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Travel behavior of low income older adults and implementation of an accessibility calculator

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Abstract

Given the aging demographic landscape, the concept of walkable neighborhoods has emerged as a topic of interest, especially during the last decade. However, we know very little about whether walkable neighborhoods promote walking among older adults, particularly those with lower incomes. Therefore in this paper we: (i) examine the relation between trip distance and sociodemographic attributes and accessibility features of lower income older adults in Metro Vancouver; and, (ii) implement a web-based application to calculate the accessibility of lower income older adults in Metro Vancouver based on their travel behavior. We use multilevel linear regression to estimate the determinants of trip length. We find that in this population distance traveled is associated with gender, living arrangements, and dog ownership. Furthermore, significant geographical variations (measured using a trend surface) were also found. To better visualize the impact of travel behavior on accessibility by personal profile and location, we also implemented a web-based calculator that generates an Accessibility (A)-score using Google Maps API v3 that can be used to evaluate the accessibility of neighborhoods from the perspective of older adults.

Keywords

Walkability; Trip distance; Multilevel; Accessibility; Web application

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1. Background and objectives

The world's population is aging at a rapid rate. In 2010, people aged >65 years accounted for eight percent of the world's population; by 2050 this figure is expected to double to 16% (United Nations Department of Economic and Social Affairs). In Canada, the proportion of people aged >65 years is projected to rise from 14% in 2010, to 25% by 2050 (United Nations Department of Economic and Social Affairs); this is largely a result of the aging baby boomer generation, declines in fertility rates and an increased life span (Certified General Accountants Association of Canada, 2005). Aging of the population highlights the need for interventions that maximize health and well-being in later life as a way to decrease strains on the health care system and to maximize the quality of life of a growing segment of our population.

Walking is an ideal activity among the older adults as it is safe, does not require any training, and can be undertaken in different settings throughout the year (Morris and Hardman, 1997; Mutrie and Hannah, 2004; U.S. Department of Health and Human Services, 2008; US Department of Health and Human Services, 1999). Walking for transportation, in particular, is highly promising and, if incorporated in daily life, can contribute towards physical activity guidelines among aging people (Cauwenberg et al., 2012; Frank et al., 2010; Moniruzzaman et al., 2014; Morabia and Costanza, 2010). Walkable neighborhoods where walking is encouraged through supportive community design features, is a popular research topic (Glazier et al., 2014; Sugiyama et al., 2012; TRB and Institute of Medicine, 2005). Past studies show that built environments are important determinants of walkable neighborhoods (Cervero, 2002; Frank and Engelke, 2001; Frank and Pivo, 1995; Frank et al., 2006; Saelens et al., 2003). Cervero and Kockelman (1997) used "3D" (density, diversity, and design) model to express built environment which was recently extended by Cervero et al. (2009) into a "5Ds" model with two additional "Ds" as destination accessibility and distance to transit.

Walkable neighborhoods, with compact and mixed land uses, connected streets, and pedestrian oriented retail, are more conducive to walking than suburban, residential only neighborhoods as destinations (e.g. shops) in the walkable neighborhoods are closer to residents and have direct access to them (Badland et al., 2013; Duany et al., 2000; Frank et al., 2004; Frank et al., 2006; Frank et al., 2009; Jackson, 2011; Owen et al., 2007; Saelens and Handy, 2008). The term "complete neighborhood" refers to a walkable neighborhood with easy and safe access to goods and services without the use of car and fulfills the necessities of all ages and abilities (Leyden, 2003). Residents of complete neighborhoods are more likely to know each other, engage in social activities together, and be politically active all of which have health and community benefits for its residents (e.g. prevention of crime) (Leyden, 2003; Putnam, 2000). These neighborhoods also support residents' physical activity (King et al., 2003) as amenities are located within a short distance (e.g. groceries, coffee shops, restaurants, banks) and residents are able to access them by walking, cycling, and/or public transit. On the other hand, car-dependent neighborhoods demand that people travel longer distances to avail of daily necessities that are relatively difficult to access without a car. Although driving a car represents independence to most older adults (Burkhardt, 1998), it imposes a sedentary lifestyle on its users (Frank et al., 2004) and

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creates a health concern as residents of the car-dependent neighborhoods become older and forced to stop driving due to medical conditions (Burkhardt, 1999; Burkhardt and McGavock, 1999). Participation in out-of-home activity significantly reduces among the older adults in the car-dependent neighborhoods who can no longer drive their car and therefore are at higher risk of social exclusion (Burkhardt, 1998; Farber et al., 2011). It has also been found that car users tend to lose mobility as they age (Mercado and Páez, 2009). Using a three year longitudinal data, Marottoli et al. (2000) showed that older adults who had lost their license participated in fewer than one third of the out-of-home activities than those who continued to drive, with consequences on psychological well-being and physical health status (Bassuk et al., 1999; Marottoli et al., 2000; Zimmer et al., 1995). Hence, living in walkable neighborhoods with pedestrian-oriented design may better support older adults' health and independence (Owen et al., 2007).

