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# Walking behaviours in older adults: A GPS-based survey in Brisbane

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## Abstract

Understanding walking behaviours of older adults is important for transport and urban planning, public health, environmental sustainability and quality of life. While there is a significant body of literature on the walking behaviours of older adults, these have tended to draw upon retrospective surveys and travel diaries to understand walking behaviour. These instruments, while providing valuable insights, produce coarse spatial and temporal data, making it difficult to isolate the neighbourhood and street level factors that facilitate walking.

This study conducts a 7-day GPS-based mobility survey of older adults in Brisbane, Australia. Walking trips were identified from GPS traces using a set of rules and were validated with respondents in a follow up survey. Results reveal that walking trips constitute a significant portion of travel (34.4%) by older adults. The average duration for walking trips was 20.59 (95%CI=18.09 – 23.09) minutes, covering a mean distance of 1130.7 (95%CI=1003.5 – 1257.8) meters and were largely concentrated during morning peak hours between 6AM and 10AM. Almost 43% of all walking trips originating from respondents place of usual residence occurred between 6AM and 10AM and most were within 1.8 kilometres of the respondents' home. About 70% of all walking trips covered more than 400 meters and nearly 38% were more than 1 kilometre. The paper demonstrates the utility of GPS-based survey data on walking behaviour to amass new information on when, where and why older adults engage in walking with important consequences for smart urban design.

## 1 Introduction

Australia, like many industrialised nations is currently undergoing substantial population ageing (Beard et al., 2016, ProductivityCommission, 2005). The 2016 Australian Census of Population and Housing reported nearly one in every six people (16%) were aged 65 and over, and this age group population is projected to increase to 21% by 2066 (ABS, 2016). While population ageing represents a triumph over disease and premature mortality (UNFPA, 2015, UnitedNations, 2015, WHO, 2015), it presents major social, economic, and public health issues (United Nations 2009). The World Health Organisation (WHO) suggests that facilitating healthy and active ageing, of which walking is an integral part, is an important response to this demographic shift (WHO, 2015).

Walking behavior varies among population subgroups. For instance, walking distance and walking duration were found to vary by population subgroups (Yang and Diez-Roux, 2012). In addition, it is suggested that aspects of neighbourhood relevant to older adults walking behaviour might be different to other age groups (Weiss et al., 2010, Ghani et al., 2016), and more research are needed to further improve on this knowledge (Moudon et al., 2007). Understanding the way in which older adults interact with their physical environment by walking and the association between walking behaviour and the characteristics of the physical environment is vital to design and develop healthy and active cities. Walking is a mode of travel and an activity in itself (Saelens and Handy, 2008); walking is one of the easiest way to remain active in old age (Prins et al., 2016, Nagel et al., 2008). Walking not only improves older adult's chances of living a quality of life by reducing physical, functional and cognitive limitations and disability (Towne et al., 2016, Pahor et al., 2014), it also promotes social interaction which can build trust and belonging (Leyden, 2003, Rogers et al., 2011) essential for a cohesive society. While there is voluminous literature on walking behaviour and its links to the physical environment, these are mostly guided by the socioecological model (Barnett et al., 2017, Cerin et al., 2017), which emphasizes individuals interaction with the physical environment. Despite considerable efforts, significant progress has not been made. Lack of quality data on walking and contextual information is considered a major barrier to understanding the drivers of walking behaviour (Millward et al., 2013).

Past studies on the walking behaviour of older adults have tended to utilize data on walking derived using retrospective surveys and travel diaries (Owen et al., 2007, Nagel et al., 2008, Christian et al., 2011, Troped et al., 2017). These studies have examined either or all weekly "walking frequency" and "walking duration" separately for transportation and recreation purposes. Using weekday travel data from South East Queensland Travel Survey, Burke and Brown (2007) examined two aspects of walking - "walking mode share", and "walked distances" for transportation purpose. Another study employed travel diary and GPS data to study "walking duration" and "walking distance" (Millward et al., 2013) - GPS data were used only to check the accuracy of the trip start and end time reported in travel diary and walked distance were computed using network based shortest distances between origin and destination of walking episodes reported.

While yielding important insights, these studies have often lacked detailed information on the timing and routes of walking trips which can be collected using Geographical Position Systems (GPS). More detailed spatiotemporal information would enable closer examination of walking by older adults, as well as the degree of engagement and interaction with the natural and built environment. A better understanding of the spatiotemporal dynamics of the walking behaviour of older adults and its links to neighbourhood attributes can contribute to better outcomes in urban planning, public health, environmental sustainability and quality of life (Neatt et al., 2017, Saelens and Handy, 2008).

This study reports on a 7-day GPS-based mobility survey with the aim to improve understanding of walking behaviours of older adults in Brisbane, Australia. The study examines six dimensions of walking behaviour: [1] Walking mode share; [2] Frequency of walking trips; [3] Length and duration of walking trips; [4] Walking trip purpose; [5] Timing of walking trips; and [6] Spatial patterns of walking trips. The remainder of the paper is structured as follows. The next section introduces the case study area. In section 3 the survey outline and methods employed are described. The results section presents the analysis of six dimensions of walking behaviour, before closing with a remark on their implications for planners and policymakers.

# 2 Study area

The study area is defined by the extent of the Brisbane City Local Government Area (LGA). It is the largest LGA in Australia "www.brisbane.qld.gov.au/about", with an estimated resident population of 1.2 million and covers a total area of 1,340 square kilometres (BCC, 2012). Brisbane offers a unique context to study walking due to its hilly terrain and subtropical climate; while both topography and extreme weather are known deterrents to walking behaviour (Cervero and Duncan, 2003, Klenk et al., 2012), these are less studied. Brisbane city like many others worldwide are embracing walking as a strategy to make their city accessible, attractive and safe. These are evident in plans and vision document throughout. In Brisbane, 'Active Transport Strategy 2012 – 2026' are being implemented with a view to achieve 14.1 % walking in 2021 and 15% in 2026 (BCC 2012). While encouraging walking is a number one priority, making walking friendly suburbs is the number two priority for the above strategy. Knowledge on how its most vulnerable residents interact with their city is a timely and relevant study.

# 3 GPS based mobility survey

## 3.1 Outline of the survey

The 7-day mobility survey recruited a total of 55 Brisbane residents between August 2017 and May 2018. The target population were the older adults aged 50 and over, living in Brisbane. Survey respondents were provided with GPS devices (Holux RCV 3000, Holux Technology, Inc., Taiwan) and chargers. These are wireless GPS data loggers that search up to 66 satellites simultaneously, reacquires satellite signals in 0.1 microseconds and updates position data per second, and allows store of up to 200,000 GPS data points. The devices needed to be charged overnight. The researcher collected the GPS device from respondents at the end of the survey period and met with respondents within a week time to validate identified walking trips. Only those respondents who participated in validation meeting and who recorded at least one walking trip were included in this paper (n=40).

