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Comparison of elderly public transport accessibility indices: time-based methods

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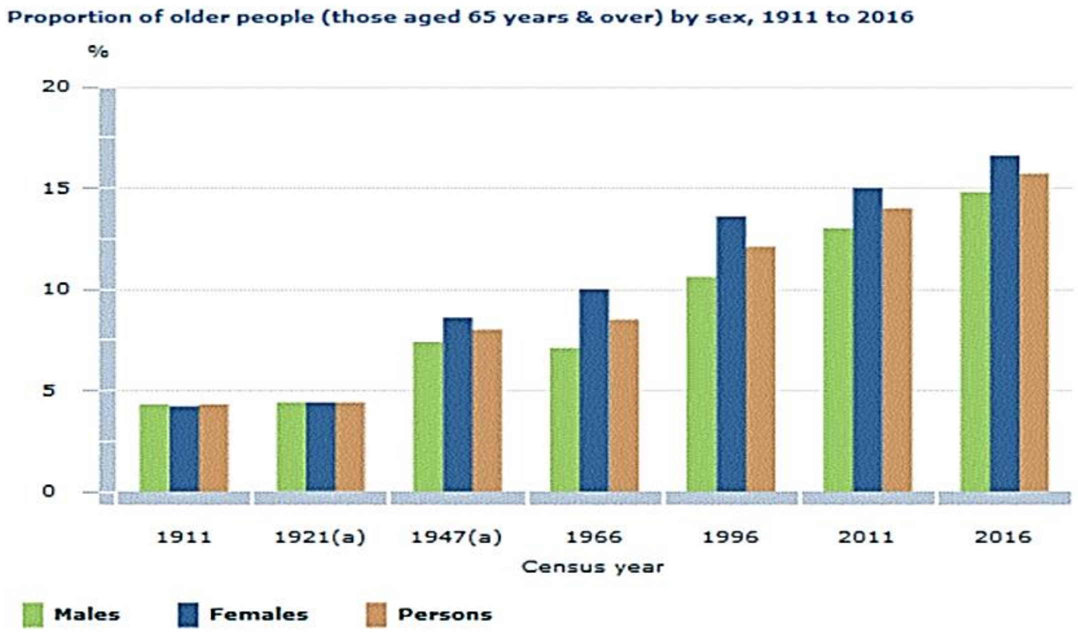
Abstract

Transport accessibility is a fundamental measure used in evaluating the quality of transport systems. A number of studies have been undertaken to measure public transport accessibility for the elderly. But very few have incorporated the travel time as an accessibility measure. This paper compares two indices of elderly public transport accessibility indices using datasets from the greater Melbourne statistical area one (SA1). The first index incorporates in-vehicle time while the second index excludes this variable (in-vehicle time). Both indices considered elderly walk time to public transport stop/destination points of interest (POI) and public transport service frequency in measuring elderly public transport accessibility. Four most commonly travelled destinations shopping centres, health care centres, education centres and recreation centres were considered as points of interest for calculating the accessibility indices. The study establishes that considering in-vehicle time for an index has a different effect on each POIs. This study identifies that the elderly shopping centre accessibility calculation always have lower accessibility if considered in-vehicle time. But in the case of health care, education and recreation centres, the considering in-vehicle time doesn't always have less impact as the shopping centre.

1 Introduction

According to the Australian Bureau of Statistics in 2016 aged 65 years and over living in Victoria State, representing 15.8% of the total population. In Greater Melbourne, 14% of the population were aged 65 years and over in 2016 compared to 15.6% in the rest of Victoria. Lack of proper transport access for this growing elderly population can lead to social exclusion (Bower 1997; Banister & Bowling 2004; Golob & Hensher 2007; Kenyon, Lyons & Rafferty 2002; Preston & Rajé 2007; Gerus et al., 2009; Spinney, Scott & Newbold 2009; Manaugh & El-Geneidy 2012; van Wee et al., 2013). Transport accessibility is a fundamental measure to evaluate the level of quality for transport systems (Fernandez & Santos 2014). Accessibility is the objective of displacement itself and concerns issues related to distance, time and cost to reach a certain destination from a particular origin. It can be identified as a measure of an individual's opportunity to attain different activities for daily life (Iwarsson and Ståhl 2003; Wu and Hine, 2003; Wretstrand et al., 2009). It can also be explained as potential opportunities for socio-economic interactions by an individual (Hine and Mitchell, 2003; Langford et al., 2012; Mithen et al. 2015). Figure 1 represents the elderly population growth in Australia. From this figure, it is identified that the growth percentage of senior people has increased steadily over the past century.