The last two decades have marked an evolution of different indices designed to assess walkability of communities and neighborhoods (Maghelal and Capp, 2011). The popularity of walkability scores has escalated recently and they are now used by urban and social planners to inform decision making, by individuals who are considering a move to a new and potentially more suitable neighborhood, and by realtors to market neighborhoods. Walk Score[1], for example, is a popular measure used to identify walkable neighborhoods. It is a publicly available walkability index that measures the walkability of an address based on distances to nearby destinations. The Walk Score algorithm also takes into consideration population density and road metrics such as block length and intersection density. Frank et al. (2009) and Kuzmyak et al. (2005) also developed a walkability index and a walk opportunity index, respectively, to quantify neighborhood walkability (see for detail about these measures: Páez et al., 2013). While these measures are based on neighborhood built environments or opportunities within a given distance, they provide only a single result for any address. In other words, these measures do not account for how mobility may differ by an individual's sociodemographic characteristics (e.g. age, socioeconomic status) and therefore do not provide unique scores relevant at the individual level. Páez et al. (2013) developed of a web-based accessibility calculator that estimates accessibility for all age cohorts and income groups based on their travel behavior. However, we know that travel behaviors and needs of older adults are different than for a younger demographic (Cao et al., 2010; Rosenbloom, 2001; Tacken, 1998). Therefore, we perceived a need to implement and evaluate an age specific web application (*accessibility calculator*) that could be used by low income older adults to locate walkable neighborhoods in the Metro Vancouver region. Similar to the online accessibility calculator of Páez et al. (2013), our calculator in this study goes beyond walkability to generate an accessibility score (*A-score*) and also identifies different opportunities in the neighborhoods that are considered important to older adults, specifically. Thus, the *A-score* can be used to understand the accessibility of neighborhoods for older people.

The objective of this study is to examine the relation between trip distance, socio-demographic, and attitudinal characteristics of lower income older adults who live in Metro

[1]www.walkscore.com

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Vancouver. While the travel behavior of people with low income has been the subject of some study (Azmi and Karim, 2012; Azmi et al., 2012; Caspi et al., 2013; Hearst et al., 2013; Millward et al., 2013; Morency et al., 2011; Roorda et al., 2010; Sundquist et al., 2011), there has been less specific attention to older adults' walking. Residents of low income housing are at high risk of not achieving adequate physical activity because of their limited access to recreational facilities (Gordon-Larsen et al., 2006). Furthermore, lower income older adults might not afford maintaining a car due to high cost of car insurance in Canada. Thus, walking for transportation could be a viable alternative among these older adults and can help to achieve physical activity without additional time demands. Although there are different measures of travel behavior, for instance trip distance or vehicle kilometer traveled, mode choice, trip frequency, we primarily use trip length to assess neighborhood walkability in this study because it is an indicator of everyday competence, as noted by Mercado and Páez (2009) in their study of older adults' trip distance in Hamilton, Ontario. It is also an indicator of quality of life and provides indirect measures of independence to explore one's neighborhood (Mercado and Páez, 2009; Rowe and Kahn, 1997; Schaie et al., 2005).

Our paper is organized into five Sections. Section 2 presents our methods, including sampling techniques, data collection, and geocoding. Section 3 presents results of the trip distance model estimated in this paper. Section 4 presents a case-study and describes the process of developing the web-based application (*Accessibility calculator)*. Finally, in Section 5 we discuss the model results, provide a brief summary, and direction for future research.

2. Material and methods

2.1. Travel diary

In order to analyze the travel behavior of lower income older adults we collected information by means of a travel diary survey. Below we explain in detail the procedure used for sampling and collecting socio-demographic and travel behavior information.

2.1.1. Study area, sampling and recruitment—Metro Vancouver is a regional district in British Columbia, Canada, that comprises 21 urban and suburban municipalities and is home to some 2.3 million residents (Statistics Canada, 2012). In 2011, approximately 13.5% of the population was aged >65 years (Statistics Canada, 2012). Our sampling frame consisted of 5806 households located in 8 municipalities (Burnaby, New Westminster, North Vancouver, Richmond, Surrey, Vancouver, West Vancouver, and White Rock) in Metro Vancouver. These represent all of the households in the study area with at least one Shelter Aid for Elderly Renters (SAFER) rental subsidy recipient aged >65 years. SAFER is a monthly rental subsidy offered through BC Housing to older adults who live across British Columbia (BC) and whose rental payments comprise more than 30% of their gross monthly household income. To be eligible for SAFER, recipients have a monthly gross household income that cannot exceed $2333 for a single and $2517 for a couple which ensures that survey participants are from lower income household. To ensure that participants were sampled across a range of walkability, we used each participant's postal code (6-digit) to

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stratify individuals within our sampling frame into deciles of walkability, as measured by Walk Score. Each stratum contained 200 individuals and we randomly sampled 10% individuals (20 individuals) from each stratum of Walk Score that accumulated a total of 200 individuals for our assessment. Recruitment phone calls took place January 24th–February 22nd, 2012.

2.1.2. Inclusion/exclusion—We excluded individuals who did not understand and/or speak English (as communication with the participants was necessary and the language of communication was English); were diagnosed with dementia (as travel behavior of people with dementia must be different); left their residence to go into the community <1 in a typical week to make sure they undertake out-of-home activities; were unable to walk at least 10 m with or without a mobility aid; and/or were unable to participate in a mobility assessment where they were asked to walk 4 m to make sure they do not experience extreme physical disabilities. We obtained approval for our study from the University of British Columbia's Clinical Research Ethics Board (certificate: H10-02913) and obtained informed written consent from each individual prior to their participation in the study.