Walking trip is defined as a trip segment with minimum duration of 3 minutes walking as well as minimum distance travelled of 50m walking. The total number of validated walking trips is 303. On average respondents made a total of 21 trips and 7 walk trips per person per week.

## 3.2 Methods

### *3.2.1 Walking trip identification*

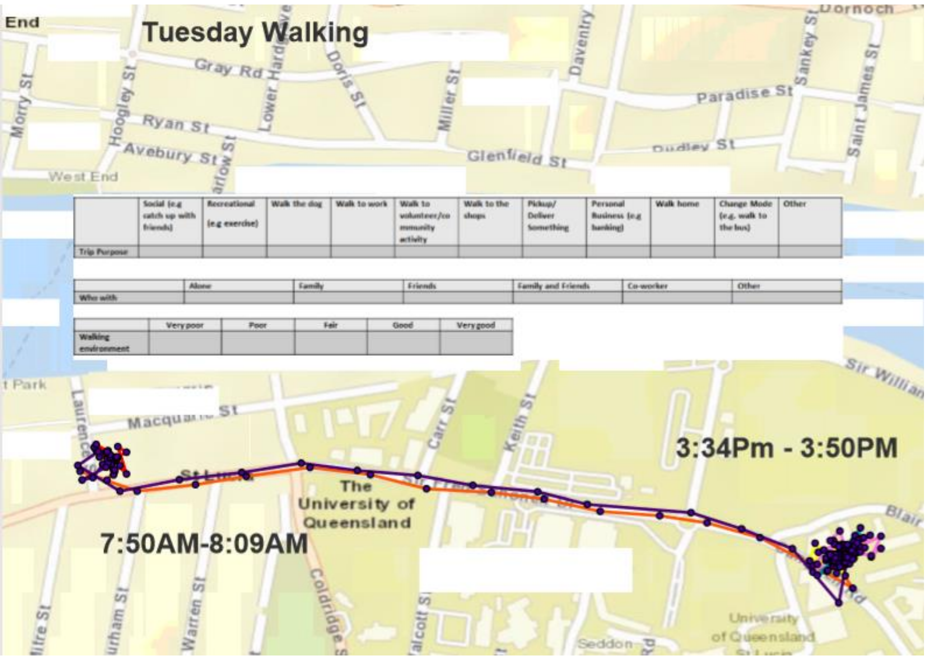
The raw GPS data points collected were post-processed to identify walking trips. The post processing of the GPS data involved four stages followed by validation of identified walk trips (**Table 1**). These steps are adapted through a review of past literature (Bohte and Maat, 2009, Cho et al., 2011, Gong et al., 2012, Schuessler and Axhausen, 2009, Stopher et al., 2008, Wolf et al., 2014). For a comprehensive review of GPS travel survey and GPS data processing, readers are suggested to look at (Shen and Stopher, 2014). Along each stage cross comparison was made by map matching GPS data with GIS data and were most useful to validate stop points.

**Table 1 Rules used in the identification of walking trips**

| **Rules used in the identification of walking trips** |
|---|
| I. Trip Identification<br>A. Import GPS data track-points<br>1) Separate continuous stream of GPS data logs into days<br>2) Separate daily logs by track records<br>3) Separate each track record into trip-based data for visualization and analysis<br><br>B. Identify unreliable points<br>Speed: greater than 200kph or less than 1kph<br>1) Adjacent points within 10m of each other<br>2) Sudden jump in speed<br>3) Instances of single point outliers in a captured trajectory can add significant error to the accumulated distances and should be removed from consideration. This can be done by comparing GPS receiver point speeds with speeds estimated by dividing the distance between subsequent points and the time interval between them; instances where the distance-derived speeds are much higher than the reported speeds should be investigated.<br><br>C. Identify track points to be considered for separate trip (unreliable points identified in steps A and B are not included)<br>1) Elapsed time of 3 minutes<br>2) Speed close to zero<br>3) Rule of latitude and longitude change of 0.00005 degree<br><br>II. Mode identification (Walk mode/ Non-walk mode)<br>1) Walk point if speed>1kph and less than 10kph<br>2) Speed of each subsequent point < 15kph<br>3) Duration of at least 3 minutes<br>4) Distance of at least 50 meters<br>5) Information from GIS – Matching GPS data and GIS information<br><br>III. Merge trips – A merge of trip is necessary if trips are just the continuation of first trip. For example, situations when someone spends long time in traffic.<br>IV. Map matching – GPS data is combined with GIS for visual inspection and analysis of trips<br>V. Ground truth identified ‘walk trips’ |

The respondents validated the identified walking trips (almost 90% of walk trips were validated as walking) and provided three additional information for each walking trip including trip purpose, social context (who they were with), and how they rated the walking environment. Social context and walking environment rating are not aspects of walking behaviour but can influence walking behaviour; these are not reported in this paper. A sample validation template is shown in **Figure 1.**

**Figure 1 Sample walking trip validation template**




### *3.2.2 Metrics to quantify aspects of walking behaviour*

Characteristics of walking behaviour were derived from the validated walking trips. The metrics used to measure characteristics of walking behaviour for this study is as below.

- Walk trip distance is calculated based on great circle distance. Distance between two consecutive GPS data log points in a walking trip is calculated and summed to get the walking distance of a walking trip
- Walking trip duration is measured as the difference in time stamp between first and last GPS log points in a walking trip
- Walking trip rate is measured as the number of walking trips per person in a week
- Walk trip share is measured as the proportion of walking trips with respect to total trips

### *3.2.3 Statistical analysis*

Summary statistics of aspects of walking behaviour were characterised by the sociodemographic characteristics. Demographic characteristics of the sample were compared using chi-square statistics, independent t-tests and ANOVA. Cross tabulations of walking trip data are used to illustrate the distributions of aspects of walking by person and by trip purpose.

Temporal patterns of walking behaviour were explained using a spider web diagram also referred to as circular plots or radial plots. Spatial pattern of walking behaviour is measured using "activity space" and explained with geographical information science visualisation.

Activity space captures the locations individuals actually visits rather than a presumed neighbourhood boundary (Hirsch et al., 2014) and indicates where and how people have contact with their social and physical environment. (Wang et al., 2018). Activity spaces for individuals are created using the minimum convex polygon as an area-based geometry to describe the geographic extent of individuals' weekly walking patterns.