Figure 1: Elderly population growth in Australia (Source: ABS census of population and housing, 1911, 1921, 1947, 1966, 1996, 2011 and 2016)



The public transport accessibility measure identifies the level of service for a specific geographic area. Most researchers encourage active transport and public transport (PT). The use of public transport for the elderly and emphasised the consequent health benefits. Many researchers have focused on public transport accessibility and mode choice modelling (Alsnih & Hensher 2003; Schmo¨cker et al., 2008; Nurlaela & Curtis 2012; Saghapour et al., 2016). A number of researchers have studied travel patterns and travel modes of elderly public transport users (Schmo¨cker 2008; Buys et al. 2012; Lin et al., 2014; O′Hern & Oxley 2015; Boulange et al.2017). For the elderly in Australia distance-based measure has been approached for train station accessibility (Lin et al., 2014). Very few researches focused on elderly public transport accessibility in Melbourne (Rosenbloom & Morris 1998; Currie & Delbosc 2010; Engels & Liu 2013; O'Hern & Oxley 2015). However, for Melbourne elderly considering travel time-based access & elderly population is not presented. This study considered the total travel time from statistical area level one (SA1) towards a point of interest (POI) and the population ratio. Statistical Areas Level 1 is the second smallest geographic area defined in the Australian Statistical Geography Standard. Another contribution of this paper is it compare two indices considering in-vehicle travel time and without in-vehicle travel time for the elderly. Both index calculation considers time-based access towards PT and POI. The index calculation also includes the population ratio of the total population and the elderly for a specific SA1. In this study people aged over 65 is considered as elderly.

The following section 2 explains about elderly accessibility background & research focus. Section 3 describes the data collection for index calculation. Section 4 introduces the methodology of the index calculation. Section 5 results & discussion and section 6 highlights the summary key results with direction for future research.

2 Background

For elderly trip-making primarily occurs during mid-day peak and daylight hours. O'Fallon and Sullivan (2003) showed that in New Zealand, make most of their trips between 9:30 am and 3 pm. The most common destinations of travel for seniors are shops, health care centres and retirement recreation centres (Fobker & Grotz 2006). Elderly travel may also include some trips to undertake voluntary work, particularly formal volunteering (Pramitasari & Sarwadi 2015). A part of the older population is involved in 'Education escorting', which means taking children to school. Seniors also travel to visit retail services including banks, post offices and chemists. For elderly people, it is important that all the basic required resources such as shopping, leisure, health care exist locally. The public transport system has to be adapted according to the needs and expectations of older people. The public transport system needs to attract older passengers and also familiarise them with the usage of the services. Mobility difficulties increase with age, with only 4% of younger people having such difficulties, which increases to 17% for those aged 60–69 and to 39% for those aged 70 and over (Mackett 2015). One reason that older people make fewer trips than younger people is that some of them find travelling by public transport difficult. Another frequent visit by Melbourne elderly is social places (Mackett 2015).

2.1 Accessibility measures categories

Public transport accessibility measure can define how easily an individual or a group of people can reach a targeted destination. In the literature, different studies have presented a number of accessibility indices using different land-use, trip variables, travel time, distance (from origin to destination, and from origin to access each mode, such as walking distance to transit stations) (Levinson& Kumar 1994; Cervero 2002; El-Geneidy & Levinson 2006; Litman 2018). Handy & Niemeier 1997 claim that the best approach in measuring accessibility does not exist. Researchers classified public transport accessibility indexes into different classes. The summary of different index classes is as follows:

- Infrastructure-based accessibility:
- Utility-based accessibility
- Person-based measures
- Distance-based accessibility index
- Gravity-based measures
- Cumulative-opportunity measure
- Land Use and Public Transport Accessibility (LUPTAI)
- Public Transport Accessibility Level (PTAL
- Public transport accessibility Index (PTAI)