2.1.3. Measurement sessions—We assessed all participants in two-hour measurement sessions between March 5th and April 4th 2012 where participants were first assessed for eligibility (for instance able to walk 4 m), then were asked to fill out questionnaires about their demographics, health status, and neighborhood perceptions. We hosted a single make-up measurement session in May 2012 for participants who were unable to attend their originally scheduled assessment and were still interested in study participation. Participants residing in the City of Vancouver were assessed at our research facility at the Centre for Hip Health and Mobility (CHHM), while those residing in surrounding municipalities were assessed at community centers near their homes.

2.1.4. Seven-day travel diaries—We used travel diaries to record participants' trips during the week immediately following their in-person measurement session. We defined a trip as one-way travel between two destinations. For each trip, participants recorded start location (address or intersection) and time, end location (address or intersection) and time, reason for the trip (walk, volunteer, exercise, education shopping/errands, social/entertainment, health appointment, other), mode of travel (walking, bicycle, wheelchair, scooter, transit, taxi, car, other), and accompaniment (alone, spouse, sibling, child, friend, neighbor, volunteer, other). A sample of Day 1 travel diary is provided in Appendix.

2.1.5. Geocoding the trip origin and destination—A total of 3687 trips were recorded for all participants using the seven-day survey. The trips were geocoded using an online geocoder[2]. To calculate trip distance both the origin and destination are needed, however, 912 trips lacked adequate information to geocode origins or destinations, and were therefore excluded. We successfully geocoded 2647 trips made by 145 individuals. Fig. 1 shows where older adult participants across municipalities lived. Trip distance was calculated from trip origin to destination using the Network Analyst tool of ArcGIS through

[2]http://batchgeo.com/

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a 2013 road network file from Statistics Canada (2013). Average trip distance of all trips is 4.34 km with a standard deviation of 6.19 km and, for walking trips, the average and standard deviation are 1.44 km and 3.05 km, respectively.

2.2. Geocoded business locations

In addition to travel behavior, the *A-score* calculator also lists important business locations (i.e. opportunities). A 2013 business location database produced by infoCanada, with business type and location information from over 200,000 sources was used. The database is an exhaustive source of local businesses, validated annually. Each business is categorized with a 4-digit Standard Industrial Classification (SIC) code. For this study, we extracted ten different business classes from the database based on their priority for seniors (Chudyk et al., in press; Frank et al., 2010; King et al., 2003; Moniruzzaman et al., 2014). These were: groceries, banks, eating places, stopping centers, pharmacies, libraries, fitness clubs, and health care facilities. We chose these business categories to illustrate the scope of possibilities; they can be expanded and/or modified as desired.

2.3. Measuring accessibility

Accessibility, in general, is defined as the ease of reaching destinations. It is an integrative measure that combines aspects of transportation and of land use (Handy and Niemeier, 1997). Accordingly, two relevant aspects of accessibility are travel cost (e.g. travel distance or time, fare) and the opportunity landscape (Páez et al., 2012). It is usually the case that accessibility is measured based on a reasonable or desired threshold, for instance 30 min travel time or 500 m buffer (Apparicio et al., 2007; Block et al., 2004; Donkin et al., 1999; Páez et al., 2013; Ribeiro et al., 2010; Sharkey et al., 2009). Nonetheless people may prefer or have to make shorter or longer trips to meet their daily activities (Islam et al., 2008; Páez et al., 2012) and the choice of travel distances varies from individual to individual. This individual-level varying travel distance is commonly used for accessibility analysis in empirical time–geography researches (Casas, 2007; Kwan, 1998) and was obtained from field survey (Casas, 2007; Islam et al., 2008). Páez et al. (2012) however note that "[direct] use of distance or travel time reported in surveys retains a high degree of specificity with respect to individual accessibility, but does not lend itself for generalization."(p.145). Both spatial interaction (gravity) models (Clarke et al., 2002; Ozbay et al., 2003; Scott and Horner, 2008) and regression analysis (Zhao et al., 2003) have been used in the past for such generalization. Using the method of "adaptive threshold" (Páez et al., 2013, p.106) it is possible to assess the individual level varying accessibility which is in our case a statistical model of individual's trip distance. Trip distance of individuals as an "adaptive threshold" was extensively used in the past accessibility researches such as in the analysis of health care facilities (Páez et al., 2010a), food deserts (Páez et al., 2010b), children day-care (Páez et al., 2012), walking distance to transit stop (Zhao et al., 2003). The model of trip length forms the transportation element and the opportunities within the buffer of trip length represent the land use element of accessibility in this study.

2.4. Statistical approach

We used a multilevel modeling approach (Bottai et al., 2006; Breslow and Clayton, 1993) to evaluate the association between socio-demographic covariates commonly considered in

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travel behavior research (i.e., age, sex, education, living arrangement, ethnicity, driver's license, and possession of vehicle) and trip distance behavior of lower income older adults. We also included other covariates in our analyses (e.g. dog ownership, use of any mobility aids, have you fallen in past six months, how much you like to walk, how confident you are in walking) that have been suggested to influence the walking behaviors of older adults (Cutt et al., 2007; Gretebeck et al., 2013). Moreover, we incorporated a quadratic trend surface based on the geographic coordinates of older adults' home location. Use of trend surface in modeling of travel behavior allows the model to capture any geographic variability in the behavior and was implemented in past studies (Moniruzzaman et al., 2013; Morency et al., 2011; Páez et al., 2013; Reyes et al., 2014; Roorda et al., 2010).

