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**Title**

Quantifying Service Accessibility/Transport Disadvantage for Older People in Non-Metropolitan South Australia

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## 1. Abstract

The proportion of Australia's population aged 65 years and over is increasing. In a highly mobile society that relies on car transportation for obtaining essential goods and services, challenges exist for the ageing population when their ability to utilise a car as a form of transport diminishes. Limited transport is a particular concern for those living in non-metropolitan areas due to reduced service accessibility.

This research aimed to develop a spatial index to quantify the degree of service accessibility/transport disadvantage for the population aged 65 years and over living in the Murray and Mallee region of South Australia. The index developed comprised two components. The first component incorporated accessibility to key services utilised by older people. The second component quantified public transport options. Together, these components formed a composite index that can be used independently or in conjunction with other spatial datasets. The index methodology developed has the capacity to be broadly applied through the adaptation of key parameters specific to other population cohorts and would benefit from application in other non-metropolitan regions within Australia and abroad.

## 2. Introduction

The movement of people from one destination to another for the purpose of accessing goods and services is an important aspect of everyday life. Car travel is the most utilised source of transport in western societies (Jordon and Nutley 1993; Robinson 2011) and people without access to a car are often considered disadvantaged (Mamun 2011; Rosier and McDonald 2011; Shergold and Parkhurst 2012). Reliance on car travel poses a challenge for older people who may have diminished physical capacity and be unable to operate and maintain a car to access required goods and services. To date, little research attention has focussed on public transport access and ageing in non-metropolitan locations (Feist 2011; Hugo et al. 2010). With increasing numbers of older people residing in non-metropolitan regions of Australia where public transport coverage is most often poor (Hugo et al. 2009), the challenge of providing continued access to essential services, particularly for this population group, remains a pertinent issue (Truong and Somenahalli 2011).

This first aim of this paper is to review the literature relevant to transportation and ageing, and specifically, to review the various spatial indices that have been developed to measure service accessibility and public transport service provision to date. The second aim of this paper is to outline the development of a spatial index that was constructed to identify areas of high and low service accessibility with respect to older people, in a non-metropolitan region of South Australia. This paper includes discussion with regard to ways in which the index that was developed and could be used (e.g., by planners and policy makers) to identify and improve service access for older people aged 65 years and over, with a critique of index assumptions. The paper concludes with recommendations for further enhancements of the index and suggestions for future research.

### 2.1 Ageing and Transportation

The nature of ageing societies has been well publicised and documented (Baster 2012; Feist 2011; Truong and Somenahalli 2011). In Australia, around one in four people will be aged 65 and over by 2056 (ABS 2008). Specific to the South Australian regional context, the Australian Bureau of Statistics (ABS) has projected that by 2056 there will be fewer than two people of working age for every older person in the non-capital city areas of South Australia (ABS 2009). As a person ages, they may experience diminished or complete loss of some or most physical capabilities. The ability to drive a car is an activity that is commonly compromised for older people with diminished or loss of physical capability and this can pose a significant challenge to older people who have built up over their lifetime a reliance on car travel to maintain social networks and access to goods and services (Kim and Ulfarsson 2004). The inability of an older person to access transportation can also have a substantial impact on their physical and mental health and wellbeing through the association of transport with opportunities for social interaction, access to essential healthcare, and a sense of general independence (Davey 2007; Kim 2011; Shergold and Parkhurst 2012; Su 2007).

Public transport (i.e., buses, trains, trams) provides an alternative to car travel. Although this alternative may be less convenient, operating at set times of the day and using designated routes, public transport provides a viable alternative means of transport for older people. The concept of geographic accessibility to public transport and its measurement is considered important for a variety of reasons within many countries, including Australia, New Zealand, North America and the United Kingdom (Currie 2004; Mamun & Lownes 2011; Pitot et al. 2005; Rocha et al. 2015; Musselwhite 2011). However, public transport accessibility in non-metropolitan areas tends

to be overlooked in research and government policies as it is generally considered uneconomical to provide frequent and regular public transport to low density populations (Nutley 2003). Public transportation is often assumed to lack relevance in non-metropolitan locations due to the high proportion of car ownership and dispersed pattern of service outlets (Jordon and Nutley 1993; Rosier and McDonald 2011) and as a result, car travel remains a necessity (AIHW 2007; Kamruzzaman and Hine 2011; Kim 2011).

## **2.2 Service Accessibility**

In Australia, the importance of developing composite geographical indices for quantifying service accessibility/remoteness has been noted for some time (Coffee et al. 2012; Mamun and Lownes 2011; McGrail and Humphreys 2009; Yigitcanlar et al. 2007). From 1965, different methodologies have been applied to distinguish metropolitan and non-metropolitan areas that contributed to identification of goods and service accessibility challenges faced by those living in rural and remote locations. As reviewed in Hugo et al. (1997), notable methodologies in Australia include: (1) the Faulkner and French index, a six-level urban centre hierarchy based on population thresholds as an indicator of localised availability of goods and services; (2) the Rural, Remote and Metropolitan Areas Classification (RRMA), a seven-level classification system incorporating ABS Statistical Local Areas (SLA) which was used to address social justice and economic issues facing non-metropolitan Australians; and (3) the Griffith Service Access Frame (GSAF), a single index value based on ABS collection districts and three key component factors of which included a time/cost/distance factor, population based urban centre size hierarchy specific to a certain purpose (e.g. access to tertiary education) factor, and an economic resource factor based on the ABS index of economic resources (Hugo et al. 1997).

