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Investigating the public transport use and transport disadvantage in a low density environment

Yogi Vidyattama[1], Hitomi Nakanishi[2]

[1]The National Centre for Social and Economic Modelling, University of Canberra, Bruce, ACT 2601 Australia

[2]Built Environment and Design, Faculty of Arts and Design, University of Canberra, Bruce, ACT 2601 Australia

Email for correspondence: hitomi.nakanishi@canberra.edu.au

Abstract

As a city with lower density dominated by the car, providing a public transport system is complex for Canberra. The public transport service could be seen as inefficient because of low patronage. However it is important, not only for those who face social exclusion (e.g. people at an economic disadvantage and older people) but also to avoid congestion and reduce pollution levels. Nevertheless, without sufficient demand the provision can be very expensive for the government and funding allocation is crucial. Therefore, this study aims to investigate how bus services can be effectively improved in Canberra. The overall aim is to minimise the transport disadvantage often caused by poor public transport services. To do so, this research will investigate the difference in travel patterns of various social groups of passengers (students, older people and pensioners and adults) by using smart card data. The study will first compare the travel patterns of these groups. We will then examine the pattern of movement of the more vulnerable such as older people and students compared to general adult passengers. We will discuss transfer between buses further in order to pinpoint specific bus stops or terminals which could be improved to meet the specific needs of certain passengers.

1. Introduction

Canberra, the national capital of Australia, is a poly-centric city with a population of 365,621 spread across an area of 807.6 km^2. Distinct town centres serving as hubs for employment and other activities have generated a lower average residential density than other Australian capital cities, and there is much less congestion and pollution than if there was one CBD. It has the highest vehicle kilometres travelled per capita among Australia's capital cities (Vincent et al., 2004). The main public transportation in Canberra is the Australian Capital Territory (ACT) Internal Omnibus Network (ACTION) which serves Canberra suburbs including a regional community minibus service. Although the level of service varies among routes, it is perceived as limited and many people prefer the car as a major transport mode. As such, more than 80% of travel to work is made by car, either drivers or passengers (Australian Bureau of Statistics, 2012). With limited transport options, Canberra also continues to have a low level of public transport use compared to other Australian cities, though slightly higher rates of walking and cycling (ACT Government 2012, Lee et al., 2005). Although the car is the most preferred travel mode in Canberra, there are people who rely on public transport for their mobility. It is critical for the public transport provider not to disadvantage those people by limited services. To achieve social sustainability, avoiding transport disadvantage of people who do not have access to car is essential as it relates considerably to quality of life (Banister and Bowling, 2004, Delbosc and Currie, 2011, Nakanishi and Black, 2015b). Further understanding of public transport use would help

government decision making in response to demand and ensure more effective allocation of funding.

This research investigates the difference in travel patterns of various social groups of public transport users in Canberra by using smart card data. Smart card data is one of the big data that has become available and applicable by recent technology. It has much potential for measuring the variability of urban public transit network use (Morency et al., 2007). However research using smart card data is rarely seen in Australia. This paper demonstrates the use of smart card data in examining the travel patterns of bus users and identifies policy implications in a low-density city of Australia.

2. Literature review

2.1. Transport disadvantage in low density environment

Transport disadvantage is a situation where a person has significant barriers in accessing services, employment, education and social activities, due to restricted mobility (Delbosc and Currie, 2011, Hine and Mitchell, 2001, Nakanishi and Black, 2015a). It is a main cause of social exclusion, and associated decrease in well-being and quality of life. Anyone may be in this situation, but older people and children, who are highly likely to have less access to car, are most vulnerable to transport disadvantage and their well-being is highly affected (Banister and Bowling, 2004, Gabriel and Bowling, 2004, Broome et al., 2009). In this context, public transport is an essential mode to enhance mobility of those people who are or may become transport disadvantaged. Availability of public transport is a key factor in independent mobility for those people (Buys et al., 2012). Especially in a low-density rural area, not having access to private transportation brings disadvantage when it comes to participation within the community and independent life because the availability of public transport is limited in those areas (Fobker and Grotz, 2006, Broome et al., 2009, Zeitler and Buys, 2014). Community transport services are becoming popular in rural areas. And is often provided door-to-door where there are few or no local bus or rail services. However the availability of services is highly dependent on the financial situation of local governments. In terms of children, one comparison found that Australian children are less independently mobile than their English counterparts because public transport is recognised as less convenient than a car(Carver et al., 2013). In some Australian regions, the majority of children now travel to school by car, with greater percentages among those living in outer-suburban areas (Babb and Curtis, 2013, Cole et al., 2007, Ridgewell et al., 2009). University students who cannot afford a car are also in a similar situation. To reduce transport disadvantage, the first step is to understand how people move around by public transport, either to services or for social interaction. Then necessary intervention could be identified where a gap exists between mobility needs and service provision.