3. Results

Table 1 reports the descriptive statistics of our sample. It can be seen there that majority of our survey participants (57%) are in the starting older age cohort i.e. 65–74 years, are female (65%), have some university education (50%), live alone (79%), and are white (79%). To estimate the model reported in Table 2, we used a backward specification search to reach the final model. Specifically, initially we included all covariates in the model and then excluded the least significant variable at each step until only variables significant at p value <0.05 remained in the model. This technique reduces the potential for omitted variable bias, and leads to more parsimonious models. We conducted a likelihood test to support using a multilevel model rather than a single level linear regression. The chi-squared test indicates that a multilevel model provides a better fit (p value <0.0001). The multilevel model had individual trips as the basic unit of analysis. Since the trips were recorded for each individual for a period of approximately seven days, the second level was the trip maker. Intra-cluster Correlation (ICC) values of 34% indicate that a relatively high proportion of total variation is explained at the level of the trip maker, unsurprisingly since this reflects habits and consistency in individual behavior.

The results of the model indicate that women traveled shorter distances compared to men. This has been reported previously (Collia et al., 2003; Kim, 2003; U.S. Department of Transportation, 2009) and may be due to medical conditions that limit travel (Collia et al., 2003).

Older adults who lived with a family member other than spouse (e.g. son or daughter, sister) traveled longer distances than those living alone. Although our results conflict with those of Sikder and Pinjari (2013), our findings may speak to the role of peer support which promotes positive lifestyle behaviors, including physical activity (McCormack and Shiell, 2011).

We also note that dog ownership was associated with a reduced trip distance. However the interaction we observed between dog ownership and walking as transportation mode had a positive association with trip distance. This suggests that those who own dogs and like to walk outside will walk further; while those who are not fond of walking, walk only short distances – despite owning a pet. Dog owners out of necessity assume a responsibility to walk their dogs – this does not necessarily depend on the built environment. Previous reports

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also showed that dog owners were more conducive to walk and therefore more likely to meet minimum physical activity guidelines than those who did not own a dog (Cutt et al., 2007; Gretebeck et al., 2013; Hoerster et al., 2011; Oka and Shibata, 2009, 2012; Thorpe et al., 2006; Toohey et al., 2013; Yabroff et al., 2008).

Use of mobility aids by older adults, in combination with walking as a mode of transportation, tends to reduce trip distance. Thus, whereas mobility aids reduce falls, increase confidence, and provide autonomy among older adults who are not able to walk independently (Smith et al., 2002; Verbrugge and Jette, 1994), they also limit the range of mobility. Therefore, given the important benefits of physical activity it seems important that even when older persons require a mobility aid they should be encouraged to walk whenever possible.

Two attitudinal statements were also tested. Liking to walk outside and confidence in walking were evaluated using a 5-point Likert scale (i.e., not at all, not much, neutral, somewhat, very much). For modeling purposes, these variables were reclassified into three categories (i.e., not at all or not much, neutral, somewhat or very much). Although individual influence of these two variables is not statistically significant, they are significant when interact with other variables. Interactions of variables in statistical models might be important in case simultaneous influence of the variables on the dependent variable is not additive (Aiken and West, 1991; Cox, 1984). We assessed the interaction between some categorical variables, with a priori expectations that interactions are an important determinant of trip distance. Older adults who chose “walking” as a mode of travel and rated liking to walk outside as “neutral” traveled shorter distances. In contrast, older adults who were “somewhat or very confident” about their ability to walk and used “transit” took longer trips. This is intuitive. A commonly identified barrier to transit use among older adults is walking distance to and from transit stops and navigation of the streetscape on the way to the stop (Hess, 2012; Peck, 2010). Other studies report that older adults with a favorable attitude towards walking and/or transit are more likely to use public transportation (Cao et al., 2010; Lynott et al., 2009).

Past studies of travel behavior usually assumed that travel behavior was constant over the geographic area of interest (Ashalatha et al., 2013; Boschmann and Brady, 2013; Cervero and Kockelman, 1997; Ho and Mulley, 2013; Kitamura et al., 1997; Vij et al., 2013). More specifically, with all else being equal, trip distance behavior of an individual would be same across the region under study. Recent research casts doubt over this assumption (Moniruzzaman et al., 2013; Páez et al., 2013; Reyes et al., 2014; Roorda et al., 2010). Accordingly, we use a trend surface to capture the geographic variability in travel behaviors. The trend surface was implemented using the latitude and longitude of participants’ place of residence. Results for the quadratic trend surface analyses were significant; this indicates that estimated behavior is variable across the Metro Vancouver area. More specifically, trip distance behavior of an older adult in the downtown area tends to be different from the behavior of a person with identical attributes but living in a suburban area. It bears noting that our trend surface analysis reveals significant geographical variations, despite the smaller sample size compared to similar studies (Páez et al., 2013; Reyes et al., 2014).