# 4 Results

## 4.1 Walk mode share

Walk mode share is the percentage of all travel on foot. Walking is a significant mode for older adults travel, accounting 34.4 percent of all trips. As shown in **Table 2**, the share of walking mode is higher for females (37.2%) than males (27.9%). On the other hand, people aged 60-64 years had the highest share of walking mode (42.9%), followed by 55-59 years(37.3%), 65-69 years(34.59%), 75-79 years (33.49%), 50-54 years (33.03%),and 70-74 years had lowest share of walking mode (24.7%). Employed individuals had larger share of walking mode than the retirees. Similarly, individuals living by themselves had higher walking mode share (43.9%) than individuals living with family. Individuals who have lived in their residence for fewer years had higher share of walking mode than older individuals who have lived in their residence for over 10 years. Owning a bicycle can suggest an attitude towards active transportation and as expected, bicycle owners walking mode share was highest than non-bicycle owners. Similarly, dog owners travel involved higher percentage of walking mode than non-dog owners. This is quite understandable as dog-owners who take their dog out for a walk will engage in more walking in comparison to a similar personality with similar travel attributes without a dog.

**Table 2 Walking profile by sociodemographic characteristic (n =40)**

| Demographic group | n | Walk trips | Total trips | Avg. walk trip rate per week | Walk trip share (%) | Avg. walk trip length (m) | Avg. walk trip duration (min) |
|---|---|---|---|---|---|---|---|
| **Gender** | | | | | | | |
| **Female** | 29 | 230 | 618 | 7.93 | 37.2 | 1172.91 | 21.94 |
| **Male** | 11 | 73 | 262 | 6.63 | 27.9 | 997.56 | 16.34 |
| **Age** | | | | | | | |
| **50-54 years** | 5 | 37 | 112 | 7.40 | 33.03 | 1251.56 | 24.32 |
| **55-59 years** | 11 | 88 | 236 | 8.00 | 37.30 | 846.27 | 15.38 |
| **60 - 64 years** | 3 | 24 | 56 | 8.00 | 42.85 | 1407.20 | 25.58 |
| **65 - 69 years** | 8 | 64 | 185 | 8.00 | 34.59 | 1146.93 | 21.35 |
| **70-74 years** | 4 | 21 | 85 | 5.25 | 24.70 | 1530.52 | 21.09 |
| **75-79 years** | 9 | 69 | 206 | 7.66 | 33.49 | 1195.56 | 22.63 |
| **Employment** | | | | | | | |
| **Retired** | 17 | 102 | 336 | 6.00 | 30.40 | 1206.67 | 23.30 |
| **Employed** | 17 | 153 | 429 | 9.00 | 35.70 | 1144.81 | 19.90 |
| **Other** | 3 | 24 | 61 | 8.00 | 39.30 | 1135.92 | 18.58 |
| **Volunteer** | 3 | 24 | 54 | 8.00 | 44.40 | 712.25 | 15.54 |
| **Living Arrangements** | | | | | | | |
| **Alone** | 12 | 116 | 264 | 9.66 | 43.90 | 1142.60 | 19.13 |
| **With children or other relative** | 2 | 6 | 39 | 3 | 15.40 | 888.67 | 32.5 |
| **With my spouse or partner** | 22 | 158 | 477 | 7.18 | 33.10 | 1128.83 | 19.71 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **With spouse and children** | 3 | 17 | 69 | 5.67 | 24.60 | 1395.70 | 35.17 |
| **Group household** | 1 | 6 | 31 | 6.00 | 19.40 | 439.16 | 18.83 |
| **Years of residence** | | | | | | | |
| **Less than 1 year** | 3 | 44 | 74 | 14.66 | 59.50 | 1168.95 | 21.56 |
| **1-5 years** | 9 | 69 | 187 | 7.66 | 36.90 | 955.79 | 21.75 |
| **6-10 years** | 2 | 20 | 45 | 10.00 | 44.44 | 831.10 | 13.7 |
| **More than 10 years** | 26 | 170 | 574 | 6.53 | 29.60 | 1226.97 | 20.68 |
| **Car ownership** | | | | | | | |
| **Yes** | 39 | 274 | 838 | 7.02 | 32.7 | 1163.64 | 21.37 |
| **No** | 1 | 29 | 42 | 29.00 | 69 | 819.13 | 13.24 |
| **Bicycle Ownership** | | | | | | | |
| **Yes** | 11 | 102 | 277 | 9.27 | 36.80 | 1115.43 | 22.70 |
| **No** | 29 | 201 | 603 | 6.93 | 33.30 | 1138.39 | 19.52 |
| **Dog ownership** | | | | | | | |
| **Yes** | 7 | 64 | 165 | 9.14 | 38.80 | 1246.84 | 20.87 |
| **No** | 33 | 239 | 715 | 7.24 | 33.40 | 1099.56 | 20.52 |

## 4.2 Frequency of walking trips

The walk trip rate is an indicator of the frequency with which old adults engaged in walking during the survey week. The walk trip rate was 7.93 per person per week for female and 6.63 per person per week for male. Walking trip distribution by age group shows that people aged 55-69 years made 8 walk trips per person per week followed by 7.66 walk trips per person per week by people aged 75-79 years. Individuals aged 50-54 years made 7.4 walk trips per week and 5.25 walk trips per person per week by individuals aged 70-74. It is interesting to see 75-79 years age group recording higher trip rates than younger age groups like 50-54 and 70-74 years, however the differences are not statistically significant for both walking trips and total trips. This is possibly because of fewer observations in some categories of demographic characteristics.