2.2. Understanding transit use by smart card data

Smart card data is a powerful data set which is increasingly used in transportation research. In addition to analysing variations in public transit use (Morency et al., 2007, Nishiuchi et al., 2012, Zhong et al., 2015), it has been used in various research. Munizaga and Palma (2012) used it to create public transport OD, Sun et al. (2013) analysed in-vehicle repeated encounters of passengers and Zhong et al. (2014) examined the spatial structure of urban movements by using smart card data. Those studies have been done in North and South America, UK, Singapore and Japan. The literature focused on the variability of public transit use compared the travel patterns of different user cohorts (for example, adults, students, senior card holders) and found that older people may have different travel patterns to other groups. Student card holders were found to have more diversified use of bus stops, followed by the senior card holders (Morency et al., 2007). Nishiuchi et al. (2012) examined public transport use in a small Japanese (370,000 population) and found children (under 13 years old) have a highly habitual temporal and spatial pattern in comparison to other card user

categories. As many public transport agencies implement smart card systems, there will be more useful data to analyse day-to-day transit of various passenger cohorts. Despite the limitations such as lack of trip purpose (Bagchi and White, 2005), smart card data has much potential to be used in research. Its advantages are summarised as: strategic-level studies (for long-term network planning, customer behaviour analysis, and demand forecasting); tactical level (schedule adjustment, and longitudinal and individual trip patterns) and operational-level studies (supply-and-demand indicators) by Pelletier et al. (2011). Major cities in Australia have implemented the smart card system (e.g. Opal Card in Sydney, Myki Card in Melbourne). However, to our knowledge, smart card data is hardly used in Australia for transportation research. Because of its low density environment, provision of public transport could be costly for governments and inefficient in Australian cities. Smart card data would be useful in further understanding the travel patterns of passengers to suggest strategic network planning as well as improvements in tactical and operational levels.

3. Method

3.1. Data

The one-month smart card data used for this research was recorded in June 2012 by the Australian Capital Territory Government. The smart card (called MyWay card) data recorded 838,448 trips on public transport at this time. The smart card data were collected by an automatic fare collection system which is used on every ACTION BUS. Passengers tap on when they board and tap off when they alight from each bus. Each record contains the attributes: bus route number, origin date, origin tap on time, origin stop name, origin stop XY coordinate, destination tap off time, destination stop name, destination stop XY coordinate and passenger type.

Passenger type is based on smart card type. There are 9 smart card categories recorded in the database. However, we only looked at the pattern of 6 card categories – over 75, senior, pensioner, adult, school student and tertiary student. The other 3 categories – current employee, past employee and student transport program – are not in the scope of this study. Pensioner card holders are mostly older people but also include other disadvantaged people who receive various government benefits. To be eligible for a senior card, a person must be over 60 years of age, a permanent resident of the ACT, and not being in paid employment for more than 20 hours a week.

The other data base that we used for this research is the Australian Bureau of Statistics (ABS) Census of population and housing. Every five years, the ABS conducts a nationwide Census to obtain a count of the number of people in Australia, their individual and household characteristics, and their dwelling characteristics. The latest census was conducted on the 9 August 2011 and captured information on more than 20 million people. The Canberra database contains 360,547 people who were resident in Canberra on the day of census and also includes 145,473 dwellings. Among these people, there were 38,134 over 65 years old, of which 16 thousand were over 75. Regarding the students, 51,382 of them were in primary and secondary while 37,513 were in tertiary education.

The census data used in this study are consolidated at Statistical Area level 2 (SA2). With an average population of about 10,000 in Australia, the SA2 level is often considered as the smallest spatial unit with reliable data. In Canberra SA2 corresponds to a suburb. There are 110 SA2 listed in the Australian Statistical Geography Standard (ASGS) for Canberra. This spatial unit represents a community that interacts together socially and economically' (Australian Bureau of Statistics, 2011; p.21). The use of SA2s that correspond to suburb allows us to present the number of bus network that listed to go through certain suburb according to ACTION BUS website (https://www.action.act.gov.au/timetables_and_maps/routes_by_suburb).

Last but not least, this study also used the school data from the Australian Curriculum, Assessment and Reporting Authority (ACARA) available on the "My School" website (https://www.myschool.edu.au/). In particular, we used "The Index of Community Socio-Educational Advantage (ICSEA)" to identify the locational advantage and disadvantage of each school in Canberra. The data contains 128 schools with 84 public and 44 non-public schools. In terms of level of school, 78 were primary schools, 23 secondary, 22 combined and 5 special schools. The data also identify their locations which were transformed to XY coordinates.

3.2. Analysis

This research is the first step in analysing this smart card ID data. Therefore, most of the analysis is based on descriptive analysis to describe the different patterns found among different passenger categories. In addition, the analysis will look at the pattern obtained from Geographic Information Systems (GIS). GIS are used frequently in research as well as policy decision making processes. In the past decade, an increasing number of researches have also focussed on the geographical and regional aspects of their work and increasing the use of GIS technology. This is partly motivated by the rapid development of new technology and methodologies of spatial analysis such as geographic information systems (Goodchild et al., 2000). In this particular study, the GIS are useful in providing early indication of the connection between different variables in spatial sense. This could involve the interactions between the characteristics of society and a certain place that can be represented by XY location such as bus stop and school.