Subsequent to the above methodologies, the Accessibility/Remoteness Index of Australia (ARIA) was developed in 1998-1999 by the University of Adelaide and is arguably the most notable methodology with regard to quantifying service accessibility/remoteness in Australia to date. ARIA was developed as a purely geographic index measuring accessibility/remoteness in non-metropolitan Australia (APMRC 2013b). ARIA quantified accessibility/remoteness by measuring road distances from populated localities/towns to four levels of service centres based on different urban centres population sizes - Category A = 250,000 or more; Category B = 48,000 to 249,999; Category C = 18,000 to 47,999; Category D = 5,000 to 17,999 (Bamford and Dunne 1999). The road distance measurements for every populated locality/town centre to each of the four service centres were standardised to a ratio score by dividing the measured distance for a given locality by the Australian average (mean) for each service centre category. Each resulting ratio value was limited (referred to in the ARIA methodology as 'thresholding') to a maximum score of three (i.e. three times the Australian mean) to remove the effects of extreme values from the index (GISCA 2004). For each populated locality/town centre, the ratio value from each of the service centre categories was summed to produce an overall index value ranging from 0 representing high accessibility/low remoteness to 12 representing low accessibility/high remoteness (DHAC 2001). Index values for each locality were then transferred to a 1 kilometre (km) square grid by application of an inverse distance weighted algorithm to permit the generation of an accessibility/remoteness score for any location within Australia (AIHW 2004). An update of the ARIA methodology took place in 2001 which resulted in the inclusion of a smaller fifth service centre level (Category E = 1,000 to 4,999), and an adjusted index range of 0 to 15 (APMRC 2013a). Since 2001, the ARIA methodology (renamed ARIA plus or ARIA+) has been updated every five years to coincide with Australian census releases and has been used to create remoteness area categories for the dissemination of various social and demographic statistics by the ABS (ABS 2011c). Since 2001, ARIA+ has been applied in a range of settings including demographic analysis, service planning and resource allocation (APMRC 2013b). Customised applications of the ARIA+ methodology include Pharmacy ARIA, General Practitioner ARIA, Cardiac ARIA, and Metro ARIA (APMRC 2015; APMRC 2013b; Clark et al. 2011).

## **2.3 Public Transport Accessibility**

There has also been a range of methodologies developed (in Australia and overseas) to qualify the effectiveness of different transportation systems as well as identifying gaps in existing public transportation service provision. From an overseas perspective, Fu and Xin (2007) developed the Transit Service Indicator (TSI) in an attempt to combine a number of different approaches that utilised: (a) transport service frequency (temporal coverage); (b) service (spatial) coverage; and (c) service accessibility, to arrive at a comprehensive multiple performance measure for evaluating the quality of a public transportation network. The TSI utilised a series of equations as part of a seven-step process to achieve a comparison between a weighted door-to-door travel time by walking and car travel and a similar weighted travel time by walking and public transport from an origin point to a destination point at the same time of day (Fu and Xin 2007). Mamun and Lownes (2011) applied three different approaches to arrive at a composite index of public transport accessibility. These approaches comprised: (1) the

Transit Capacity and Quality Service Measure; (2) the Local Index of Transit Availability; and (3) the Time-of-Day-Tool. These approaches were chosen to reflect three primary accessibility measures common amongst previous public transportation research, namely: (a) trip coverage: availability of public transport to and from desired origin and destination locations; (b) spatial coverage: transit stop locations in proximity to a person's residential address; and (c) temporal coverage: service accessibility at different travel times during the day (Mamun and Lownes 2011).

In Australia, Currie (2004) developed a method for assessing the ability of public transport to meet the needs of transport-disadvantaged persons which were defined as adults without access to car travel; persons aged 60 and over; persons on a disability pension; low income adults; unemployed adults; and students (Currie 2004). Currie's methodology comprised two components: (1) network supply modelling to determine the quality of travel by public transport; and (2) a measure of accessibility from a person's home to basic services (Currie 2004; Mamun and Lownes 2011). Also within Australia, the Land Use and Public Transport Accessibility Index Model was developed in 2005 by the Griffith University, Queensland Transport, and the Gold Coast City Council, and considered walking distances and public transport travel times (Pitot et al. 2005; Yigitcanlar et al. 2007). This index was used as a decision making tool to assist Australian local and state governments to quantify access from specific land use destinations, such as health, education, retail, employment, financial and postal services (Pitot et al. 2005; Yigitcanlar et al. 2007).