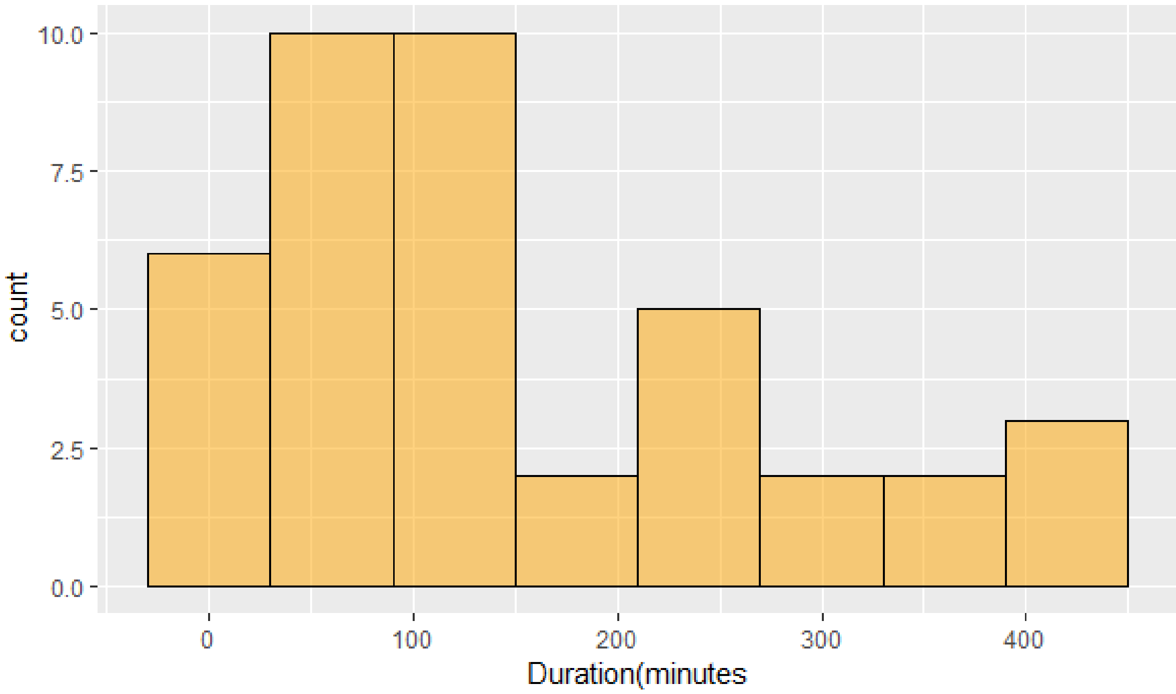
It is reasonable to expect that employed individuals would make more trip than those that have retired, simply because employed people have scheduled trips. Similarly, in our sample, people who were active in some way (employment part time or full time, volunteer or community engagement) made more walking trips and the retirees made fewer walking trips. Single individuals on average recorded higher walking trip rate than those living with the family. Individuals who have lived in their residence for fewer years made higher walk trips on average than the individuals who have lived in their residence for over10 years, however this difference was not significant at 0.05 significant level. This is consistent with finding elsewhere in Adelaide where older adults who moved to a new residence three years ago or less were found to take more walking and public transport (Truong and Somenahalli, 2011). This suggest that newer residents may be making more trips to get familiar with the new environment or they selected new residence to suit their lifestyle needs. As expected, trip rates were greater among dog owners and bicycle owners. The study had a single respondent without a car and made 29 trips during the survey week. As older adult face the challenges posed by having no access to cars or when driving license is revoked, walking perhaps becomes the major mode of travel to manage life obligations.

## 4.3 Length and duration of walking trips

Walking distance and duration are important concepts in the fields of transportation and public health. In the study sample, the mean distance walked for all trips was 1130.7 (95%CI=1003.5 – 1257.8) meters which is greater than the usually assumed 400-500 meters walking distance in walking research study (Yang and Diez-Roux, 2012). The average distance walked per walking trip by each sociodemographic characteristic is presented in **Table 2**. T-test and ANOVA test were carried to identify if walking distance varied by their sociodemographic characteristic. There was no statistical difference in walking distance between any of the sociodemographic characteristics at the 0.05 significant level. On average females walked 1072 meters per walking trip while males on average walked 997.5 meters per walk trip.

Walking duration has received significant research attention because walking as little as 30 minutes a day for at least five days is considered to have a significant positive impact on health. The mean duration for all walking trips was 20.59 (95%CI=18.09 – 23.09) minutes. Further analysis was carried for the distribution of walking duration by each respondent over the week (**Figure 2**). On average the sample respondents walked 156 minutes which is slight above the recommended level of physical activity for older people. Almost 85% of the respondents walked more than 100 minutes.

**Figure 2 Distribution of walking duration over 7 days by respondents**




## 4.4 Walking trip purpose

One of the common methods of reporting a travel is by the purpose of the trip. Travel is called a derived demand as it is induced by the purpose of performing an activity. Trip purpose is of paramount importance to transport planners, travel demand modellers and forecasters, and an accurate information of these are significant. Walking trips are categorized into eleven groups including home, work, change mode, social, recreational, walk the dog, volunteer/community activity, shops, pickup/deliver something, and other.

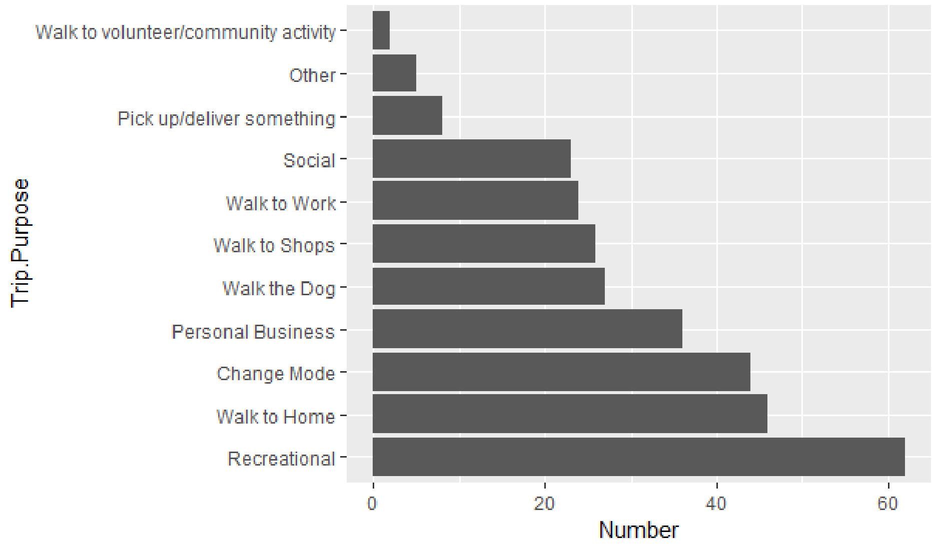
The recreational trips primarily for exercise constitute the highest proportion of all walking trips for the whole sample followed by walk to home and change mode (**Figure 3**). Any walking done to change mode is significant as this indicates either trip chain or a multimodal trip involving at least two modes (Walk + other modes). Same goes with walk to home and walk to work. Almost 40% of all reported walking trip occurred as part of a larger trip. This provides evidence that walking is a critical link to a multimodal transport system and existing travel surveys focussing on motorised modes undermine the relative importance of walking. **Table 3** presents the number of trips, average distance and duration by trip purpose.