Besides the overall pattern, one specific pattern that we look at is the pattern of transfer between buses. This is when a passenger has to move from one route to another to get to their final destination. This particular issue is raised because the passenger may need some services while waiting for the next bus. If more people are willing to transfer from one route to another ACTION would need to provide less direct routes or better timetables to reduce connecting times. The only benefit that has been provided for passengers under the existing scheme is free transfer within 90 minutes of boarding the first bus. This is also the main variable that can be used to identify transfer patterns. There are two ways to analyse this. Firstly, by using the fare paid (whether it is zero) and secondly, by comparing the time the passenger boards the next bus with the boarding time of the previous bus. We used the second method, mainly because certain categories of people such as 70+ are eligible for free travel on ACTION buses at any time which means they can transfer without time limit. This transfer pattern is also very important in identifying the real origin and destination of the passenger.

The analysis was conducted to evaluate the stability of regularity in the temporal and spatial dimension through measuring the variability of mobility patterns over multiple days (Zhong et al., 2016). From the 838,448 trips recorded by smart cards in a month, we only used the data taken on Monday-Friday (weekdays) from 8th to14th of June. The main reason for this was to avoid the truncation of data at the beginning and end of the database. Furthermore, the sample is sufficiently large, while the pattern that we observed does not have vast variation from one week to another. From beginning to end, 405,766 trip data were extracted over 10 working days (48.4% of total data). These observations came from 47,792 different smart card users. More than half of the users were in the adult category. Primary and secondary students were the next big group at around 20% while tertiary students' use was 11%.

4. Results

4.1. Usage pattern by passenger groups

The first pattern is of daily usage. Table 1 shows the average number of trips taken in the 10 days of our observations, the time of the trip and the proportion of those that can be considered as transferred. The 47,792 card holders that appear in this database represent 13% of the total population of Canberra. However, table one shows that on average, they only take 8.5 trips in these 10 days. This is less than 1 trip a day. This indicates that most of the card holders are not regular users. The data actually reveals that only a third of those card holders use the bus more than once a day and only around 9% use it more than twice a day. People in adult and student (primary and secondary) categories reflected this proportion as well. Tertiary students and pensioners have a higher proportion of transfers while seniors and people over 75 have a much lower proportion.

Table 1: The different pattern of bus usage in different category of passenger

Passenger Categories	Average trips per 10 days	Proportion of transfer (%)	Average number of trips considering transfer	Average time spent riding bus per trip (minutes)	Average time spent riding bus with transfer (minutes)
Over 75	6.1	30.0	4.3	15.5	20.8
	(6.6)	(45.9)	(3.9)	(9.8)	(14)
Senior	6.1	29.7	4.3	17.2	22.7
	(6.8)	(45.7)	(4.2)	(10.1)	(14)
Pensioner	12.5	37.0	7.9	18	24.7
	(10.7)	(48.3)	(5.8)	(58)	(58.8)
Adult	8.2	20.1	6.5	19.8	23.6
	(7.6)	(40.1)	(5.4)	(37.4)	(38)
Student	8.4	21.4	6.6	16.5	20.6
	(7.5)	(41)	(5.2)	(9.3)	(12.6)
Tertiary	9.9	26.9	7.3	19.7	24.5
	(8.7)	(44.4)	(5.5)	(93.5)	(93.7)
Total	8.5	23.3	6.5	18.7	23
	(8.0)	(42.2)	(5.4)	(45.2)	(45.8)

Note: Standard deviation is in bracket

Although not as regular as other passengers, both of the older people categories – Senior and Over 75 – have a higher proportion of transfers than adults or students (Table 1). This means they may be optimising their trip by going to as many places as possible in one journey. This may also mean that they are not constrained by strict time schedules and are more willing to take the risk of transferring to another route which may involve long waiting time. This argument can be supported by the fact that pensioners have the highest proportion of transfers. Nevertheless, pensioners also have the highest usage of the buses on average. This is because this category includes those who receive the “Newstart Allowance” and have an obligation to seek jobs as well as those who receive the carers’ allowance who may need to use public transport to fulfil their duties.

