pi}	***Rank***
Cannington	17	130	13.08	263,309	1,081,166	24.35	0.54	*3*
Claremont	12	113	10.62	39,796	159,311	24.98	0.43	*4*
Greenwood	6	87	6.90	106,702	456,789	23.36	**0.30**	***7***
Midland	37	167	22.15	288,274	1,205,807	23.91	**0.93**	***1***
Murdoch	23	158	14.56	203,910	846,707	24.08	**0.60**	***2***
Warnbro	13	138	9.42	52,156	228,943	22.78	0.42	*5*
Warwick	14	147	9.52	127,812	544,566	23.47	0.41	*6*

[1]For the definitions of variables in Table 3, please see Formula 1.

5.1 Mixed Land-Use

The mixed land-use index was used to measure land-use diversity based on the four types of land uses, mentioned in Section 4.2, located in an 800m buffer of a train station. The dominant land-use type around Greenwood station is parks, including Fernwood Park, Newham Park and Kanangra Reserve. There is also a school nearby, St Stephen's school. The calculated value of the mixed land-use was 0.37. For Midland, shopping, entertainment and health care, major activities for the elderly, are all located around the station. Its entropy level was 0.44. For Murdoch station, residential and health/welfare and community services dominate. In addition, there are a few shops and a recreation centre located in the residential area, leading to an index of 0.36. The land use maps of the three stations are shown in Figure 4.

5.2 Route Directness Index

The route directness varies considerably for the WnR mode (See Figure 4). A major issue for the accessibility via WnR is noted at the Greenwood station. Figure 4 shows an example of a street block near Greenwood. Its route directness is between 5 and 6, which means that a pedestrian has to walk five or six times more than straight-line distance in order to access the station platform.

Figure 4: The Mixed Land-Use within 800m of Train Stations (left); Route Directness of a Train Station (right)

5.3 Facility and Service Quality of Train Stations

Service and facility quality was measured using Relation 4. The average value of each facility and services quality item at the train station is shown in Figure 5. Murdoch and Midland stations have higher overall values than Greenwood station. The major issue with Greenwood station is the inadequate provision of facilities, both basic (staff, restrooms) as well as seating or availability of shops around the station. For Midland, safety and security are a major concern, especially secured parking facilities. For Murdoch, some elderly patrons complained about not enough seats on the platform and a lack of parking. Our survey results supported the a priori assumption that insufficient parking capacity has a negative influence on accessibility to train station for PnR elderly users. The facility and service quality index (in brackets is the index excluding the parking items) of Greenwood, Midland and Murdoch train stations were 0.61 (0.59), 0.68 (0.69) and 0.68 (0.71), respectively.