**Table 3 Measures of walking by trip purpose**

| S.N | Trip Purpose | Number of Trips | Average Duration | Median Duration | Average Distance | Median Distance |
|---|---|---|---|---|---|---|
| 1 | Recreational | 62 | 34.30 | 34 | 1961.08 | 1800 |
| 2 | Walk to Home | 46 | 11.91 | 7.5 | 691.97 | 482.5 |
| 3 | Change Mode | 44 | 10.18 | 9 | 598.70 | 431 |
| 4 | Personal Business | 36 | 13.33 | 9.5 | 603.58 | 403.5 |
| 5 | Walk the Dog | 27 | 24.25 | 23 | 1365.29 | 1257 |
| 6 | Walk to Shops | 26 | 28.84 | 11.5 | 1166.80 | 485.5 |
| 7 | Walk to Work | 24 | 10.45 | 7.5 | 683.16 | 457.5 |
| 8 | Social | 23 | 33.52 | 34 | 1890.60 | 1788 |
| 9 | Pick up/deliver something | 8 | 10.75 | 6.5 | 764.62 | 407.5 |
| 10 | Other | 5 | 18.00 | 7 | 1111.20 | 231 |
| 11 | Walk to volunteer/community activity | 2 | 17.00 | 17 | 1174.50 | 1174.5 |

There are significant differences among all trip purposes for both trip distance and trip duration. The analysis of variance showed that the effect of distance on trip purpose was significant, $F(10, 292) = 9.6$, $p<0.001$ and the effect of duration on trip purpose was significant, $F(10, 292) = 7.8$, $p<0.001$. Distance and the duration older people walk for each trip purpose are of primary significance. Recreational trips and social trips tend to be longer both in time and distance with a median distance of 1800 meters and duration of 34 minutes, followed by dog walking trips. While the walking done to change mode, walk home, walk to work are all under 800 meters on average. This indicates individual trips that were undertaken with the idea to gain exercise, for health reasons and generally for recreation were longer compared to walking trips for other purposes. The smallest distance travelled as expected were walk to home, change mode, and walk to work all under 800 meters which may be a valuable evidence for policymakers and transport planners to consider in number of initiatives such as TOD and public transport station analysis.

**Figure 3 Share of walking trip purpose**




The distributions of the distances and duration walked for each walking category are shown in **Figure 4** and **Figure 5**. The shape of these distributions is interesting as the count of trips are higher for shorter distances and duration and shows some peak after which gradually decrease. Recreational trips and social trips distance show uniform distribution, however when we look at the distribution of walking duration, recreational trip duration initially increase, peak at 50 minutes and gradually decrease.

**Figure 4 Distribution of walking distance by walking purpose**

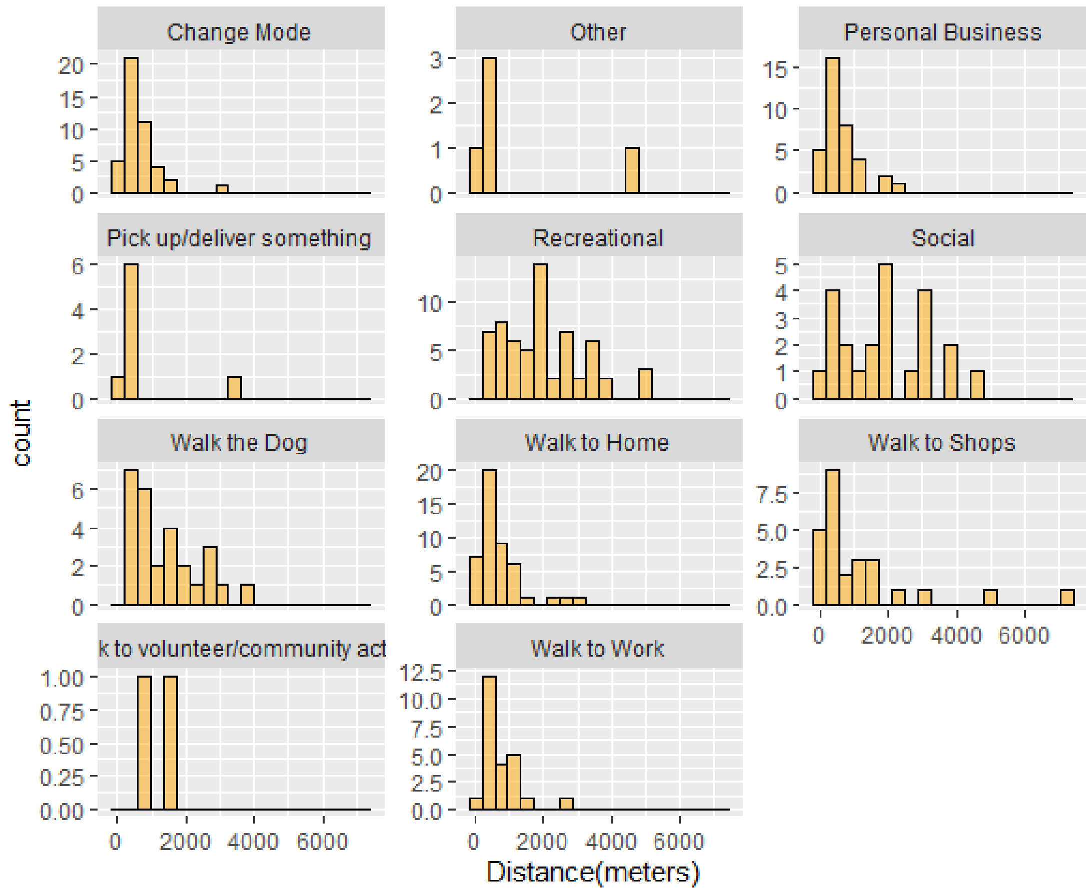
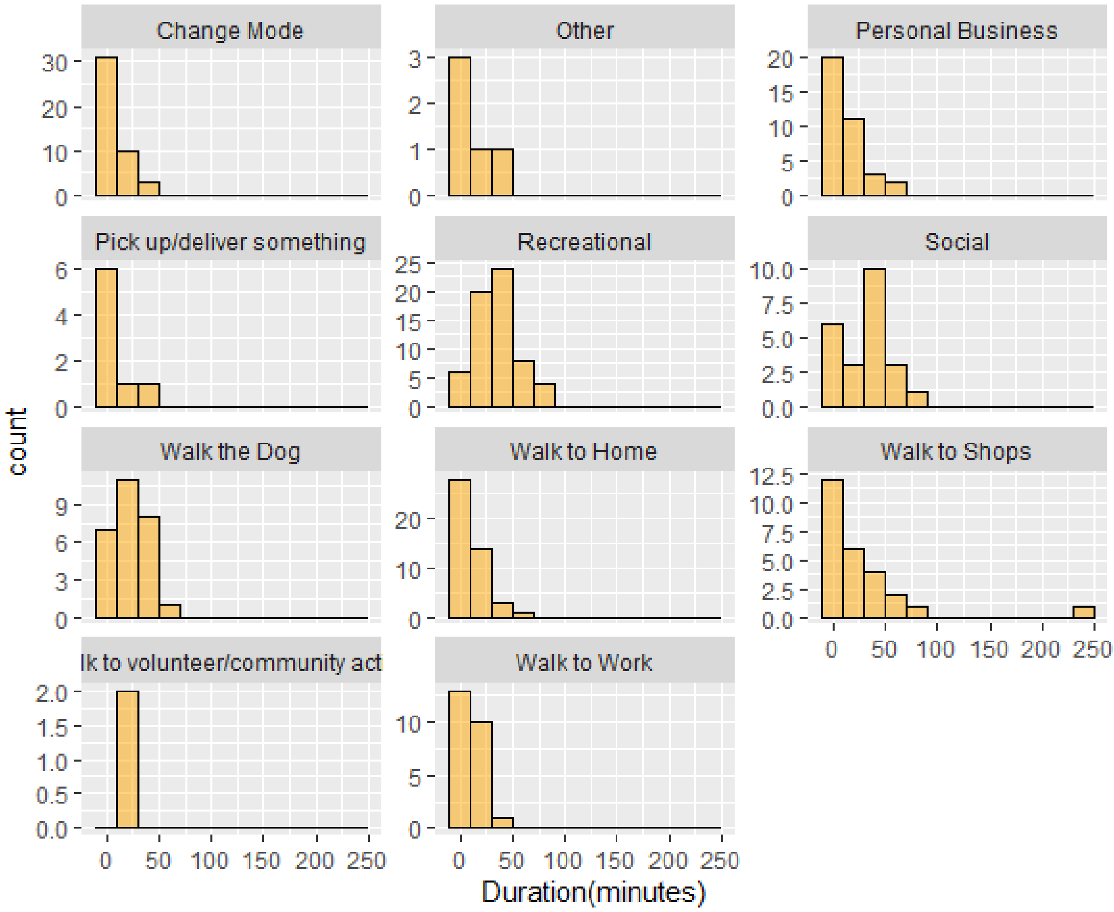