A recent study of South Australia non–metropolitan elderly developed an accessibility index (SATDI) (Lange & Norman 2018). This research developed a spatial index to quantify the degree of service accessibility/transport disadvantage for the elderly population of two specific regions of South Australia. The index considered two variables as utilization of accessibility by elderly & quantifying the public transport availability. This index also considered the bus frequency & walking distances for the elderly. SATDI is a good measure of regional elderly public transport accessibility. However, a metropolitan area with a combination of bus, train and tram the calculation will not be straight forward. Another index (Lin et al., 2014) was proposed by a group of researchers from Perth, Australia. The index is distance-based. The index has a good impact on calculating elderly public transport accessibility. The index considered a variety number of components. This index considered network connectivity, the distance between origin and destination, service quality, activities elderly participating.

2.2 Research focus

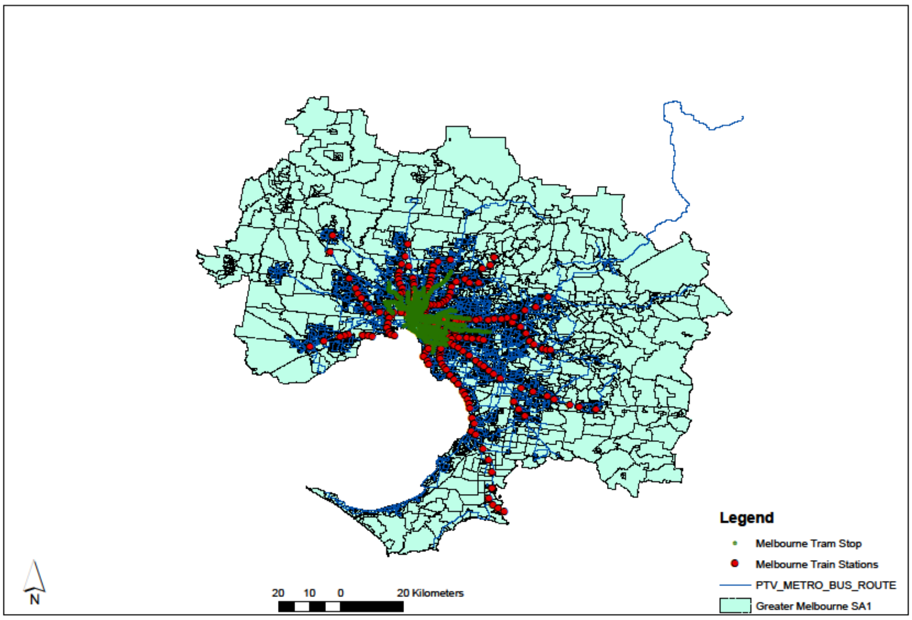
This research developed indices from SA1 towards the point of interest (POI) in the Greater Melbourne area. Form each SA1 four mostly travelled POIs by the elderly accessibility have been calculated. This paper introduces two sets of accessibility indices. The in-vehicle time during travel is one of the major variables. This comparison shows that considering the in-vehicle time for accessibility index calculation is not constant for all POI. If POI needs to reach by a public transport mode then the in-vehicle time has a large impact on it. The index value becomes higher while considering in-vehicle time. It indicates that the elderly need to travel more time to reach their designated destination. Some POI is easily accessible by private mode of transport. However, if the same destination needs to reach by PT mode it takes more time. The average waiting time (for PT mode) and the in-vehicle time is a major element for this extended travel time. For the elderly long travel time, time to reach the destination is always out of comfort level. This research focused to identify the impact of in-vehicle time for the elderly public transport accessibility.

3 Data collection

3.1 Study area

Melbourne, the state capital of Victoria, Australia, consists of several interlinking transport modes. Public transport including the tram network, trains and buses is a key part of the transport system. This study developed indices considering the elderly travel & population of SA1. From elderly trip details data using VISTA four mostly travelled POI (Shopping Centres, Health Care Centres, Education Centres & Recreation Centres) has been chosen for index development (Fatima & Moridpour 2019). Figure 2 shows the distribution of public transport stops/stations within Greater Melbourne statistical area.