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4. Web application

In this section we explain how the online *A-score* calculator works with two examples. The popularity of web-based applications that assess neighborhood walkability and accessibility has increased over time. Páez et al. (2013), for instance, developed a web-based accessibility calculator, with greater customization powers than some alternatives (e.g. WalkScore). In this research, we develop an evidence-informed tool specifically for an older age cohort. As we adopted and adapted the web-based *A-score* application to make it user-friendly for older adults to use, the design of its interface is very simple. Its application is relevant for any lower income older person who resides in the Metro Vancouver area or is interested in identifying neighborhoods where most travel needs can be fulfilled by walking and/or public transit. To calculate the *A-score*[3] the user must enter some socio-demographic characteristics, travel preference, and place of residence (or preferred residence). Based on the results of the model of trip length previously discussed, the application requires seven user-specific attributes and an address for the location they wish to score. The seven user-specific attributes are gender (male/female), type of living arrangement (single/living with spouse/living with other family member/other living arrangement), dog ownership (yes/no), preference of travel mode (walking/transit/car/other modes), use of mobility aids (yes/no), confidence in walking (not at all/not much/ neutral/somewhat/very much), and liking to walk outside. Of these seven user attributes, three are simply radio buttons; the remaining four are selected from a dropdown menu. The interface therefore requires the user to click and select across categories listed. The exception is that the address field must be typed in using a keyboard. We designed the application using javascript and Google Maps API v3 (for further details see: Páez et al., 2013).

Once the seven attributes and the user's address of choice are provided, the user would click on the "SEE MY MAP" button. When the user clicks this button, the script underlying the application geocodes the address and retrieves its latitude and longitude coordinates. The specific attributes of the user and the geocoded latitude and longitude values are entered into the hardcoded model of trip distance shown in Table 2. Output is an estimate of average trip distance older adult with the characteristics and at the location he/she entered. We conceptualize this estimated trip distance as a proxy for activity space of the older adult and call it accessibility score (*A-score*) of the person (Morency et al., 2011; Páez et al., 2013; Schonfelder and Axhausen, 2003). After calculating the *A-score*, the application creates a buffer with a radius equal to the estimated trip distance. It then queries business locations within the buffer. Business locations that the user marks as important provide information about the opportunity landscape (Naess, 2006; Schonfelder and Axhausen, 2003). We limit business locations to ten categories to illustrate use of the application, below. However, choices can be customized based on preferences of the user. We note a significant advantage of our model over other walkability measures developed previously. Specifically, it captures variation in walkability based on actual walking behavior, as well as the personal characteristics of users and geographic location.

[3]http://www.science.mcmaster.ca/cspa/vancouver/index.html

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To further illustrate, we provide an example of two older persons who both reside at 23 East 11th Avenue in Vancouver, British Columbia but with very different personal characteristics.

Although residential location is assumed to be the same, the *A-score* generated differs based on differences in their socio-demographic and accessibility preference. Person B's buffer zone is much smaller which limits their access to amenities located outside the smaller buffer zone. Person A generated an *A-score* of 519 whereas Person B generated an *A-score* of only 192. Person A is able to access 29 grocery stores, 77 restaurants, and so on whereas Person B is unable to access a grocery store or restaurant (Fig. 2).

To further illustrate use of the Accessibility calculator, lets say Person A hypothetically moves to a new address at 7694 Sunnydene Road, Richmond, British Columbia. The *A-score* generated for Person A increases to 962 based on their change in location and their now closer proximity to 4 grocery stores and 2 restaurants (Fig. 3).

We selected the addresses at random to illustrate how the calculator might be used. However, the addresses have another distinguishable characteristic. The first address is very close to Vancouver's west end where there are many activity opportunities in close proximity to each other. However, the second address is in a suburban neighborhood in Richmond where only a few activity opportunities are available. Even though Person A at the second address generated a higher *A-score* than at first address, the number of opportunities around the second address are few and not in close proximity. It is thus less likely that Person A living at the second address would walk more frequently to access activities. Conversely, the same person living in an opportunity-rich neighborhood (as her first address) is more likely to walk short distances to access these diverse opportunities. Therefore, it should be noted that higher *A-score* does not necessarily indicate higher walkability. Instead walkability of a neighborhood is determined by a combination of the *A-score* and number of opportunities with the buffer zone relevant to the *A-score*.

In addition to our data-based findings, the *A-score* the calculator generates holds relevance for older adults, their caregivers, municipal and provincial governments, organizations that provide housing or seek to solve housing crises (e.g. BC housing or Street to Home in Vancouver) and even realtors as it may provide some insight into areas that may be more or less attractive and feasible neighborhoods for older adults to grow old. We acknowledge that the *A-score* is specific to lower income older adults in Metro Vancouver, from whom the data were acquired. However, we also deem this as strength of the application, given we currently know very little about this vulnerable population and are therefore unable to meet needs specific to them. Although relevant to other users, we adopted and adapted this tool with older adults in mind as evidenced by its user-friendly interface and based on travel and other personal characteristics relevant to older adults. The *A-score* and cumulative opportunity measures provide information about both walkability and destinations deemed important to older persons in selected neighborhoods. The application has many uses that include comparison across neighborhoods to find a suitable place for an older person to move that is specific to their personal characteristics and travel preferences, potential locations for new developments (e.g. neighborhood houses or accommodation that caters to older persons) and information about neighborhoods that strive to become age-friendly.