**Figure 5 Distribution of walking duration by walking purpose**



## 4.5 Timing of walking trips

Temporal pattern of walking behaviour is described using spider web diagram. A spider web diagram is a circle divided into 24 equal sections using radial lines (Shoval et al., 2011). The visualisation of the timing of walking trips indicates the time of the day when walking among old adults is most prevalent, as well as the temporal distribution of walking trip purpose. Walking trips were consistent across each day of the week except for Sunday. The highest number of trips were on Thursday and lowest trips were on Sunday for the sample.

### *4.5.1 Frequency distribution of walking trips by hour of the day*

An important aspect of walking activity is that its intensity varies by the hour of the day. The frequency distribution of trips by the hour of the day is presented in **Figure 6**. Walking trips peaks in the early morning between 5AM and 7AM and between 3PM and 4PM. Further analysis was made of the temporal distribution of walking trips for all home-based walking trips (**Figure 7**). Walking trips were grouped into two distinction: All walk trips (AWT) include all walking trips while home-based walk trips (HBWT) includes every trip with home as either the start or end point of the trip. **Figure 6** & **Figure 7** shows similar pattern for both AWT and HBWT, it is interesting to notice that AWT are almost double the HBWT at every hour, which indicates that equal number of walking took place outside of the home in other places at every hour. Walking trips are more frequent in the morning between 6AM to 9AM and later in the afternoon between 3PM and 4PM. Between the hours of 9AM and 3PM, the walking trips were almost half the number of trips during the morning peak and afternoon peak. The number of walk trips reduced in the evening after 5PM and every hour after that until 7PM. No adults in the sample engaged in walking after 7PM.

**Figure 6 Frequency of walking trips (AWT) by hour of the day**

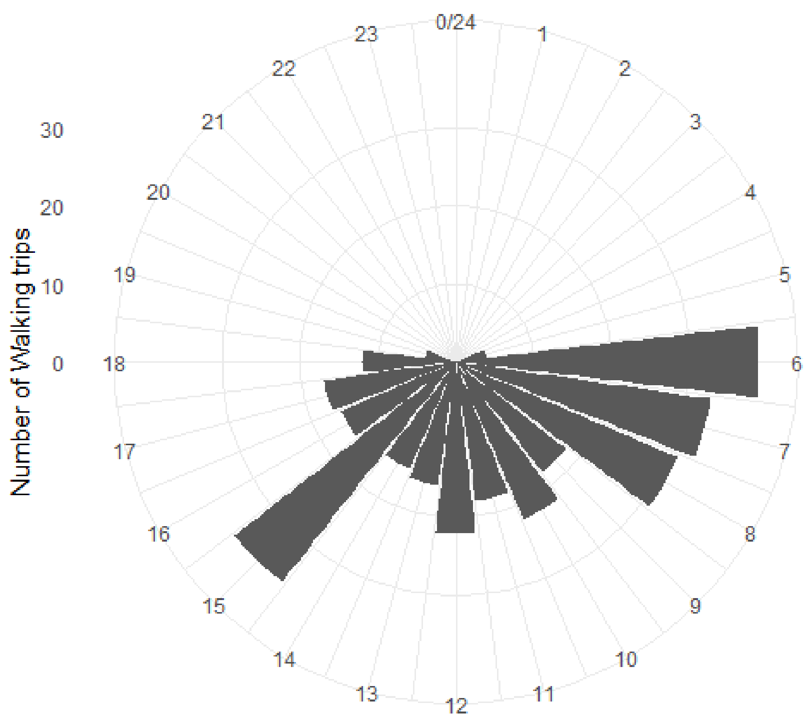
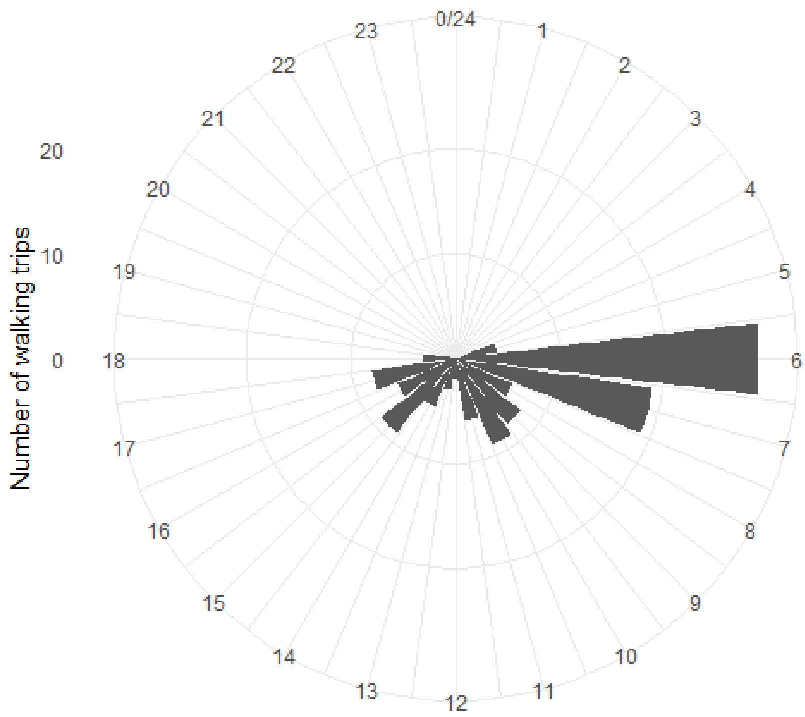