Figure 2: Greater Melbourne public transport distribution



3.2 Time calculation

- Walking speed for the elderly has been considered as 0.70 m/s although the index calculation. Standard walking speed is 1.1~1.2 m/s. For cases as the elderly, much lower speed of walking is considered (Graham et al., 2010; Yang & Ana 2012).
- Service frequency data were calculated from the timetable of each mode during the elderly morning peak hour travel (9:30 to 10:30 am) for weekdays. Public transport Victoria (PTV) journey planner has been used to calculate the in-vehicle time between two stops. From a specific SA1, the nearest PT stops have been calculated through ArcMap 10.3.1. The same procedure applies to calculate distance from POIs' nearest PT stops. From the Victoria government open datasets, map data files have been extracted to plot the greater Melbourne statistical area and public transport coverage.
- Victorian Integrated Survey of Travel and Activity (VISTA) is a detailed picture of Victorian household travel is collected. VISTA data sets are a wide range of data including all age range, destination, travel mode, time, all statistical area& weighted value. Around 46563 trip details responses for weekdays & weekend have been documented on VISTA 2012-2016 time period. Around 6967 elderly trip details responses separated from the original datasets using SPSS analysis.
- From the various Victoria government open data source, the total travel distance between origin point (SA1 centroid) and destination (PT stops /POI) has been separated. The travel time using the train, tram and bus has been calculated from public transport Victoria website. Datasets have been analysed using SPSS and ArcMap. From each SA1 the nearest PT stop has been considered.

3.3 Population data

The total population of the elderly for each SA1 has been analysed and extracted. The total population for each SA1 has been collected from the Victoria government census data.

4 Methodology

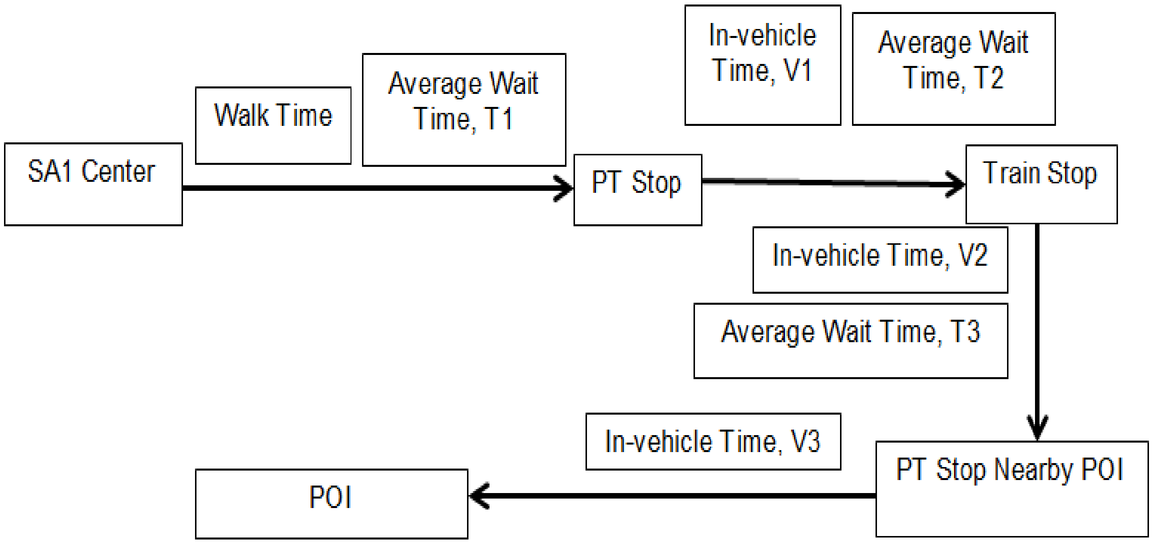
For the elderly reaching to POI from one specific SA1 can be classified into three different methods. The time calculation for the elderly accessibility indices considers these three different ways of travel steps. The elderly public transport time calculation for both indices are presented in table 1. From the centre of SA1 walk time for the elderly towards the nearest PT stop has been calculated. If the elderly are catching a bus (or tram) to reach a train station the total average waiting was considered for both bus and train. Again if the elderly needs to catch a bus (or tram) to reach the POI from the train station then average waiting time also considered this waiting time. In-vehicle time has been considered as the travel time spending in a transport mode. This time has been analysed and extracted from the Public Transport Victoria website (PTV). Figure 3 illustrates an example of the calculation method. The calculation of average waiting time for method one is cumulative of T1, T2 and T3. In-vehicle time calculation is cumulative of V1, V2 and V3. The method two was considered when T1, T2, T3, V1, V2 and V3 are zero value. Again method three has been considered when V3 and T3 is zero value. For the calculation of Index 2 in-vehicle time was not considered.