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5. Discussion and conclusions

The rate of participation in physical activity is low among older adults and further declines after retirement. This is attributed to reduced or no walking for transportation that was associated with a person's commute at a younger age (Slingerland et al., 2007). Active transportation (e. g. walking and cycling) has the potential to compensate for the diminished physical activity that accompanies aging. This is based on the many well-known health benefits of a physically active lifestyle, such as obesity prevention, controlling type-2 diabetes, reducing high blood pressure, increasing leg bone density, and reducing the risk of colon cancer (Janssen, 2007; Mangani et al., 2006; Pate et al., 1995; Smith et al., 2007; Takahashi et al., 2007; Warburton et al., 2010). Walking as a physical activity is recommended by physicians, especially for older adults as they can meet the required minimal intensity to achieve health benefits (Elsawy and Higgins, 2010; Pate et al., 1995). Moreover, it is feasible and affordable as it requires no specific equipment or training and can be done with ease in most places (Eyler et al., 2003; Hillsdon et al., 1995).

For the above reasons it seems essential to better understand the factors that promote walking by older adults within different neighborhoods. Factors such as pet ownership, proximity to amenities and cultural differences emerge as walking "enablers". Therefore, governments and organizations that support older adults (lower income older adults specifically) can use this evidence to inform their decision making regarding programs and mechanisms that support older adults growing old in the "right place". In addition, low income older adults can directly use the online accessibility calculator by visiting the web link (http://www.science.mcmaster.ca/cspa/vancouver/index.html) to find a walkable neighborhood that suits their needs and lifestyle.

Implementation of the online tool is not without limitations although using characteristics of the built environment to estimate travel behaviors is now a common practice. Incorporating characteristics of the built environment related variables into a model is relatively easy. However, devising a web-based application based on these characteristics is much more difficult. Ideally, including elements such as street density (for example) around place of residence could be done automatically by extracting these data from Google Maps and other sources. This demands a more sophisticated interface and extensive computer and software capabilities. We suggest it is an important area of further research and development.

Another avenue for future research is a model of trip frequency. Trip frequencies of the older adults should be analyzed to get a more complete picture of their travel behavior. While the model of trip distance tells us how far the older adults are traveling, a model of trip frequency would provide information on how frequent they are making those trips. Combining the model of trip distance and trip frequency, we can to assess the total contribution of walking towards physical activity requirements of older adults using the Compliance Potential Mapping tool as proposed by Moniruzzaman et al. (2014) in their study of older adults' walking behavior.

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Glossary

Active transportation

transportation modes that use human power to run. Popular active transportation modes are walking and cycling. Active transportation is also known as active transport in British English

Adaptive threshold

a length which is frequently adjustable based on need or purpose

Baby boomer generation

a sudden rise in the birthrate observed from year to year is known as baby boom and people born during the baby boom are known as baby boomer generation

Buffer

a circular area surrounding a point of interest

Food deserts

area with little or no access to affordable and nutritious food without car, in particular

Geocoding

it is a processing of obtaining geographic latitude and longitude against a given address

Network Analyst tool

a tool to conduct network analysis within ESRI developed ArcGIS platform

Transit

transit is synonymous to public transport or public transportation. Transit is frequently used in North American English whereas it is public transport in British English

Trend surface analysis

the use of geographic coordinates as explanatory variables is called trend surface analysis

Vulnerable population

group of people who are at risk and therefore require special attention

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Appendix A

See the Table A1

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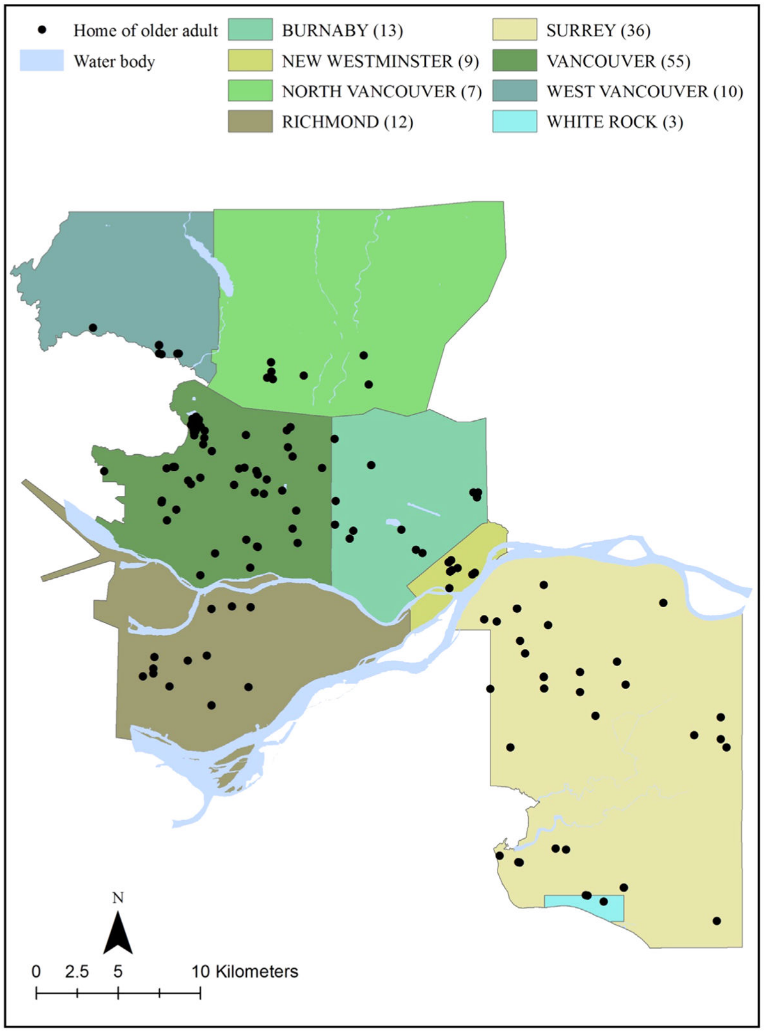
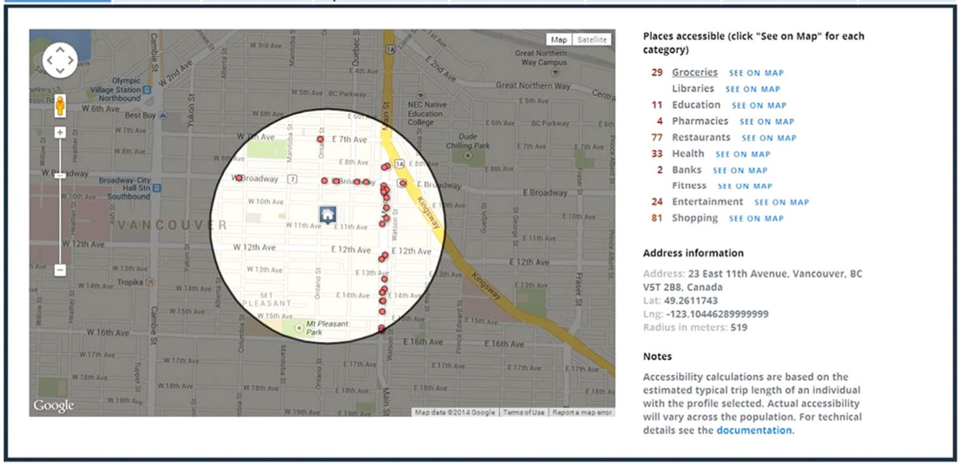