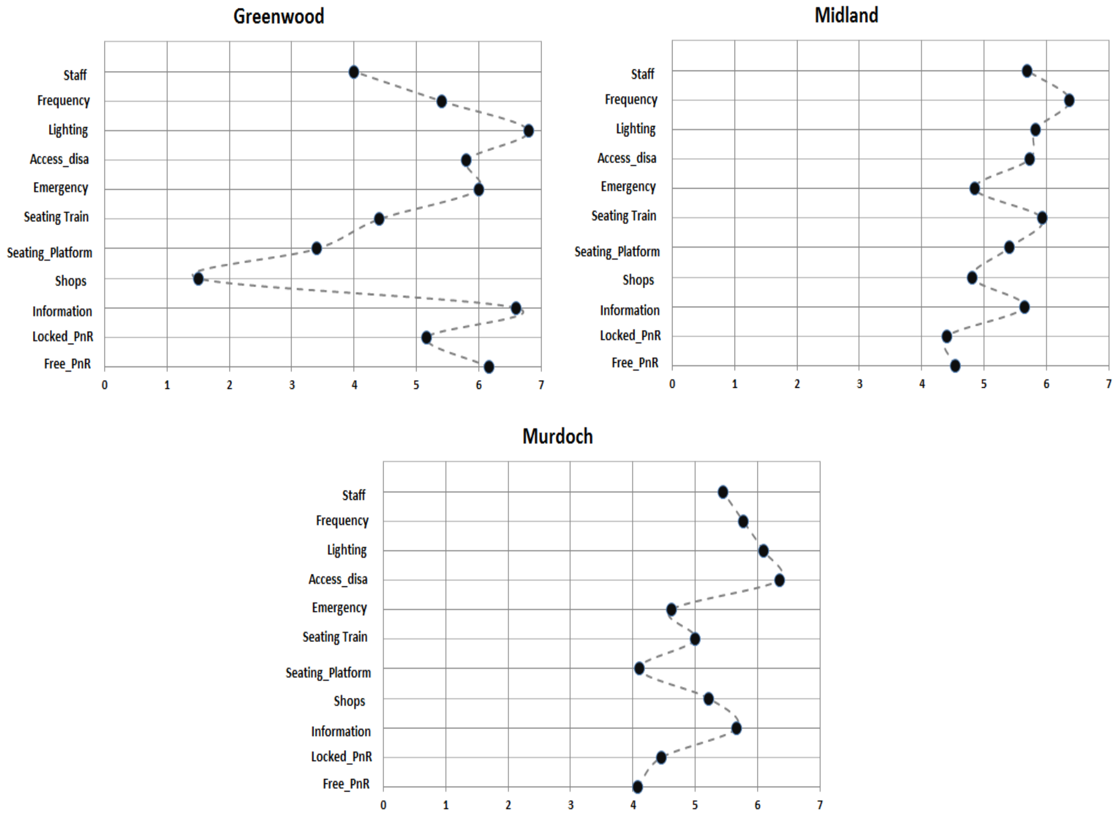

Figure 5: Service Quality of Train Stations

5.4 A Composite Accessibility Index

Overall accessibility was measured for WnR, PnR and BnR modes separately using composite indices. The variables for measuring accessibility were scaled into five unified categories (see Table 3). The weights of these variables are shown in Table 4. The accessibility composite indices for WnR, BnR and PnR were calculated using relations 5-7 respectively (see Figure 6 and Table 5). Generally, the PnR and BnR elderly users considered mixed land-use less important. For WnR, the route directness was evaluated as the most important variable. However, it was less important for PnR users. For them, parking availability and facility and service quality are the key facilities.

Table 4 Weights of Various Factors of Accessibility

WnR	*Weight*	*BnR*	*Weight*	*PnR*	*Weight*
$W_{D_{ij}}$*	0.25	$W_{F(b)_{ij}}$	0.24	$W_{N(p)_j}$	0.2
$W_{d(r)_{ij}}$	0.3	$W_{D_{ikwalk}}$	0.23	$W_{NO(p)_j}$	0.2
W_{H_j}	0.24	$W_{D_{kjbus}}$	0.2	$W_{D_{ij}}$	0.15
W_{Q_j}	0.21	W_{H_j}	0.12	$W_{d(r)_{ij}}$	0.13
		W_{Q_j}	0.21	W_{H_j}	0.13
				W_{Q_j}	0.19

*The definition of the factors can be found at the beginning of the Section 4.2. The origin is *i*, the rail station is *j* and the bus stop is *k*.

Greenwood has more areas with poor or very poor walking accessibility to the train station than other stations. The Midland station has a good accessibility from a PnR perspective. The Murdoch station is in the middle, while Greenwood station again was found to have the poorest PnR provision. From a BnR viewpoint, Greenwood station has a much smaller catchment area than the other two stations. Its accessibility by BnR is from poor to average because there is just one bus service connected to the train station. For both the Midland and Murdoch stations, the areas around the stations have good accessibility by feeder buses. However, this decreases with the distance from the station, which means that towards the edge of catchment areas there is low bus coverage. From Table 5, it can be observed that the average BnR accessibilities of Midland and Murdoch Stations are nearly the same, but the minimum values are quite different. The lowest bus accessibility to Midland train station is relatively lower (1.3) than Murdoch (1.8).