Table 1: Comparison of index 1 and index 2

	Index 1 ($EPTAI_{In-v}$)*	Index 2 ($EPTAI_{Win-v}$)*
Method One	Walk time from SA1 to nearby PT stop plus average waiting time plus in-vehicle travel time plus walk time to nearest PT Stop of POI plus in-vehicle time & average waiting time.	Walk time from SA1 to nearby PT stop plus average waiting time to reach POI.
Method Two	Walk time from SA1 to POI when the point of interest is closer than any public transport stop.	Walk time from SA1 to POI when the point of interest is closer than any public transport stop.
Method Three	Walk time from SA1 to PT stop plus average waiting time plus in-vehicle travel time plus walk time to POI.	Walk time fromSA1 to PT stop plus average waiting time plus walk time to POI.

1.*($EPTAI_{In-v}$)= Elderly public transport accessibility $index_{in-vehicle}$
2. *($EPTAI_{Win-v}$)*= Elderly public transport accessibility $index_{without\ in-vehicle}$

Figure 3: Time- based index calculation



4.1 Approach

EPTAI introduces a time-based approach. The time approached has calculated several occasions (Ewing & Cervero 2010) but for the elderly very limited index available.

This paper identifies a comparison between two developed time-based indices for elderly travel considering three modes of PT towards four major points of interest. This index uses the nearest PT stop distance for both SA1 location & POIs. The indices developed in this paper calculate the sum of equivalent doorstop frequency (EDF) of all different public transport modes. The proposed accessibility index considering in-vehicle time is presented in Equation 1.

$$EPTAI_{in\text{-}vehicle} = \sum_{j=1}^{4} TT_{ratioPOI} \times (P_{ratio} * 10^2) \text{ --------(1)}$$

$$\mathrm{TTratio} = \frac{\mathrm{TT}\ of\ POI1}{TT\ of\ (POI1+POI2+POI3+POI4)} \text{ --------(2)}$$

$$Pratio = \frac{\mathrm{Total}\ Elderly\ Population\ in\ SA1}{Total\ population\ in\ SA1} \text{ --------(3)}$$

Where, TT_{ratio} is the total travel time ratio for a specific POI.
TT=WT to nearest PT stop+ In VT+ AvWT+WT to nearest stop of POI+WT to POI
TT=WT to nearest PT stop+ In VT+ AvWT+ WT to POI
(if WT to nearest stop of POI=0)
POI1-Shopping centre
POI2= Health Care centre
POI3= Education centre
POI4=Recreation Centre
Pratio=Total population ratio of SA1 (Elderly & total).
j indicates the destination considering four main destination POI for the elderly.
WT=Walk time
In VT= In-vehicle time
AvWT=Average waiting time
The second accessibility index for the elderly without considering in-vehicle time is presented in Equation 4.

EPTAIwithout in-vehicle= $\sum_{j=1}^{4} TT_{ratioPOI} \times (P_{ratio} * 10^2)$ ---------------------------------------(4)

TT=WT to nearest PT stop + AvWT+WT to nearest stop of POI+WT to POI
TT=WT to nearest PT stop+ AvWT+ WT to POI (if WT to nearest stop of POI=0)
TTratio POI =same as Equation 2
Pratio = same as Equation 3

4.2 Accessibility calculation

This study calculates the elderly level of accessibility towards POI for specific SA1. Both accessibility indices considered the closest PT stop for calculation.