In summary, the service accessibility approaches within Australia have culminated in the development of a concept based on accessibility/remoteness, derived from a person's potential to access required goods and services. However, this perspective does not consider the transportation means for accessing required goods and services. Of the public transport approaches reviewed, various performance measures have been utilised to quantify public transport service quality, network coverage, and to identify gaps in existing public transport provision with respect to accessing basic services or key land use destinations. In general the transportation accessibility methodologies reviewed have a focus on metropolitan locations where public transportation services are likely to be more frequent and well-developed. To our knowledge, research to date has not developed a tool that combines service accessibility and transportation approaches specific to the needs of older people residing in non-metropolitan regions. To this end, the objectives of this research were: (1) to develop a spatial index that quantified the degree of service accessibility/transport disadvantage for the population group aged 65 years and over; and (2) to determine the usefulness of index developed from a transport/service planning perspective. The Murray and Mallee region of South Australia was used to develop and test the methodology.

### **3. Methodology**

The composite index developed was termed the Service Accessibility/Transport Disadvantage Index (SATDI). The SATDI was designed to incorporate: (1) an indication of accessibility/remoteness to a desired destination as a measure of distance travelled along the road network; (2) representation of access to essential goods and services most required by people aged 65 years and over to maintain independence and quality of life; (3) a performance measurement for the effectiveness of public transportation; and (4) an indication of a person's residential proximity to public transportation services. The SATDI was fashioned from the consolidation of these factors into two components: (1) service accessibility; and (2) public transport accessibility. Spatial analysis techniques utilised ESRI ArcGIS 10.1 for Desktop software.

#### **3.1 Service Accessibility Component**

Service accessibility was quantified by measuring the distance (along the road network) from residential locations to five key services identified as important to older people outside of their home. Three datasets were used for this component. The first dataset was a subset of primary data compiled as part of a study by Hugo et al. (2010) which explored access and connection to the broader community by older people living in the South Australian Murray and Mallee region. Data from a subset of participants from this study (n=705) was extracted for analysis. Participants were selected for analysis if they were aged 65 years and over at the time of recruitment to the Hugo et al. (2010) study and if they were living within the study area (i.e., the Murray and Mallee region). The spatial distribution of participants selected for analysis was found to be generally representative (+/-5.64%) of the total number of older people within the study area for most of the eight Local Government Areas (LGA) when compared against the total number of older people (using recent Australian census data) as a percentage by LGA. As part of the research conducted by Hugo et al. (2010), participants were

asked to “List the name and location of any services that you use outside of your home”, with the option of listing up to eight different service names/types. As part of the development of the SATDI, participant responses to this question were combined, yielding 2,174 individual responses which were subsequently grouped into 55 service types. The top five service types (comprising over 60% of all participant responses) were chosen for incorporation into the service accessibility component of the SATDI. These were: (1) medical clinic/General Practitioner (GP); (2) groceries; (3) general shopping; (4) optometrist; and (5) dentist. All services currently operating and located within the study area that could be classified within one of the five service types were included in the analysis. Services located within a 20 kilometre buffer zone of the study area were also included since people generally do not limit their access to required goods and services to the administrative and/or census geographical boundaries in which they live. The ABS Urban Centre/Localities dataset (ABS 2011b) was used to represent “general shopping” locations, using the centre point (centroid) of each urban centre within the study area and locations within the 20 kilometre buffer zone since the service access category “general shopping” did not allow for identification of specific retail locations for inclusion. In accordance with the ARIA+ methodology, urban centres over a population size of 1,000 were considered to have some basic level of services (APMRC 2013a) and were therefore considered appropriate for use to represent this generic service category.

South Australian Dwelling Points (derived from the 2011 South Australian Digital Cadastral Data Base and Land Valuation Data), formed the second dataset used for the service accessibility component of the SATDI. These dwelling points represent the centroids of South Australian residential property locations, provided by the South Australian Department of Planning, Transport and Infrastructure. For the SATDI, residential property locations were used to measure service accessibility (by road distance) to out of home services used by older people. This approach was based on the Metro ARIA methodology (APMRC 2015) and incorporates a measure of accessibility to the five key service types identified as relevant to older people from every residential location that exists within the study area.

The final dataset for the service accessibility component of the SATDI comprised a detailed road network for South Australia, provided by the South Australian Department of Planning, Transport and Infrastructure (DPTI 2012). This dataset contained road centrelines, road directions (e.g. one way streets), elevation information (to incorporate freeway overpasses) and road classes (e.g. local roads, main streets and freeways). The road network covered the study area and extended 100 kilometres from the boundary of the study area. Distances along the road network were calculated from each dwelling point to the closest service location for each of the five service types.

A four-step process that was adapted from the ARIA+ methodology and utilised the above three datasets was used to calculate service accessibility. First, the road distance from each dwelling point to each of the nearest five service types was calculated. Second, the average distance from all dwelling points to each of the five service types was calculated. Each calculated distance was then divided by the average distance to each service type, resulting in a ratio score for each dwelling point. Third, all ratios above a score of 3 were limited (i.e., “thresholded”) to a maximum ratio score of three. Thresholding was implemented to remove the effects of extreme values on the SATDI whereby a very large ratio score for one or more service types could significantly increase the final service accessibility measure. Finally, in step four, all standardised ratio scores were summed so that a final index score ranging from 0 (high accessibility) to 15 (low accessibility) was produced for each dwelling point.