4.2. Travel time pattern by passenger group

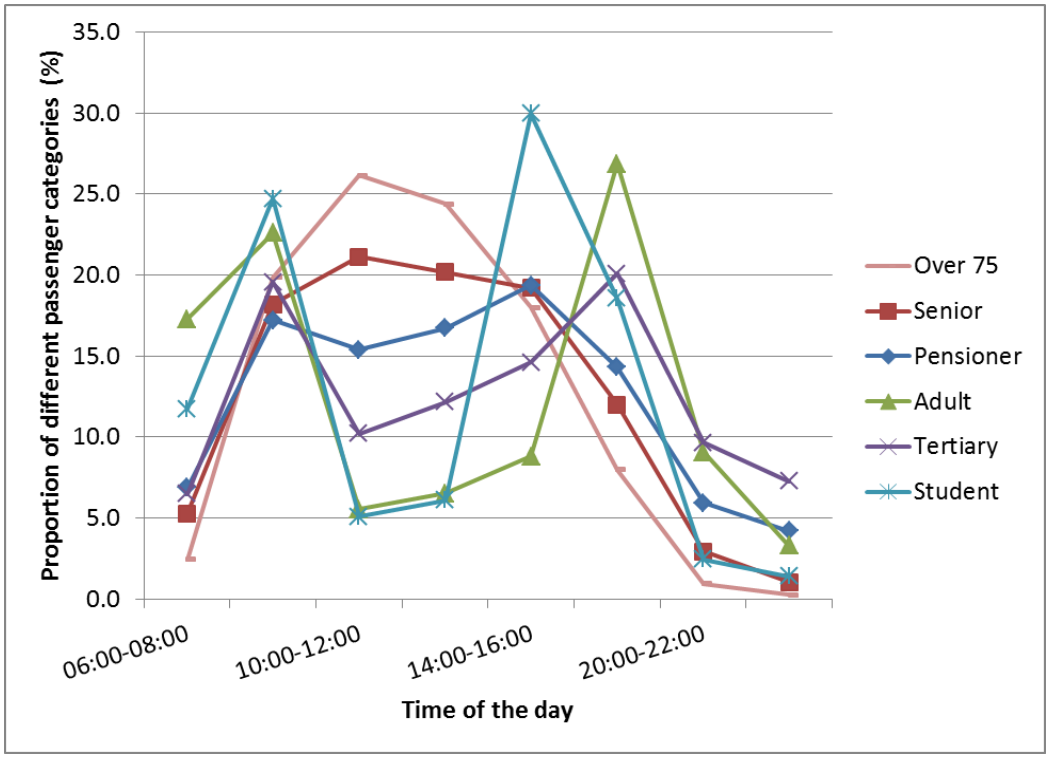
Another pattern revealed by the data is the difference in travel time spent on the bus. Adult passengers and tertiary students spent the longest time in the bus (Table 1). However, the

standard deviation is considerably large especially for tertiary students. This means that some of them can spend a very long time on the bus. A similar trend can be seen in pensioner categories. It is understandable that adult passengers have lower standard deviation than tertiary students as they have fixed working hours. Nevertheless, the high standard deviation also shows that some of them do spend a long time on the bus. Anecdotally, this is because some of them are more willing to stay on the same bus to get to the destination rather than transferring to another route that could bring them to the destination faster. This is supported by the lower proportion of transfers in the adult passenger cohorts.

The older generation, represented by Senior and over 75, stays on the bus for less time. This may be due to the short distance they are travelling on buses. The argument against that is the proportion of transfers by older people is relatively high. The counter argument is that even after adding the time spent after they move to another route (transfer), the time the older people spent on the bus is still relatively shorter (Table 1).

Another argument that may explain the relatively short travel time of older people is that they start travel relatively later compared to adult or student passengers, i.e. off-peak hour. As shown in Figure 1, the time of passenger travel varies among categories. Adult passengers heavily represented in morning and afternoon peak hours while older passengers (over 75 and senior) use bus non-peak hours after 10am and their usage drops after 2pm. On the other hand, students' peak time of usage is 2-4pm, which is after school hours.

Figure 1. Travel time patterns by card type



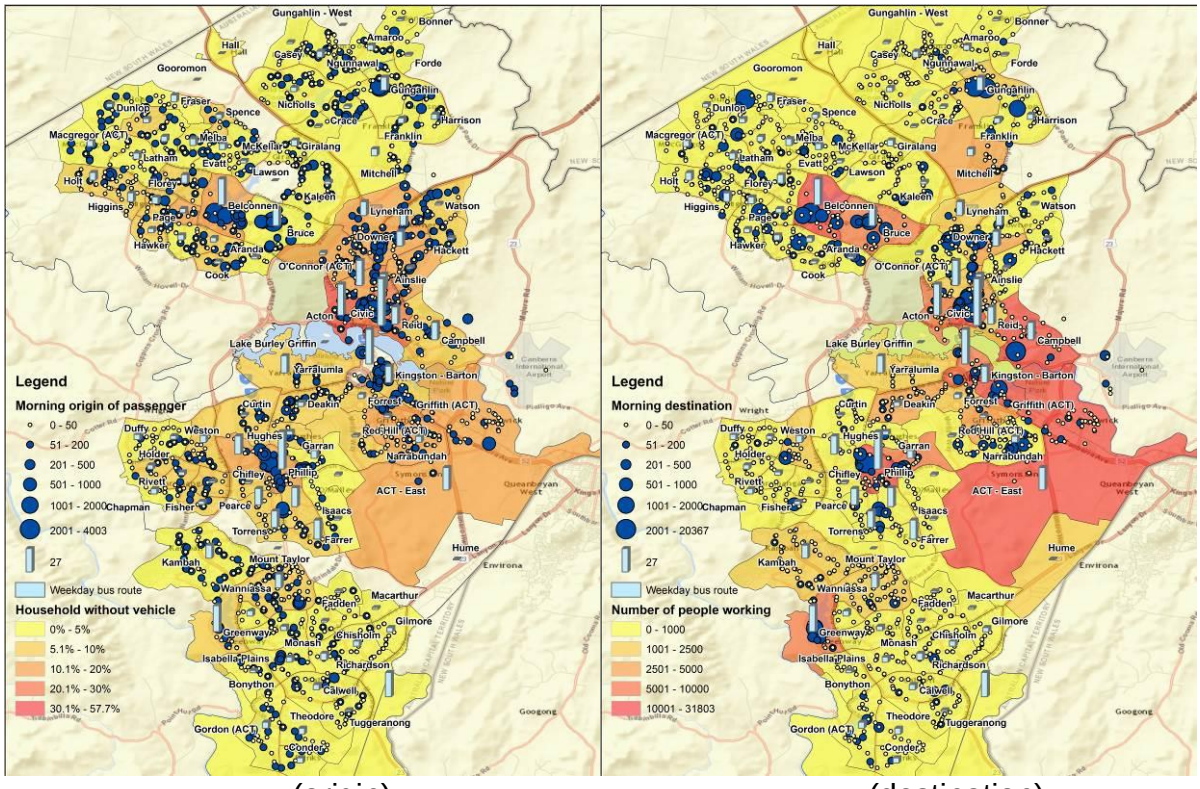
The time patterns of students and adult passengers tell their own story. The proportion of trips used by the two categories in the morning is lower than the one in the afternoon especially for students. This means there are adult and student passengers who are more