Fig. 1.

Location and distribution of participants (*n*=45) across Metro Vancouver municipalities. Numbers in brackets represent participants from respective municipalitie.

	Gender	Dog ownership	Living arrangement	Use mobility aids	Confidence in walking	Likeliness to walk outside	Mode of travel
Person A	Female	Yes	Living with spouse	No	Neutral	Very much	Walking



	Gender	Dog ownership	Living arrangement	Use mobility aids	Confidence in walking	Likeliness to walk outside	Mode of travel
Person B	Male	No	Living alone	No	Very much	Neutral	Walking

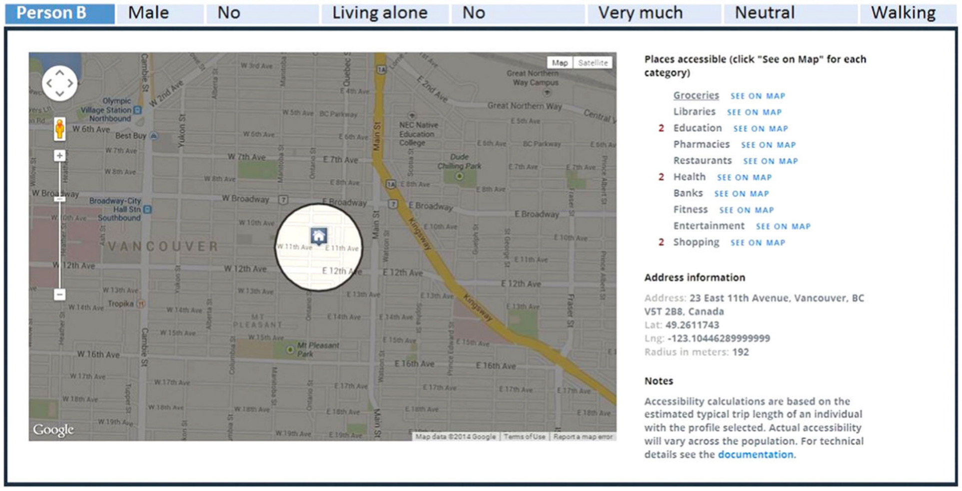


Fig. 2.

To illustrate the specificity of the *A-score* based on socio-demographic and accessibility preference illustration of the different *A-score*s and buffer zones (and related opportunity landscapes) we present two older adults (Person A on top and Person B on bottom) with very different characteristics.

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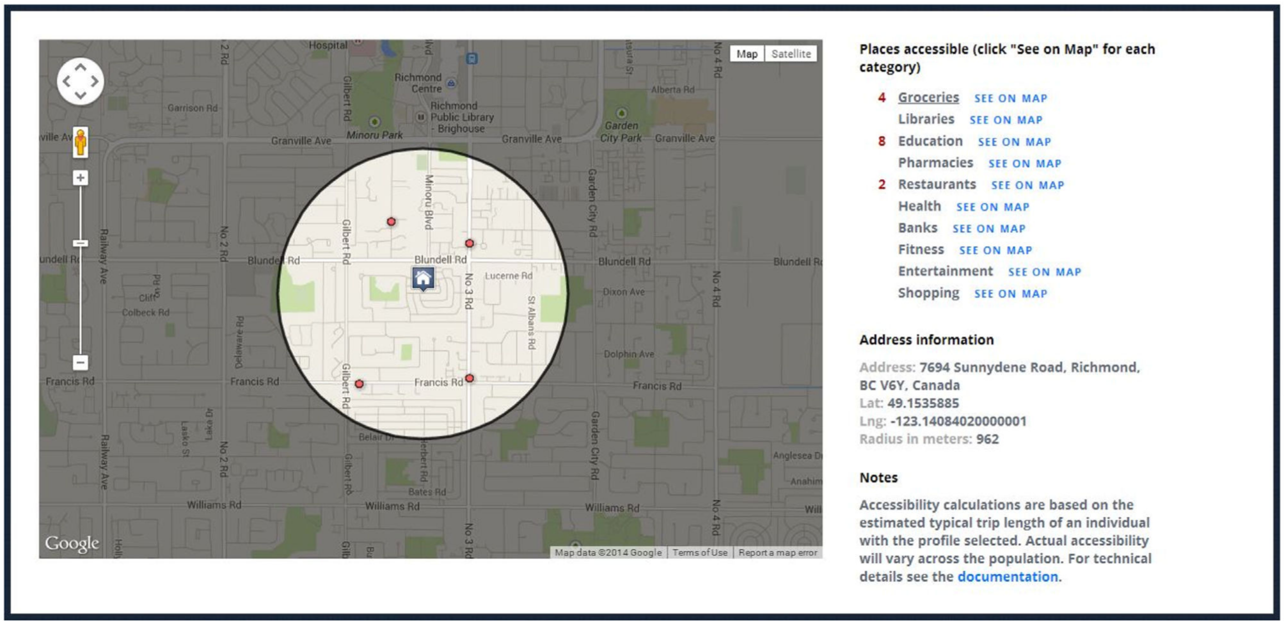