### **3.2 Public Transport Accessibility Component**

Public Transport Accessibility was quantified by measuring: (a) the frequency of public transport services from each public transport collection point (located within the study area); and (b) the distance a person was likely to walk from their residential address to access the nearest public transport collection point. Frequency of public transport services focussed on accessibility to transport by bus since bus services were the predominant form of public transport available across the study region. Based on a review of the literature regarding previous transit accessibility measures, a measure of bus frequency from each bus stop location over the course of one week was applied (termed ‘bus frequency’ from this point forward). A weekly measurement cycle was utilised given the infrequency of bus services across the study region. In addition to this, a number of further criteria were developed to determine the final bus frequency score, with the resulting criteria and rationale detailed in Table 1. Applying these criteria resulted in a total of 21 bus routes (comprising 121 individual bus stops) eligible for inclusion.

**Table 1:** Bus frequency criteria

<b>No.</b>	<b>Criteria</b>	<b>Criteria Rationale</b>
1	Each bus route must offer (as a minimum) a return trip to the bus collection point for the same day bus travel occurred.	A small number of bus services operating within the study area were not intended to provide local transportation services (e.g. The V-Line Adelaide to Melbourne bus service). These bus services were omitted.
2	The bus stop collection and return times must be within the hours of 8am and 6pm.	A number of bus services appeared to target the movement of passengers to and from work and education institutions which were not conducive to the transportation needs of older people. Therefore, some bus services were only available for very early in the morning and/or very late in the day which were unlikely to be used by older people due to safety concerns and long wait times for return journeys.
3	Bus services must be available to the public without restrictions (e.g. not for medical trips only).	Community bus services are provided by local councils, but these were often targeted to specific population groups based on locally developed priority needs or in accordance with requirements specified through government funding criteria. Although important, these services do not offer general transport access which was the focus of the SATDI.
4	The second to last and last bus stops for any given bus route were not given a frequency score.	Boarding a bus to travel one stop to the final bus stop on a bus route is likely to result in little to no utilisation of this bus service, especially if the distance could be travelled by other means (e.g. walking). Furthermore, the last bus stop on a bus route does not provide an opportunity to travel to another stop.
5	Bus stops were not given a frequency score if a bus collection point had less than two hours from the point of boarding to the alighting time for a return trip.	Some bus routes offer a return trip from the final bus destination a very short time after arrival (in some cases, within an hour), thereby limiting a person's ability to access goods and services at that destination. In some instances, the return trips from bus stops before the final bus destination were also less than two hours. Should services being accessed at the final destination be delayed, an older person may be faced with a decision to abandon the appointment or find alternative and possibly more expensive return journey options.
6	Each bus service/route must intersect one or more of the five key service locations and be within a specified distance of the nearest bus stop.	The intention of the SATDI was to quantify general accessibility to goods and services required by older people. Therefore, any bus route that did not facilitate access to one or more of the five key service locations was omitted. One of the five key service locations also had to be within a specified walking distance from a bus stop to ensure the bus service was initially considered a viable transportation option.
7	Bus frequency scores were allocated in accordance with regular bus schedules.	The focus of the SATDI was general accessibility based on regular bus services. Seasonal or occasional timetable changes (e.g. for school holiday periods) were not considered for inclusion.

There were no pre-existing spatial datasets that captured the public transport services available within the study area. As such, required datasets for constructing the Public Transport Accessibility component were developed using the following information sources: the Murray and Mallee Transport website (Murray Mallee Transport 2012); Google Maps including Google Streetview (Google 2013); and public transport timetables from public transport providers servicing the study area.

Walking distance was considered in conjunction with the frequency of bus transport since the location of a bus stop is useful only up to a certain distance, based on the physical capacity and willingness of an individual to walk to their nearest bus stop. Research and transport planning guidelines suggest that people are most likely to walk up to 400 metres (0.25 miles) to access bus services (Currie 2004; Daniels and Mulley 2011; Yigitcanlar et al. 2007; Zhao et al. 2003). In line with this, circular buffers with a 400 metre radius around each bus stop were created for the purpose of identifying the likely distance a person would walk to access a bus stop. Bus frequency scores were then assigned to each bus stop buffer zone. Where overlapping sections of two or more buffer zones existed, overlapping sections were assigned the largest bus frequency score based on the assumption that a person living within walking distance (400 metres) of two bus stops would most likely use the bus stop which allowed access to more frequent bus services.

### 3.3 Combining the Service Accessibility and Public Transport Accessibility Components

Both the service accessibility and public transport accessibility components of the SATDI were developed with the intent of combining both components, resulting in a composite index score for each dwelling point within the study area. However, due to the relatively low number of bus routes in the study area, the level of frequency and public transport service coverage and the potential reluctance of older people to utilise alternative transportation options to car travel, it was not considered appropriate to weight each SATDI component equally. Therefore, more emphasis was placed on the service accessibility component by transferring bus frequency scores into a weighted bus index score using a scale range of 0 to 5 (as presented in Table 2) and then subtracting the bus index score from the service accessibility score to arrive at the final SATDI score. The weighted bus index score was designed to represent a modification to the service accessibility score of up to a third of the total service accessibility score. Bus index scores were subsequently assigned to dwelling points that fell within the 400 metre bus stop buffer zones. When subtracting the bus index score from the service accessibility score in some locations, there were instances where negative SATDI scores resulted. Since a score of zero represents the most accessible score possible for the SATDI at any given dwelling point, all negative scores were set to zero.