willing to take a bus when they are going home than when going to office or school. This means they may share vehicles in the morning probably to minimise commuting time. The higher peak for students can be explained as they have different end of school time to end of working time. It means that they can go to school with their parents or adults by car but have to go home by themselves using the bus. This is likely to be the case for some of the adults but with to a lesser extent as the proportion of bus usage is still higher at the end of work. Again, a family may travel together rto ensure everyone arrives on time in the morning, the time constraints are less later in the day. .

4.3. Location pattern of origin and destination

The next pattern that can be observed from this data is the location difference. The combination of GIS and the data that provide XY coordinates allows us to see and analyse the pattern based on location. Figure 2 shows the locations of origin and destination of all passengers in the morning (before 12pm). The blue dot shows the number of passengers at certain bus stops. The bigger the size the more people using that bus stop. The left hand map shows the origin of passengers. The colour of the suburb in the left hand map shows vehicle ownership and the darker colour shows the proportion of those who do not have access to a vehicle and therefore, a more in need of public transport. The bar graph shows the number of bus routes through that suburb. The left hand map shows that there is a correlation between those components. Most of the big blue dots are in the main bus terminals – Civic, Belconnen, Woden, Gungahlin and Tuggeranong (Greenway). Understandably, there are more bus routes in those terminals. The vehicle ownership in those suburbs close to bus terminals, is lower. The causality of these three patterns has to be determined by further analysis.

Figure 2. Morning Origin and Destination of all passengers



(origin) (destination)

The map in the right hand side shows the destination. The blue dot and the bar graph have the same meaning while the colour of the suburb shows the number of people working in the area. Many of the destination areas are in the suburbs where many people work but the map shows that there are places where many people work without people using buses to get to that destination. These include the areas in the ACT's east such as Fyshwick and Griffith. The relatively limited bus route may contribute to this and may explain the relative heaviness of traffic in that area in the morning. Similarly, the extent of movement to the South of Canberra compared to the North can be explained by the fact that more people used buses to get to work in the north compared to the south.

The possibility of analysing the origin and destination patterns of different categories of passenger allows us to discuss the specific issue of the needs of disadvantaged passengers. For example, Figure 3 shows the travel origin of older people (Senior and Over 75). We compared the location of retirement villages with the number of older residents in the suburb to obtain more insight into their patterns of travel origin. This is because older people who reside in retirement villages are unlikely to have access to their own car. The figures indicate that the location of the retirement village could increase the use of nearby bus stops. Although the figure only shows the origin, this applies both to origin and destination. There seems to be a high correlation between the location of retirement villages and the two latter variables. We could identify several areas which did not follow the pattern. Narrabundah is one of those areas that need further study. There are several retirement villages in these areas, the number of older people is relatively high and the car ownership is low but there are not many older people tapping on from the area as an origin stop. The low number of bus routes in the area may explain this. Nevertheless, the higher number of old people that tap off in this area as a destination may mean that they may have used other mean of transport to leave . Another category of passenger that provides interesting findings is the students (primary and secondary). Figure 4 shows the destination of student passengers. We did not show the origin map as the origin of students is spread relatively evenly throughout the different suburbs of Canberra. The interesting findings come from the destination map. The round and square signs on the t map indicate the locations of school. The red square shows school with relatively low ICSEA i.e. the more disadvantaged school, while the green circles show the advantaged schools. The figure shows that more students use buses to go to the more advantaged schools. A possible explanation for this pattern is that the more disadvantaged students usually go to the school in the local suburbs and therefore, do not have to use buses. They can walk or ride bicycles. In contrast, the more advantaged students are likely to go to the more popular schools and willing to go outside their local suburbs. This is why these students need to use buses and alight at the bus stops near those schools.