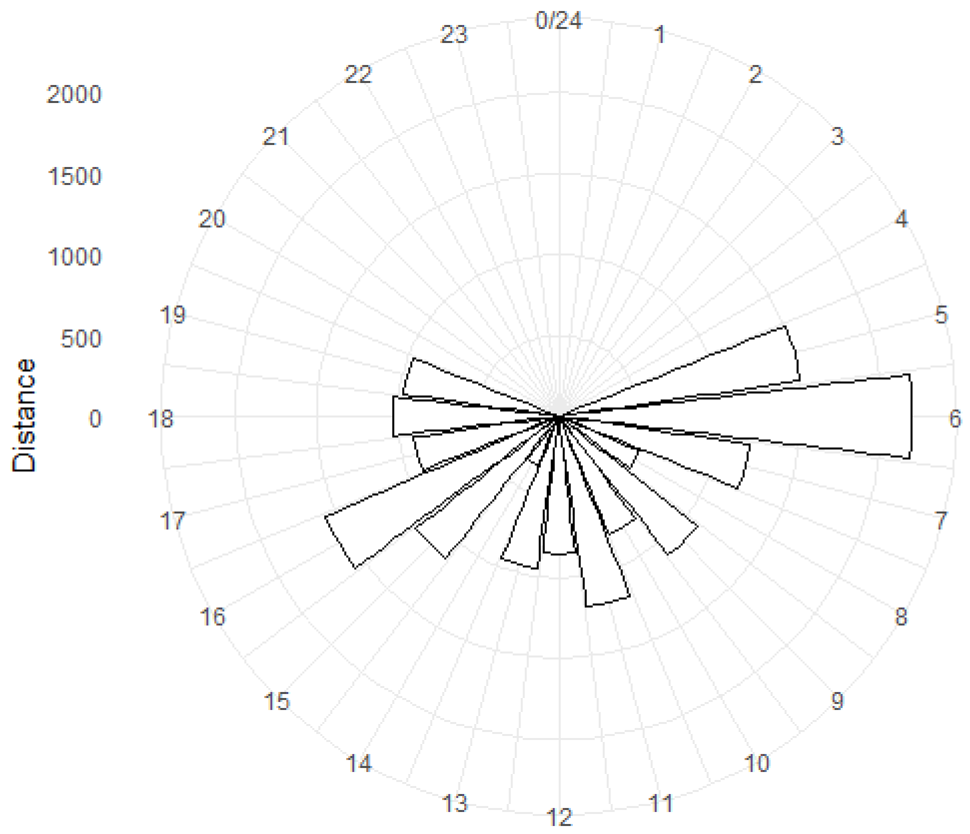
**Figure 7 Frequency of walking trips (HBWT) by hour of the day**



### 4.5.2 Walking distances by hour of the day

As shown in figure below, people walked longer distance between the hours of 6 and 7 and between 4 and 5PM, the walking distance reduced after the hours of 5PM in the evening.

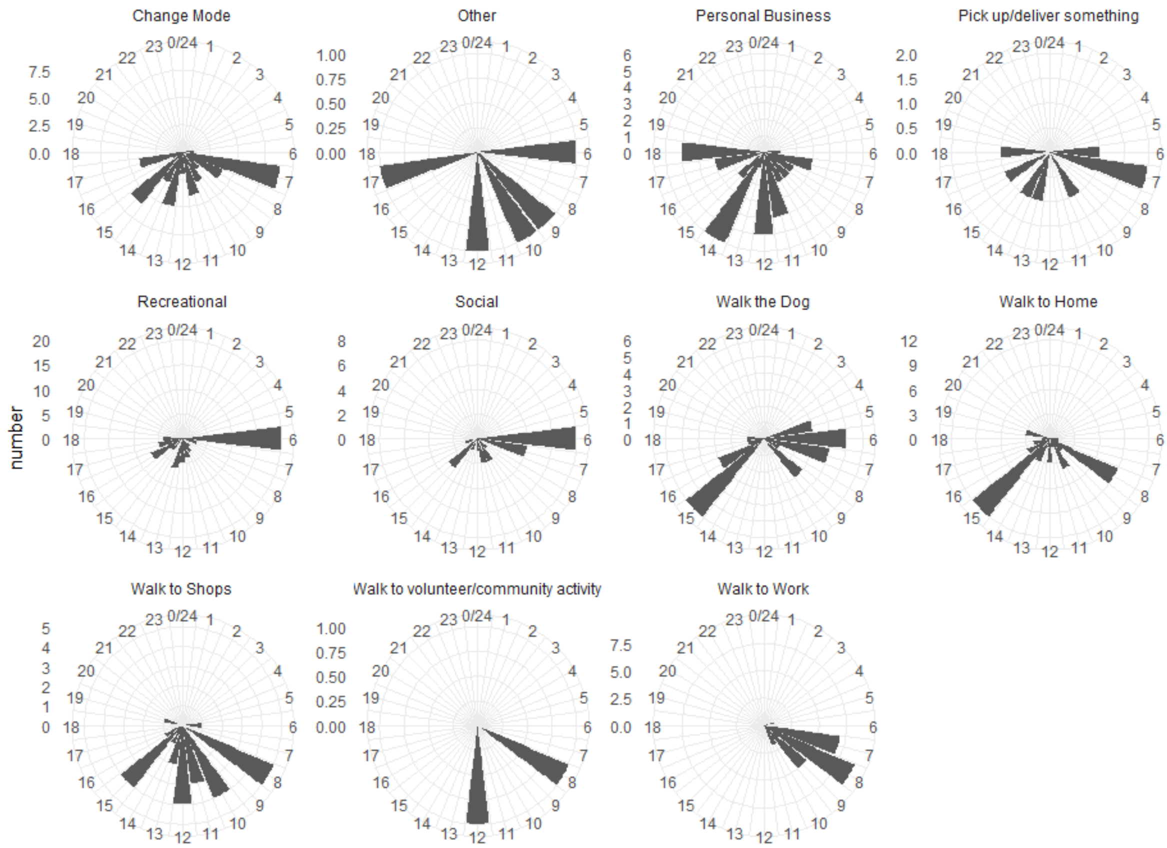
**Figure 8 Average distance of walking trips by hour of the day**




### 4.5.3 Hourly distribution of number of walking trips by various trip purpose

An analysis is conducted to see the hourly distribution of walking trips by the hour of the day for each walk trip purpose. The number of trips to change mode shows a peak between 7 AM and 8AM as well as between 3PM and 4PM. Recreational trips for exercise are done early in the morning between 5 and 7AM. Walk to home peaks between 3PM and 4PM. Walk to work occurs during morning so no one in the survey were working in the night. Dog walking trips occurred between 5AM and 9AM and between 3PM and 5PM. Personal business trips occur throughout the day as do walk trips to the shops.