**Table 2:** Public transport component weighting scale

<b>Bus Index Score</b>	<b>Description</b>	<b>Bus Frequency Score</b>
0	Very Infrequent - little to no services per week	0.00 to 0.50
1	Infrequent - up to one service per week	0.51 to 1.00
2	Frequent - one to three services per week	1.01 to 3.00
3	Regular - three to five services per week	3.01 to 5.00
4	Very Frequent - five to ten services per week	5.01 to 10.00
5	Highly Frequent - ten or more services per week	10.01 or greater

There was one bus route treated differently to all other bus routes when assigning bus stop frequency scores. The Murray Bridge ‘Link SA Dial-a-Ride’ service (also referred to as ‘Highway Hiker Dial-a-Ride’) provided a door to door service for travel anywhere within the township of Murray Bridge, including east of the Murray River (Murray Mallee Transport 2012). This was the only publicly accessible form of non-traditional public transport available within the study area. The Murray and Mallee Urban Centre boundary for Murray Bridge (based on ABS Urban Centre and Locality 2011 boundaries) was used in place of a 400 metre buffer zone since the urban centre boundary was a close fit to the geographical area covered by this bus service. The ‘Link SA Dial-a-Ride’ service was assigned a bus index score of ‘5’ as this bus service was the most accessible and responsive public transport services available since it operated on a user demand system rather than a regular

timetable. Therefore, dwelling points falling within the Murray Bridge urban centre boundary were assigned a bus index score of '5'.

An inverse distance weighted algorithm, similar to the algorithm used for the ARIA+ (APMRC, 2013a), was used to interpolate the SATDI scores assigned to each dwelling point into a raster layer. This approach ensured a continuous SATDI score was available for the entire study area since the distribution of dwelling points was not uniform across the study area. Unlike the ARIA+ methodology which uses a 1 kilometre square grid interpolation, a smaller grid resolution of 25 metres was used for three main reasons. Firstly, a smaller grid resolution could effectively reflect the spatial variations of service accessibility/transport disadvantage across the study area without resulting in a large interpolated surface computer file. Computer file size was deemed to be an important factor to consider should the SATDI be made available as an interactive web map/layer to enhance its usability and reach to a wider audience base. Secondly, the 25 metre grid scores permitted the generation of zonal statistics, enabling the SATDI grid scores to be summed and averaged to generate an aggregated SATDI score for a given area/spatial unit for further analysis and incorporation with other datasets. Thirdly, since the dwelling point data was provided under agreement to not be made freely available, an interpolated surface offers a medium by which the detailed calculations of the SATDI can be made available while not infringe on this data provision requirement.