Figure 3. Origin of old passengers

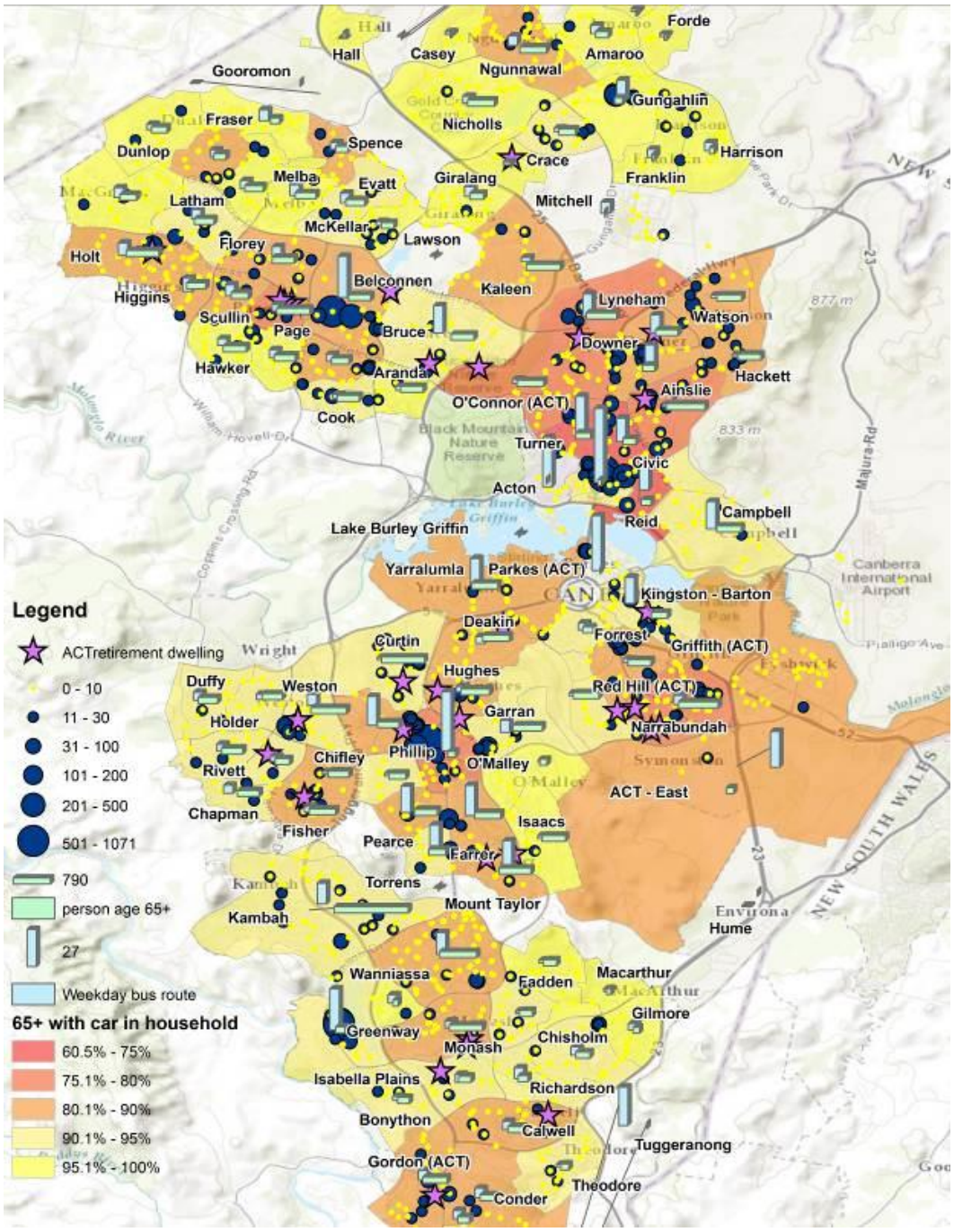