**Figure 9 Count of trips by hour of the day for every trip purpose**

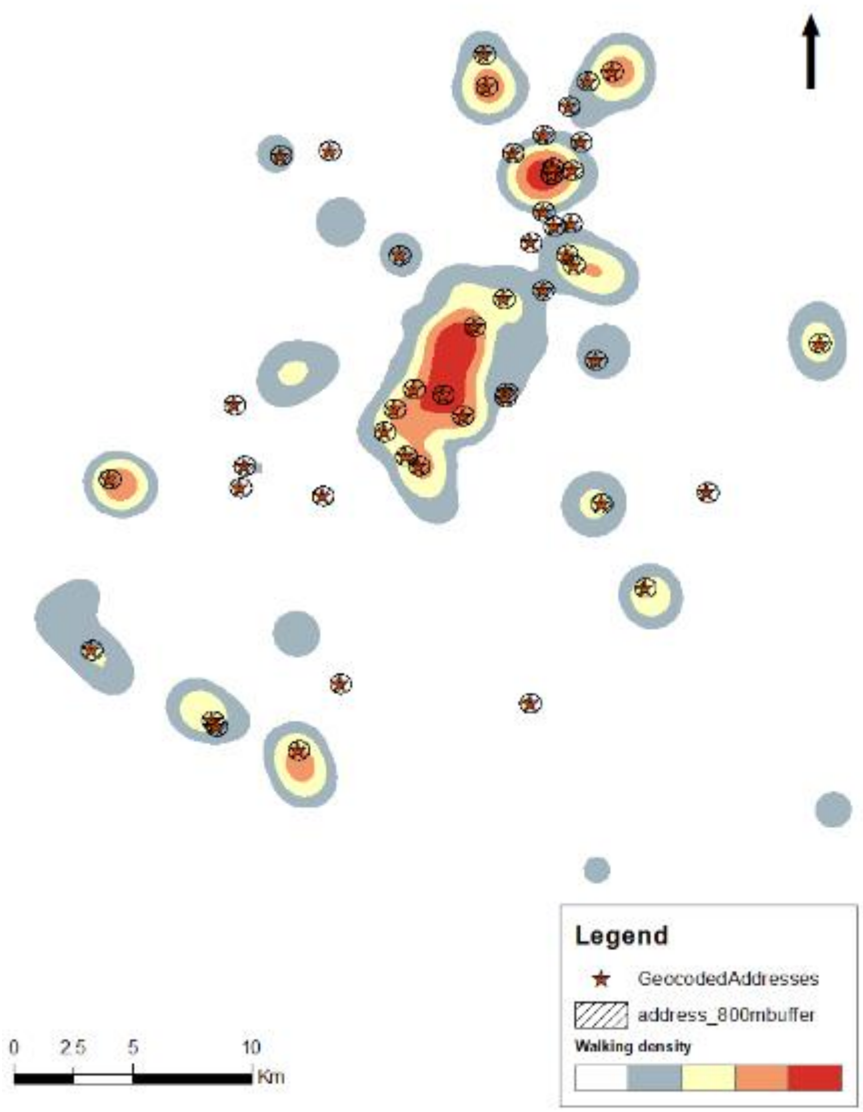



## 4.6 Spatial patterns of walking trips

To explore the links between the built environment and walking behaviour, we draw on the concept of activity space from the field of time geography to understand the geographical extent of walking activity. Minimum boundary geometry tool in ArcGIS were used to calculate the minimum convex polygon containing all the activity locations visited by the individuals. The area of the walking activity space measured in square kilometres is the indicator of individuals' spatial walking footprints. The average walking activity space size is 56.78 square kilometres. There is substantial variability across the sample – standard deviation (219.19 sq. km). The minimum area of walking activity space is 0.080 sq. km and maximum area is 1365 sq. km. The variation in walking activity space size demonstrates how different individuals engage in multiple spatial contexts.

A simple visual representation of individuals' home neighbourhood both as an administrative unit and a home buffer of 800m and walking density surface is presented in **Figure 10.** It is clear that individual's extent of walking extends well beyond their immediate home neighbourhood and they participate in walking in multiple spatial context. This revelation establishes that walking occurs in multitude of places and therefore delineating walking environment as static area creates misclassification and inappropriate evidence on environmental influences of walking behaviour. While the variation in the walking activity size could be a result of several sociodemographic indicators, the purpose here is to highlight the dynamic context of walking and the environment where they occur. The next step is to examine walking where they occur (at the trip level) and provide evidence to what contextual factors are likely to influence walking behaviour.

**Figure 10 Geocoded address, 800meter neighbourhood and density surface[1]**




# 5 Conclusion

This paper has investigated walking behaviours in older adults through a GPS-based mobility survey. An analysis of GPS traces allied with a follow up survey with respondents has unveiled when where and why older adults engage in walking.

The results indicate that walking forms a substantial portion of older adults travel (34.4%). Furthermore, walking mode share and walking trips were highest among individuals who have lived in their residence for fewer years than residents who have lived in their residence for a longer period of time. These findings indicate that walking

[1] Geographic detail has been removed in order to preserve the anonymity of respondents

is important to older adults, therefore much attention needs to be given to walking as a mode of travel to improve mobility and access for this population group.

Unlike in most of prior scholarships that have used either perceived distance (Cerin, 2007), shortest path or network distance (Giles-Corti et al., 2011, Millward et al., 2013), walking distances were computed using 'great circle distance'. Findings on distance reported in this study may be more accurate and represents a useful information to validate some of the assumptions in established planning guidelines.

The temporal pattern of walking behaviours shows that older adults are engaged in walking throughout the day, but are most active during morning primarily for exercise. Using simple circular visualisations of walking trips might provide useful visual analytic for planners and policymakers to create an understanding of the temporal dynamics. The spatial pattern of walking trip shows that walking is not limited to one's home neighbourhood rather it occurs across a suite of spatial contexts. These findings support those found elsewhere (Millward et al., 2013) and highlight the need to move beyond conventional neighbourhood perspective in existing walkability studies.

Taken together, the findings of this study are important in the way they reveal various dynamics of walking behaviours with practical utility for planners and policymakers in the way that can be used to inform the (re)design urban environments to help ensure that they are conducive for health and well-being outcomes. Finally, the analytic approach used in this study has utility for application across other population groups such as adults and children along with other situational contexts.

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