Table 5 The Overall Accessibility

Station	**Average accessibility**			**BnR accessibility**	
	WnR	***BnR***	***PnR***	***Min***	***Max***
Greenwood	2.38	2.36	2.38	1.7	3.06
Midland	3.1	2.55	3.63	1.3	4.22
Murdoch	2.7	2.55	2.61	1.8	4.22

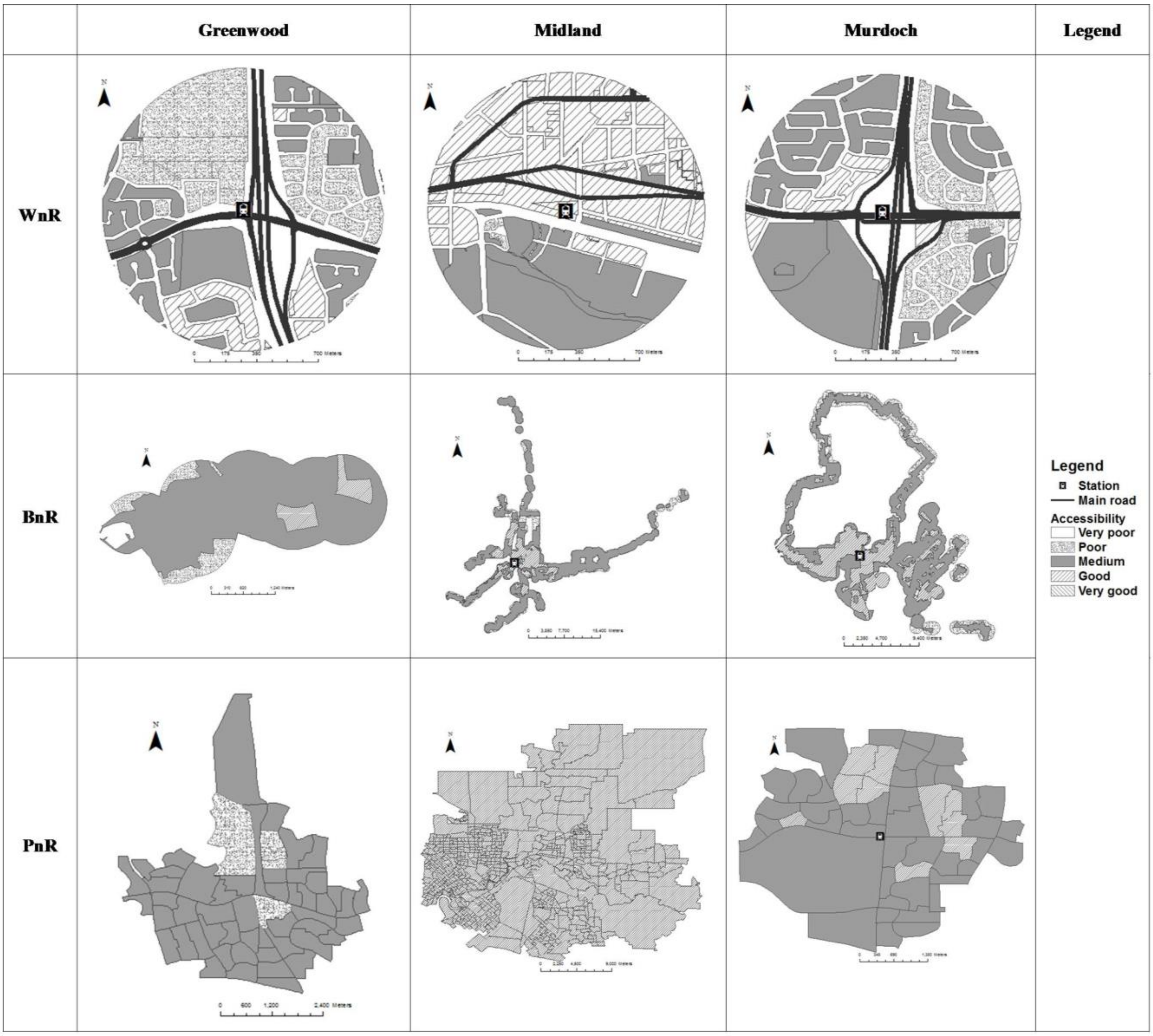

Figure 6: A map of access to and accessibility surrounding three train stations

In order to validate the composite index developed, we also asked the elderly to evaluate the overall accessibility of each station. We call this their perceived accessibility and it was measured on a scale 1 to 5 (Table 6). Because we only have a limited number of responses from the elderly, we did not categorise the perceived accessibility based on various travel modes.