4.2.1 Walk time (WT)

The elderly walking speed 0.70 m/s (Graham et al., 2010; Yang & Ana 2012) has been considered to calculate walk time. Centre of each SA1 has been located using ArcMap. The walk distance to nearest PT stop from the centre of SA1 has been measured using ArcMap. The second step of WT calculation includes walk distance from POI to the nearest stop of POI.

4.2.2 Average waiting time (AvWT)

The average wait time is between the arrival time to the nearest PT stop & the service arrival. For each selected route, the average waiting time was considered as the service frequency. For example, if a service runs every 10 mins then the frequency of the service is 6/hr. For this case, AvWT will be 5 mins. The AWT is estimated as half the headway (i.e. the time interval between services) as shown in Equation 5 and Equation 6.

$AvWT_{SA1}$=0.5∗(60/Fi)+ 0.5∗(60/Fj) ---(5)
$AvWT_{SA1}$=0.5∗(60/Fi) if Fj=0 ---(6)

Where, $AvWT_{SA1}$ is the average waiting time (minutes) for SA1 towards specific POI. Fi is the frequency of PT mode towards POI. Fj is the frequency from PT stop to connecting PT mode to destination POI. If the POI is within walking distance then Fj=0.

4.2.3 In-vehicle time (InVT)

In-vehicle, time is the total travel time within a transport mode. The nearest PT stop for both SA1 & POI was measured & identified using Arc Map.

4.2.4 Total travel time (TT)

After calculating WT, AvWT, InVT the total travel time was calculated for each POIs from one specific SA1. All the distance & time has been calculated & analyzed separately for major POI. The travel time is different form each SA1 toward one specific POI. Separately calculated TT provides a more accurate elderly accessibility measure for each POIs. Equations 6, 7, 8 & 9 are the time ratio equation for four POIs mostly used by the elderly.

$$\text{TTratio} = \frac{\text{TT } of\ POI1(Shopping\ centre)}{TT\ of\ (POI1+POI2+POI3+POI4)} \quad (7)$$

$$\text{TTratio} = \frac{\text{TT } of\ POI2(Health\ care\ centre)}{TT\ of\ (POI1+POI2+POI3+POI4)} \quad (8)$$

$$\text{TTratio} = \frac{\text{TT } of\ POI3(Education\ centre)}{TT\ of\ (POI1+POI2+POI3+POI4)} \quad 9)$$

$$\text{TTratio} = \frac{\text{TT } of\ POI4(Recreation\ centre)}{TT\ of\ (POI1+POI2+POI3+POI4)} \quad (10)$$

4.2.5 Elderly population calculation (P_{ratio})

The population is one of the key variables to calculate accessibility (Ewing & Cervero 2010). Population calculation for elderly accessibility index is not very common. The reason is the unavailability of proper data & estimation. From various data sources, the elderly population has been analysed & calculated using SPSS.

5 Results and discussion

For each SA1 the distance has been measured & analysed using ArcMap direct distance. Equation 1 has been used for elderly accessibility index including in-vehicle time. Equation 4 was considered for elderly accessibility index without the in-vehicle time. For each POI total travel time ratio was calculated using Equation 7, 8,9,10 according to the travel destination. Table 2 represents a summary of the travel time calculation for POI1. The average distance of the PT stop from SA1 is a much lower value than the standard deviation. It indicated not all SA1 having easy access to PT stop. Again distance from SA1 to the shopping centre also varies from average to standard deviation value. From Table 2 average travel distance is 35% lesser than the standard deviation. The difference between the standard deviation & means indicates that the datasets don’t have a constant flow or it is not uniform all through. The reason behind it from each SA1 shopping centre distance is different. When calculating both EPTAI (with and without in-vehicle time) each SA1 needs to calculate separately as no two SA1 have the same access.

Table 2: Elderly travel statistical summary for a shopping centre (POI1)

Stv.* (SA1 to PT Stop), km	Avg Dist* (SA1 to PT Stop), km	Stv. (Dist of SA1 to POI1), km	Avg Dist (Dist of SA1 to POI1), km	Stv. (Total Travel Time), Min	Avg. (Total Travel Time), Min
1.92	0.576	7.752	5.739	98.948	86.839

3. Stv.*= Standard Deviation, 4. Avg Dist*= Average Distance

Table 3 represents the statistical travel summary of the health care centre. This table also indicated that the health care centre travel distance &time is different for each SA1.