Fig. 3.

An illustration of *A-score* for Person A in a different address a suburban address as opposed to an opportunity-rich address in Fig. 2).

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Table 1

Descriptive characteristics of the study population across measured variables (n=145).

Variables	***n***	**%**
Age		
65–74	83	57.24
75–84	50	34.48
85+	12	8.28
Education		
Secondary	45	31.03
Some university	73	50.34
Completed university	27	18.62
Gender		
Male	51	31.17
Female	94	64.83
Living arrangement		
Alone	116	79.31
Couple	15	10.34
Other family	11	7.59
Other	3	2.07
Ethnicity: white	114	78.62
Visible minority (yes)	22	15.17
Driver's license (yes)	104	71.72
Vehicle ownership (yes)	77	53.10
Dog ownership (yes)	15	10.34
Use of mobility aids (yes)	22	15.17
Fallen in past 6 months (yes)	30	20.69
Like to walk		
Not at all or not much	8	5.52
Neutral	9	6.21
Somewhat or very much	128	88.28
Confidence in walking		
Not at all or not much	5	3.45
Neutral	6	4.14
Somewhat or very much	134	92.41

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Table 2

Results of multilevel linear model. Independent variable is trip length in km (n_T =2647) undertaken by lower-income older adults in sample (n_I =145).

Variables	Estimates	*p*-value
Constant	2.770	0.000
Socio-demographic characteristics		
Age		
65–74	Reference	
75–84	–	–
85+	–	–
Education		
Secondary	Reference	
Some university	–	–
Completed university	–	–
Female	−0.242	0.025
Living		
Alone	Reference	
Couple	–	–
Other family	0.525	0.012
Other	–	–
Ethnicity: white	–	–
Visible minority	–	–
Driver's license	–	–
Vehicle ownership	–	–
Transportation mode		
Mode: Walk	−1.407	0.000
Mode: Car	Reference	
Mode: Transit	–	–
Mode: Others	−0.358	0.000
Vehicle ownership	−0.402	0.050
Use of mobility aids	–	–
Fallen in past 6 months	–	–
Attitude towards walking		
Like to walk		
Not at all or not much	Reference	
Neutral	–	–
Somewhat or very much	–	–
Confidence in walking		
Not at all or not much	Reference	
Neutral	–	–
Somewhat or very much	–	–
Interactions: dog ownership		

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Variables	**Estimates**	***p*-value**
*Walk	0.494	0.028
*Car	–	–
*Transit	–	–
Interactions: mobility aids		
*Walk	−0.433	0.021
*Car	–	–
*Transit	–	–
Interactions: like to walk: neutral		
*Walk	−1.142	0.010
*Car	–	–
*Transit	–	–
Like to walk: somewhat or very much		
*Walk	–	–
*Car	–	–
*Transit	–	–
Confidence in walking: neutral		
*Walk	–	–
*Car	–	–
*Transit	–	–
Confidence in walking: somewhat or very much		
*Walk	–	–
*Car	–	–
*Transit	0.436	0.000
Trend surface: home location		
Latitude	−0.601	0.014
Longitude	−1.580	0.004
Latitude*Longitude	0.353	0.005
Latitude squared	0.121	0.008
Longitude squared	0.361	0.012
Summary statistics		
Number of trips (n_T) =2647; number of seniors (n_I) =145Log-likelihood=−3976.646		
Std. deviation (constant)=0.543, Std. deviation (residual)=1.038, ICC=34.34%		
Likelihood ratio test (multilevel vs. linear regression): chi-squared=430.57, *p* value=0.000		

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Table A1

Sample Travel Diary.

Travel Dairy Day 1		Date:	
	Start location	**Start time**	**End location**
	Provide name and address	**State time, including AM or PM**	**Provide name and address**
Trip#	Home – 800 West 7th	2:00 pm	Safeway at Broadway and MacDonald
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
End time	Reason	Mode of travel	Accompaniment
State time, including AM or PM	See instruction for specific categories	See instruction for specific categories	See instruction for categories
2:55 pm	Shopping	Walk and transit(public bus)	Son (John)