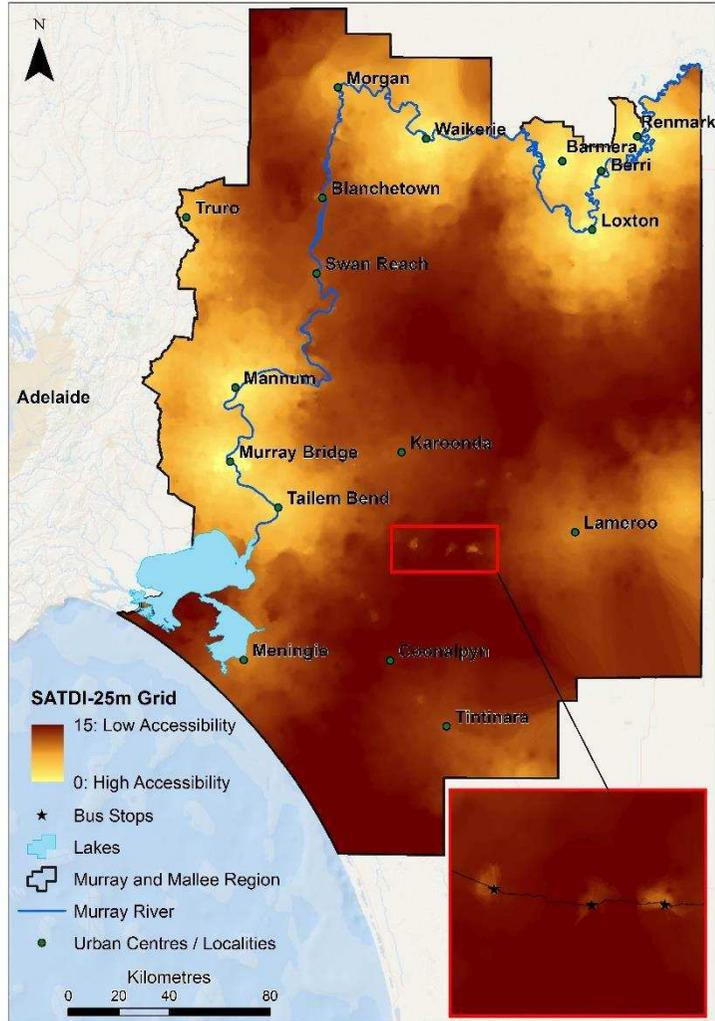
#### 4. Results

Figure 1 shows the SATDI as a 25 metre grid across the study area, including the location of major towns. The Figure 1 inset map highlights the impact of the public transport component whereby service accessibility is higher around three particular bus stops due to more frequent bus services. Figure 2 shows the locations of all service types within and 20 kilometres beyond the study area. Bus stop locations also feature in Figure 2. The service locations and bus stops overlaying the SATDI highlight the dispersed service provision within the study area and the townships where service access may require further attention. Although the service and bus stop locations in isolation could be argued as adequately indicating areas where there may be low levels of service accessibility, the SATDI provides a relative measure that attempts to quantify accessibility. This is particularly advantageous when trying to compare the degree of need across the study area, particularly in locations away from town centres.

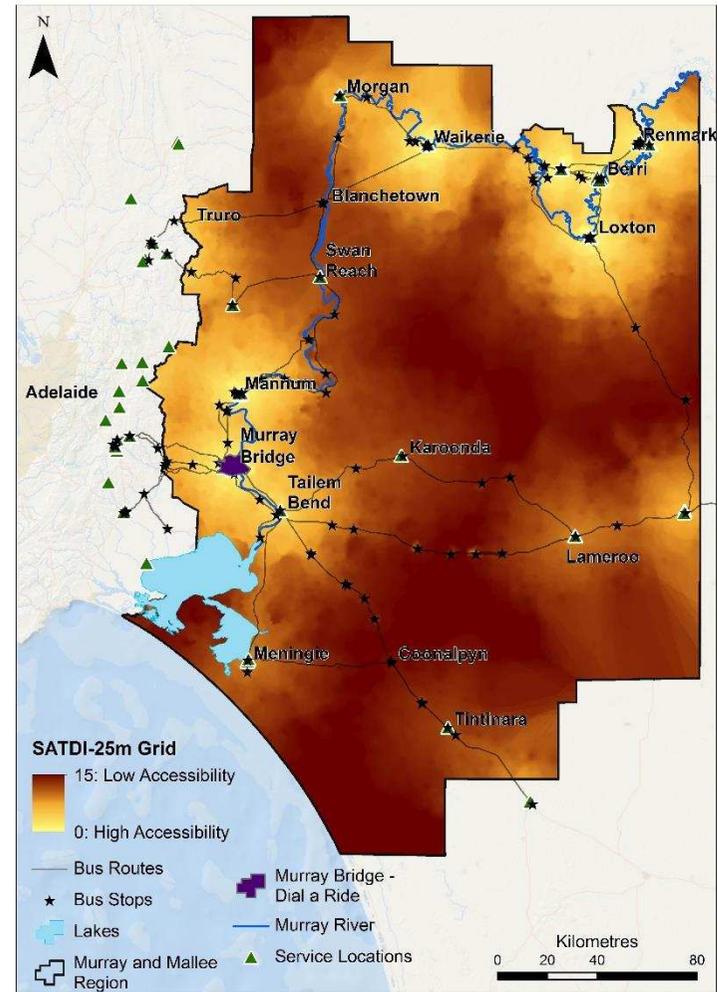
The SATDI can be visualised in a number of ways including an interactive web map or as a data layer within a Geographic Information System (GIS). Although a series of printed maps can also effectively indicate varying levels of service accessibility/transport disadvantage across the study area, an interactive web map or a data layer within a GIS provides an interactive mechanism for further analysis, not limited by predetermined map scales. For example, a web map combined with street and satellite imagery can enhance the ability for a broad range of individuals, including planners, policy makers and the general public, to identify and retrieve accessibility information at precise locations. The use of a 25 metre grid resolution offers specificity and enhances the capacity of the SATDI to capture subtle variations with respect to service accessibility and transport disadvantage.

From an analysis perspective, the SATDI can be combined with other datasets to further quantify the potential need for assistance by older people to access required goods and services based on their residential location. The 25 metre resolution of the SATDI permits the extraction of zonal statistics (summed and average SATDI scores) by administratively defined boundaries, such as Australian census boundaries. Aggregation to Statistical Area 1 (SA1) spatial units (the smallest level for which the majority of Australian census variables are available) facilitates the incorporation of additional information to support various demographic analyses (i.e. income, lone person households, core activity need for assistance). Practical applications of the SATDI could include the development of funding formulas that incorporate the SATDI score as one component (e.g. used to defining low service accessibility based on SATDI scores between 10 and 15). This type of application is similar to the means by which the Government of Australia currently distributes funding to schools, whereby a school's relative measure of geographic accessibility/remoteness, as represented by ARIA+ scores, is taken into consideration with regard to distribution of funding for education services (Australian Education Act 2013).

**Fig 1: SATDI 25 metre interpolated grid surface**  
 Data sources: ABS 2011a; ESRI et al., 2014; Geoscience Australia 2006.



**Fig 2: Service and public transport locations used to construct the SATDI**  
 Data sources: ABS 2011a; ESRI et al., 2014; Geoscience Australia 2006.