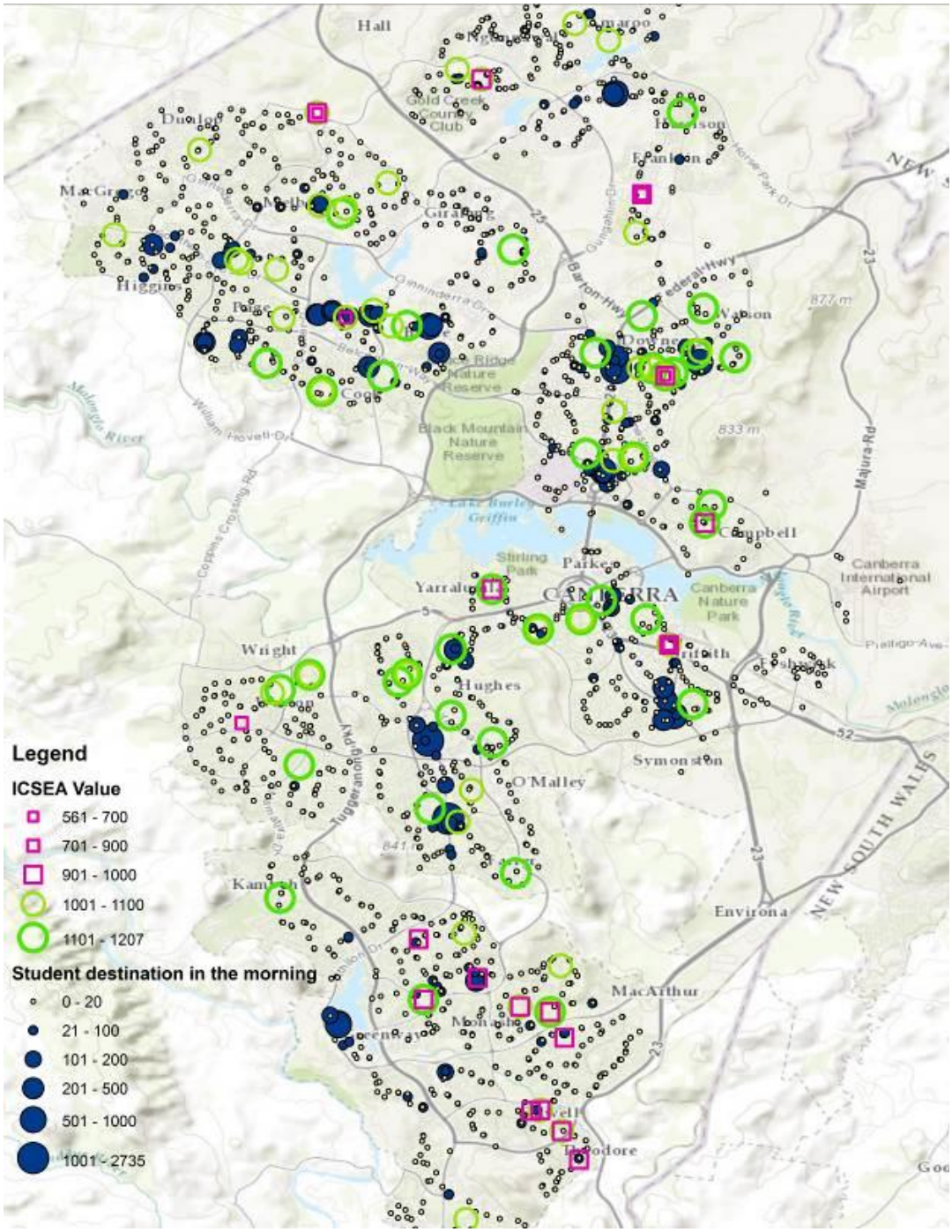