Table 3: Elderly travel statistical summary for health care centre (POI2)

Stv.* (SA1 to PT Stop), km	Avg Dist* (SA1 to PT Stop), km	Stv. (Dist of SA1 to POI2), km	Avg Dist (Dist of SA1 to POI2), km	Stv. (Total Travel Time), Min	Avg. (Total Travel Time), Min
1.92	0.576	3.127	1.709	76.484	43.629

Table 4 and Table 5 represent the statistical travel time summary for the education centre and recreation centre respectively.

Table 4: Elderly travel statistical summary for the education centre (POI3)

Stv.* (SA1 to PT Stop), km	Avg Dist* (SA1 to PT Stop), km	Stv. (Dist of SA1 to POI3), km	Avg Dist (Dist of SA1 to POI3), km	Stv. (Total Travel Time), Min	Avg. (Total Travel Time), Min
1.92	0.576	0.555	0.441	20.202	13.414

Table 5: Elderly travel statistical summary for recreation centre (POI4)

Stv.* (SA1 to PT Stop), km	Avg Dist* (SA1 to PT Stop), km	Stv. (Dist of SA1 to POI4), km	Avg Dist (Dist of SA1 to POI4), km	Stv. (Total Travel Time), Min	Avg. (Total Travel Time), Min
1.92	0.576	1.464	0.987	39.739	28.891

Table 6: Elderly indices summary comparison

POI	Avg. Total Travel Time, Min	Avg. In-Vehicle time, Min	Mean EPTAIIn-v	Mean EPTAIWin-v	%Comparison
SC*	86.839	22.272	44.334	41.103	7.287
HCC*	43.628	11	19.159	20.482	-6.905
EC*	13.414	0.24	7.981	9.166	-14.847
RC*	28.892	1.935	16.425	18.167	-10.605

5.*SC= Shopping Centre, 6. HCC=Health Care Centre, 7. EC=Education Centre, 8. RC=Recreation Centre

Table 6 represents the summary comparison of two developed indices for each POIs. From Table 6 the parameter in-vehicle time has an impact on accessibility index which measures the quality of PT access. This is one of the reason elderly use private vehicle than public transport (According to VISTA data). Higher the travel time that accessibility index value is also high. The higher index values shows are lower the accessibility for that specific SA1. Table 6 also describes that for shopping centre accessibility in-vehicle time has a positive effect, It can be clarified as shopping centres are usually far away compared to the other three POI. For the shopping centre, in-vehicle time is one-fourth of total travel time. The elderly generally attended health care facilities nearby. So the overall in-vehicle travel time is not higher. For health care centre average of indices varies around 7%. Again education & recreation centre is stated nearby the place of origin (VISTA data). So elderly use short cut & walking mode to reach this destination.

6 Conclusion and future research direction

The aim of this study focused to compare two different indices for elderly PT accessibility in the greater Melbourne region. This study summarized that health care, education and recreation centre accessibility index value is better without calculating in-vehicle travel time. This study also summarized that considering the in-vehicle time for elderly public transport accessibility is significantly important.

The technical approaches on these indices can be applied for any public transport mode in urban cities for the elderly. These indices also can be calculated for another point of interest elderly visit frequently. This paper has analyzed that one major variable (in-vehicle time) can be a huge impact on accessibility index calculation. The indices can be used to identify elderly PT accessibility level. In-vehicle time index can implement to resolve elderly PT travel issues. Specially for shopping centres, the elderly faced major delay for in-vehicle travel time length. The study also summarizes that in case of elderly PT usage point of interest is also a key factor. The elderly travel behaviour to various POIs is different. The study didn't consider the private transport access from SA1 to nearest PT stop or POIs to the nearest stop. Using private transport to reach public transport accessibility is a mode choice varies from person to person. If the elderly use private transport to reach any PT stop that has not been considered for EPTAI calculation. Future research may consider these effects.

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