Table 6: A Comparison of Measured and Perceived Accessibility

	Accessibility											
Station	***1***		***2***		***3***		***4***		***5***		***Average***	
	M*	***P****	***M***	***P***	***M***	***P***	***M***	***P***	***M***	***P***	***M***	***P***
Greenwood			20%	40%	73%	60%	7%				2.37	2.33 ($5^{\#}$)
Midland			7%		29%	14%	62%	57%	2%	29%	2.96	3.84 ($6^{\#}$)
Murdoch			10%		70%		20%	63%		37%	2.75	4.33 ($8^{\#}$)

* *M* is measured accessibility and *P* is perceived accessibility.

\# Number of seniors interviewed at the train station, who provided the overall perceived accessibility.

Table 6 shows that except the Greenwood station, the perceived accessibility was evaluated relatively higher than the measured accessibility.

6. Summary and Final Remarks

The main purpose of this paper was to introduce a measure of accessibility to train stations for the elderly population. This composite accessibility index distinguishes among the combined modes of WnR, PnR and BnR using spatial methods.

The approach was implemented in a case study on seven stations in Perth, Western Australia. Respondents were asked to evaluate train station service and facility quality and to provide travel information such as travel time, origin, destination and purpose. It was found that Greenwood station has the lowest elderly patronage and accessibility for the elderly for all three travel modes. In addition, we also found that shopping opportunities around the station, seat availability on the platform, intermodal connectivity and network connectivity or route directness and lack of street parking need to be improved if elderly use of the Greenwood station is to be increased. The Murdoch and Midland stations have relatively good patronage. The walking accessibility to Midland station is generally above average. The areas on the eastern side of Murdoch station have poor access to the station platform and the route directness is relatively low there. In order to improve accessibility of elderly for the PnR, efforts need to be put into increasing short-term parking and street parking capacity for them. This is because on weekdays the elderly usually travel between 9:00am and 3:30pm (when travel is free of charge) when the parking areas are already full. For BnR, the bus frequency and connectivity to trains are the key variables for determining accessibility of elderly travellers to the station.

Another interesting finding of this study is the way in which the elderly respondents evaluated the importance of variables for measuring accessibility. The results can help experts understand the elderly's perception and their possible misconceptions on this matter. This study and the indicators derived are able to point clearly where and what type of interventions are needed to improve the overall public service and in particular the way it can be tailored to the needs of the elderly.

Some limitations were found from this study, such as a misunderstanding of trip origin in the survey by respondents. In our questionnaire, we phrased the question as "Where and when did you start that trip?" Some respondents considered their trip origin as their place of residence, while some of them referred to it as their location immediately before the train trip. Better wording such as "When and where was your last activity (e.g. home, work, education, shopping) immediately before heading to the train station?" could be used in subsequent surveys. In addition, although the Google Directions API is an effective tool to generate routes for the study, some flaws of the tool were found due to the incompleteness of road data. For example, some routings were found missing sidewalks or pedestrian paths.

We used perceived accessibility to validate the measured accessibility. However, the perceived accessibility was found to be relatively higher than measured accessibility. This could be due to a number of reasons, including: sampling error, response bias, and possibility of omitting other important factors that were taken into account by elderly respondents in their assessment. Also, the weighting methods and variables selected for the accessibility index development are somewhat subjective. Ordered logit regression may be used to identify the significant variables and generate weights from the coefficients of the model for the accessibility index.

In future research, it would be worthwhile to compare accessibility to stations for the elderly among different age groups (e.g., 60-69, 70-79 and 80+), as they are likely to have distinct needs, levels of mobility and attitudes towards various facilities and services. This approach is likely to provide further insights on the links between personal mobility and the provision of transport services.

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