To explore the usefulness of the SATDI to provide a reasonable and acceptable quantification of service accessibility/transport disadvantage, the index was assessed by Community Passenger Network (CPN) officers responsible for the coordination of transport assistance programs to the eight LGAs within the study area. CPN officers commented that the SATDI interpolated surface effectively highlighted spatial variations across the study area, and was largely representative of the service accessibility/transport disadvantage challenges faced by older people who resided within the study area. The SATDI components (service accessibility and public transport accessibility) and methodology were reported to be easy to understand and appropriate for quantifying such information. The development and presentation of the SATDI as an interactive web map (GIS software was used when feedback was sought) was viewed as having the potential to stimulate productive discussions with public transport providers and government agencies. The ability to extract SATDI scores from discrete locations across the study area from the 25 metre grid was viewed as useful for comparing various locations within the region. The weighting applied to the bus index score and its modification to the service accessibility component was considered by CPN officers to be reasonable given the limited public transport available across the study area. CPN officers endorsed the potential to incorporate the SATDI with other spatial datasets as useful in order to assist with readily identifying geographic areas where additional transport services may need to be prioritised when combined with demographic information (e.g. Australian census data). It was suggested that if the SATDI was regularly updated, it could be regularly used as a reporting tool to inform local councils and funding bodies of priority areas for targeting limited community transportation resources.

In terms of suggested improvements, CPN officers recommended that the costs of catching a bus be considered for future developments of the SATDI. It was also suggested that the identification of the medical clinic/GP service category could be enhanced by incorporating the provision of outreach GP services to the region. Specifically, it was noted that GPs attend to patients at local hospitals and as this information was not captured in the SATDI this may have resulted in some areas having lower service accessibility scores for this service type. CPN officers also expected that older people would prioritise access to the local pharmacist over some of the five service types used to create the SATDI. It was noted that the number of pharmacy responses in the participant subset of these data may have been higher if the data collection had prevented respondents from reporting “general shopping” as a service accessed outside of the home. It was also noted that the SATDI did not account for access to specialist health services which are only available in the South Australian capital city of Adelaide (located a minimum of one hour from the Murray and Mallee region). This was seen as a limitation of the SATDI given the frequent utilisation of transport services (often coordinated by CPN officers) for older people to access specialist medical services in Adelaide. In line with these identified limitations, specific areas for future development of the SATDI identified by the CPN officers related to further examination of the types of services required/utilised by older people outside of their home and a more detailed assessment of the public transportation provision within the study area, including capacity to incorporate non-public transport services such as local government funded bus services and medical bus services often coordinated through current CPN service initiatives.

## **5. Discussion**

The SATDI provides a method of assessing the service accessibility/transport disadvantage needs of older people living in non-metropolitan regions with respect to location. The SATDI offers an important contribution to the research literature with respect to enhancing available methodologies to explore service and transport accessibility as relevant to older people in non-metropolitan locations. The SATDI has the potential to be used independently or in combination with other datasets in further research and to guide policy and planning with respect to service and transport accessibility for older people. It is important to note that this index was not intended to provide a definitive or complete picture of service accessibility/transport disadvantage across the study area, but rather a method and mechanism by which service and transport accessibility could be analysed in combination and further explored based on geographic location and proximity to service outlets identified as essential to older persons.

There are both strengths and weaknesses to consider in relation to the SATDI. With regard to the service accessibility component, data from a relatively large number of older people within the study area was able to be collated in order to identify key service areas. The resulting top five service types incorporated over 60% of older people’s responses from the Hugo et al (2010) study and as such, can be considered broadly representative of key services of relevance to older people. However, the service accessibility component of the SATDI did not consider access needs to specialist services such as cardiologists and other medical specialists that may only be available within Adelaide and that are likely to be regularly accessed by older people in the Murray and Mallee region. In addition, access to services was based on the closest service to an older person’s residential address, thereby excluding service choice. In line with these limitations, the index could be enhanced by consideration of

non-local service accessibility for specialist medical services not available within the local region, possibly through the application of weighting towards the nearest capital city or nearest large metropolitan centre where specialist services are available. Service utilisation data could assist with providing specific information with regard to those services utilised by older people. Furthermore, administration of a purpose-designed questionnaire that includes appropriate service category options to allow for detailed information with regard to the type and frequency of services accessed by older people outside of the home would enhance the service accessibility component of the SATDI.

Further considerations with regard to the strengths and weaknesses of the SATDI relate to the public transport accessibility component. A walking distance of 400 metres to a bus service was achieved by developing a straight line buffer zone from the bus stop location. This approach assumes no environmental barriers exist and a straight line walking distance of 400 metres can be achieved, which may overestimate accessibility to bus stops (Zhao et al. 2003). The 400 metre walking distance also assumes older people can traverse this distance without assistance or difficulty. While this assumption was needed to determine bus stop catchment areas, in reality, an older person may be able and willing to walk further than 400 metres to access a bus service and as a result this buffer zone may lead to an overestimation of transport disadvantage. Conversely, another older person may be frail and unable to walk more than a few metres and as such, their level of transportation disadvantage may be underestimated regardless of their geographic proximity to a bus stop. It was also assumed that an older person would utilise the closest bus service with the highest bus service frequency if the older person has two bus stops within walking distance of their residential address. This may not be the case in reality, as the desired bus route may have a greater influence on the choice of bus stop. In addition to attempting to address these limitations, future applications of the SATDI could be enhanced by taking into account other factors that may influence the public transport accessibility such as the expense involved for the passenger and the actual and perceived reliability of public transport services.