Figure 4. Morning Destination of secondary and primary students



4.4. Transfer pattern by passenger group

In section 3.2, we have explained the importance of recognising transfers in identifying the origin and destination of passengers. Table 2 shows another advantage of identifying transfers. This is the time spent waiting for the next bus. The table shows that the average time spent waiting for the next bus can be longer than the time spent on the trip on the bus itself. This may be because Canberra is a relatively small city and the average time on the bus is relatively short at 18.7 minutes. Nevertheless, this at least indicates that the services provided at the bus stop while you are waiting to transfer to another bus route can be as

important as the services on the bus trip (i.e. the possibility of accessing services during transfer time).

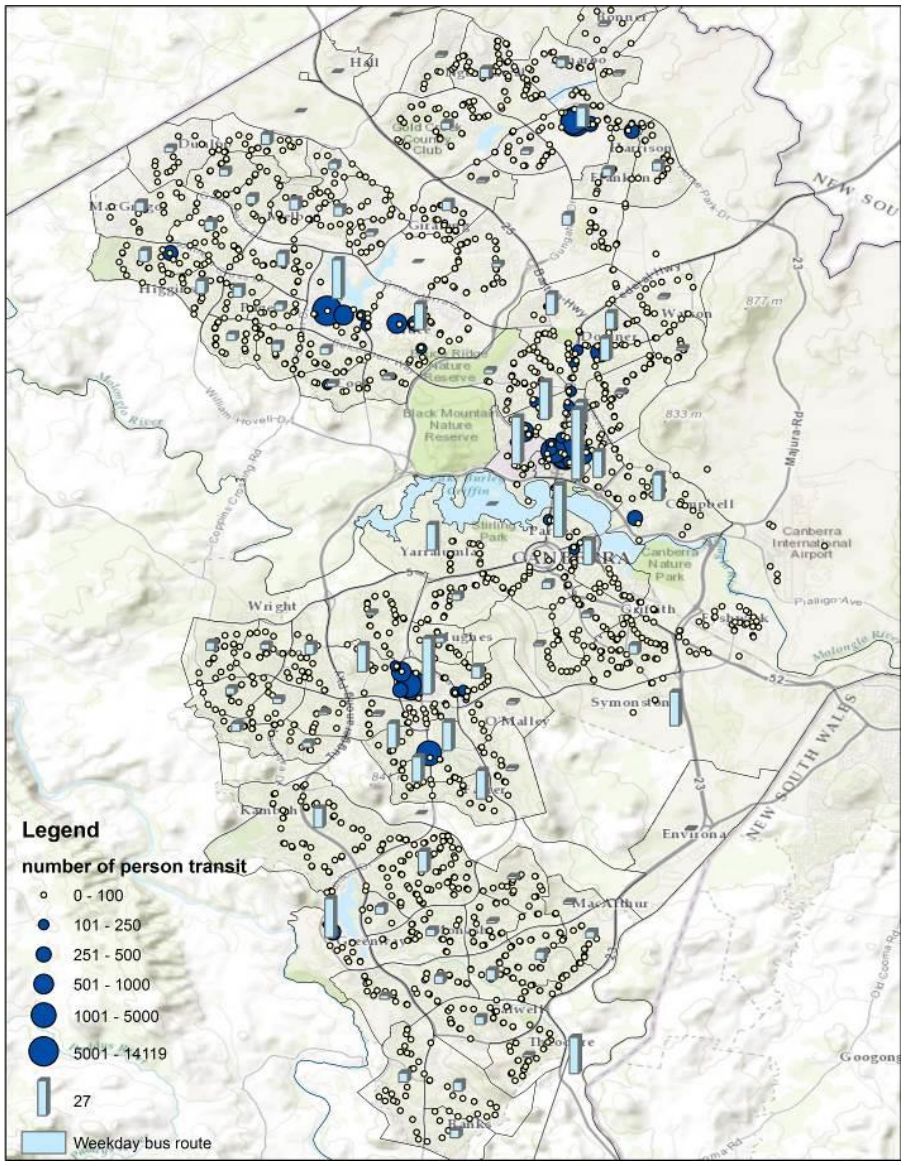
Table 2 shows that older people may spend more time waiting for the bus than other categories of passengers. This means that the ACT government needs to consider the convenience/needs of older people more when considering services and land use around the bus stops that often become transfer hubs. The relative lack of time spent by older people become more pronounced when transfer time is excluded – it is in average the shortest among different passenger categories. Those who are over 75 are spending around 3 hours on average while other seniors spend almost four hours. This is much less than the 7.6 hours of an average adult or around 6 hours for students.

Table 2. The different pattern of bus transfer in different category of passenger

Passenger Categories	The average time spent on bus per trip (minutes)	Proportion of transfer (%)	The average time spent waiting for the next bus in transfer (minutes)	The average time in-between rides not involving transfer(minutes)
Over 75	15.5	30	34.5	188.7
	(9.8)	(45.9)	(27.1)	(94.5)
Senior	17.2	29.7	31.2	239
	(10.1)	(45.7)	(26.9)	(138.5)
Pensioner	18	37	29.1	269.2
	(58)	(48.3)	(25.4)	(148.7)
Adult	19.8	20.1	17.9	458.5
	(37.4)	(40.1)	(21.5)	(152.8)
Student	16.5	21.4	21.1	358
	(9.3)	(41)	(22.3)	(126.4)
Tertiary	19.7	26.9	21.3	361.2
	(93.5)	(44.4)	(23.3)	(169.5)
Total	18.7	23.3	21.7	397.6
	(45.2)	(42.2)	(23.4)	(166.4)

As we address the importance of facilities or services at transfer locations, it is important to identify the most popular transfer points. Figure 5 shows that these locations are concentrated in only a few places - Westfield Belconnen, Gungahlin market place, Civic Canberra centre and Woden are the main transit points. These locations contain bus terminals as well as market places (shopping mall). As consequences, it has become more likely that people do not wait at the actual bus stop but used the shops. However this points to the need for other services. For example, the availability of bus schedule in the shopping mall and announcements of bus arrivals and departures.

Figure 5. Location of transit



5. Discussion and conclusion

This study aims to use Smart ID bus card data to identify travel patterns of different passenger categories in order to provide better services especially for the more disadvantaged part of society. Our analysis shows some important findings – the different travel patterns of each passenger category, different travel time of each passenger category and their patterns of transfer. This study demonstrates the potential of smart card data in transportation research in an Australian city where public transport is less preferred as a main mode of transport. Buses are much used by those who are likely to be transport disadvantaged (students and older people). The finding emphasised that buses are important for older people's independent mobility because bus stops near retirement villages have considerably higher usage by those people. The interesting finding of this research is that older people are highly likely to use more than one route to their final destination. Further research on smart card data may allow us to identify the factors that are associated

with this pattern. Nonetheless these findings provide us with an important research direction to advance the understanding of older people's travel patterns. The lack of information on this particular pattern could be lessened by further surveys or qualitative interviews. The locations of transfer points are major town centres in Canberra. This should be a starting point for a policy of more integrated land use and transport planning leading to user-friendly services to enhance the experience of using public transport.

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