As a composite index, a strength of the SATDI (in line with the strength of the ARIA+ methodology) was the ability to aggregate the 25 metre SATDI grid surface to different geographical areas for the incorporation and overlaying of various spatial datasets. However, it should be noted that spatial aggregation of indices such as the SATDI has the potential to result in misleading or incorrect interpretations due to the 'modifiable areal unit problem' and 'ecological fallacy' (Openshaw 1984). Specifically, zonal statistics generated from averaging SATDI grid scores to produce a revised SATDI score for different spatial units can result in a loss of index sensitivity across the study area through the averaging process (modified areal unit problem). The assumption that older people located within an administratively defined boundary experience the same level of service accessibility/transport disadvantage (ecological fallacy) needs to be acknowledged so that the true nature of service accessibility/transport disadvantage at particular geographic locations across the study area are not misrepresented. The modifiable area unit problem and ecological fallacy are two factors commonly identified as potential pitfalls within the spatial analysis field (Heywood et al. 2006; Longley et al. 2005) and should be taken into account when aggregating the SATDI for integration with other datasets for decision making purposes. Moreover, derived measures such as area indices should not, ideally, be converted between geographies (Norman 2010). The individual inputs should be converted and then the index recalculated for the alternative geography (Norman 2010). It also needs to be acknowledged that the service accessibility calculation component of the SATDI (based on the ARIA+ methodology) limited the ratio score for each service category to a threshold of three. This process of 'thresholding' was based on ARIA+ methodology where the rationale is that beyond a certain point, the relationship between distance and low accessibility/high remoteness is no longer linear (DHAC 2001; GISCA 2004). Although it seems likely to apply generally, whether this rationale is also applicable to a smaller geographic areas (such as the Murray and Mallee region utilised in the current study) remains an aspect for further analysis.

On a broad level, further research using the SATDI methodology could incorporate the role of social networks in relation to the examination of service and transport accessibility. Research suggests that those with strong social networks may be able to utilise these networks to supplement transportation needs (Hugo et al. 2010; Kim 2011; Musselwhite 2011). An enhancement of the SATDI could be the inclusion of a third accessibility component measuring social connectedness. This might be achieved by using key census variables (e.g. lone person households) in a similar manner to which census data have been applied to identify locations where transport assistance may be required (Scott and McInerney 1998). From a methodological perspective, the index constructed may benefit from a dedicated review of the key assumption/parameters (in conjunction with local experts) to validate the choice of final assumption parameters (e.g. 400 metre walking distance and public transport frequency weightings) and the relative sensitivities of each parameter influencing the final index scores. It may also be beneficial to determine the usefulness of the SATDI methodology to other population cohorts (e.g. low income earners, single parent families, frail elderly, and people with disabilities) who may rely

on access to public transport for obtaining required goods and services as well as other geographic locations where additional forms of public transport are available (e.g. train travel).

## 6. Conclusion

This research has reviewed the literature with regard to service accessibility and public transport accessibility methodology and constructed an index designed to quantify service accessibility/transport disadvantage for older people living in a non-metropolitan location. The population group with which the index methodology was developed included persons 65 years and over living in the Murray and Mallee region in South Australia. The index derived, the Service Accessibility and Transport Disadvantage Index (SATDI), comprises two components, namely a service accessibility component and a public transport accessibility component. The methodology of the Accessibility/Remoteness Index of Australia (APMRC 2013a) was used as a basis for the development of the SATDI. The SATDI methodology offers a framework for quantifying service accessibility/transport disadvantage for older people living in non-metropolitan regions, which incorporates the key services used by older people outside of the home and the availability of public transport to access these services. The SATDI can be used as a standalone dataset or in combination with other datasets.

GIS technology has been used to depict the SATDI and provide a visual representation of areas of high and low accessibility with respect to key services for older people. These depictions have the potential to facilitate dissemination of the index to planners, policy makers and the general public through interactive web maps, printed maps, or as a data layer within a GIS. The SATDI has potential to offer insights into complex and often challenging service provision and transportation planning questions through the quantification and visual demonstration of service accessibility/transport disadvantage. The SATDI methodology also has the capacity to be universally applied through the adaptation of key parameters specific to other population cohorts.

Areas for future development for the SATDI include enhanced specificity with regard to the service accessibility and public accessibility components. Specific areas include the use of service utilisation data or purpose-designed questionnaires for older people with regard to service accessibility and preferences. Incorporation of factors such as the cost involved to access public transport would also be beneficial. At a broader level, the SATDI may benefit from the incorporation of additional components such as social connectedness.

With the proportion of older people within Australia and abroad increasing, and of particular relevance to those residing in non-metropolitan regions where public transport coverage is poor, addressing the barriers faced by older people when attempting to access essential services outside of the home remains a pertinent issue. Spatial indices such as the SATDI can therefore play an important role through the assessment and identification of geographic locations where service and transport accessibility improvements are most needed.

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