**Spatial biases in residential mobility: implications for travel behaviour research**


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## Abstract

Transport researchers conceptualise residential mobility as a BE intervention because there is the potential for residents to be exposed to a different urban form following relocation. Residential mobility studies therefore overcome the weaknesses of cross-sectional studies in establishing causal links between urban form and travel behaviour. However, what if residential mobility is spatially biased (e.g. a move characterised by a shorter distance, along the direction of home-CBD line, or within a wedge-shaped home sector), and as a result, residents are unable to perceive changes in urban form because their accustomed structural settings (major roads, public transport routes) remain unchanged? This study hypothesises that the true effects of urban form differences on travel behaviour can only be observed if residents overcome the spatial biases in their residential mobility. The research examines the spatial biases of 274 individuals in Brisbane who experienced significant changes in urban form following relocation and estimates the effects of urban form and spatial biases on mode switch behaviour. Results show that 70%, 68%, and 62% of the sample experienced distance, direction and sector biases respectively. Respondents who overcame the sector bias (i.e. experienced a structural change following relocation) were likely to switch to more sustainable mode of transport. The effects of urban form on mode switch behaviour was only evident when movers overcame the sector bias. The findings suggest that, in the presence of strong spatial biases, the true effect of urban form on travel behaviour might be obscured in studies using residential mobility as BE interventions.



***Keywords*****:** Residential mobility; spatial bias; travel behaviour change; mode choice; urban form; urban structure; residential self-selection

## 1. Introduction

City residents experience two levels of built environment (BE) through their day-to-day activity: a) the BE in close proximity of their activity locations (home, work) – referred to as urban form; and b) the BE representing wider urban context – referred to as urban structure. Urban form is the characteristic morphology of settlement within a city whereas urban structure is the manner in which transport networks and land uses are distributed throughout a city (Grosvenor and O' Neill, 2014; Horton and Reynolds, 1971). Therefore, the latter is considered as the macro structural context within which micro level urban form operates. Urban structure is the key element in forming the image of a city and helps people to differentiate between places (Giraldi and Cesareo, 2014; Harrison and Howard, 1972; Lynch, 1960). Despite urban form has widely been studied in the transport/planning literature (Ewing and Cervero, 2010); little is known how urban structure affects travel behaviour of individuals. The aim of this research is to investigate the effects of these two levels of the BE on travel behaviour.

To date, most studies examining the impacts of urban form on travel behaviour are based on cross-sectional data (Kamruzzaman et al., 2016). These studies show that individuals living in moderate to high density neighbourhoods with diverse land use patterns, well-connected street networks and good active or public transport options are likely to use more sustainable mode of transport (Brownson et al., 2009; Frank et al., 2005; Handy et al., 2005). Despite the correlations between urban form and travel behaviour, the findings of these studies have been criticised because they are unable to determine causality (Handy et al., 2006; Singleton and Straits, 1999). For example, they have rarely taken into account residential self-selection effects, and as a result, it is not clear whether the observed behavioural differences are due to differences in urban form or residents' travel attitudes or preferences – i.e. people who prefer to walk, may choose to live in more walkable communities. Similarly, these findings do not satisfy the time precedence criterion for assessing causality (i.e. changes in urban form precede behavioural changes). To properly account for these effects, panel data comparing travel behaviour before and after BE interventions is required. However, such data are rarely available to transport researchers (Handy et al., 2005; Knuiman et al., 2014).

In this context, residential relocation is conceptualised by transport researchers as a surrogate of a BE intervention because there is potential for residents to be exposed to a different BE after relocation (Aditjandra et al., 2012; Cao et al., 2007; Handy et al., 2005; Handy et al., 2006). Therefore, a comparison of travel before and after relocation is likely to address the above two limitations. First, data are collected from the same person, and as a result, if relocation results in moving to a neighbourhood with different BE attributes, any differences in behaviour observed are likely to be due to the differences in the BE and not attitudinal differences, at least in the short-term. Second, changes in BE precede the changes in behaviour, which addresses the temporal sequencing criterion to demonstrate causality. However, early behavioural studies have shown that residential mobility behaviour is not random and may comprise three types of spatial biases (Adams, 1969; Brown and Holmes, 1971; Clark, 1970; Donaldson, 1973; Freeman and Sunshine, 1976; Johnston, 1972): a) distance bias – move closer to pre-move home; b) directional bias – move along the line of CBD and pre-move home; and c) sectoral bias – move within a sector (certain angle) of pre-move home. It is not known whether (or how much) a lack of control of these biases influences research findings on the relationship between urban form and travel behaviour.

Hypothetically, what these spatial biases mean to travel behaviour is that the accustomed overall structural settings (major roads, public transport routes) of individuals remain unchanged (Grosvenor and O' Neill, 2014; Horton and Reynolds, 1971). This means that despite the potential of changing urban form due to relocation, residents are less likely to perceive such changes because of pre-existed urban image in their head. As a result, the true effect of urban form differences can only be observed if residents overcome the spatial biases in their residential mobility behaviour. Nevertheless, studies identifying spatial biases in residential mobility behaviour have been conducted in the 1970s (discussed in Section 2). Since then significant technological changes have occurred which have the capacity to alter the spatial biases in mobility behaviour. However, if they exist and affect travel behaviour, this means that researchers using residential relocation as a BE intervention need to rethink about their research design and sampling strategy to understand the true effect of urban form on travel behaviour. Similarly, this bears implications for policy focusing on BE interventions in terms of whether changes are needed in urban form or structure or both in order to enhance sustainable travel behaviour.

Based on the above discussion, the objective of this paper is twofold: first, to validate whether spatial biases in residential mobility behaviour exists in a Brisbane cohort; and second, if so, to examine the implication of such biases for travel behaviour. Section 2 reviews the literature on spatial biases in intra-urban residential mobility; and summarises studies investigating the link between residential mobility and travel behaviour. The data and methods used to reach the above objectives are described in Section 3. Section 4 presents the results of the research. Section 5 discusses findings in policy terms and concludes this research.

## 2. Literature review

### 2.1 Spatial biases in residential mobility behaviour

Intra-urban residential relocation is a multi-stage decision making process (e.g. whether to move; and if yes, where to move). Once a household decides to move, it involves a range of activities, including: a) developing a set of 'aspiration criteria' for evaluating new dwellings and neighbourhood environments; b) undertaking a search for dwellings that satisfy these criteria; and c) select a specific dwelling amongst the alternatives (Brown and Moore, 1970). Distance bias occurs when the relocation distances (i.e. distance between previous and relocated dwelling) are not randomly distributed and exhibit distance decay properties – i.e. people are less likely to move further away from their current dwelling (Johnston, 1969; Johnston, 1972). Two types of factors have been identified to contribute to this distance bias: supply side factors, and demand side factors (Brown and Moore, 1970; Donaldson, 1973; Huff, 1986). Supply side factors are the constraints of disseminating vacancy information about housing availability to wider city population. Research has shown that in the past, none of the media used to advertise the availability of properties are fully effective in disseminating vacancy information, including newspaper, television, radio, billboards, agents, on-site advertisement, and personal contacts (McPeake, 1998; Rossi, 1955). This means that the information about all properties available in a city will not reach all anticipated movers.

The demand for residential properties is also spatially biased. Rarely, households look for dwellings all over a city, rather they typically search areas in which they are familiar. This means that the search spaces correspond with the activity space concept. Activity spaces are a sub-set of all locations in which an individual has direct physical contact due to his/her regular activity-travel behaviour (Horton and Reynolds, 1971). This includes: first, movement within and near the home; second, movement to and from regular activity locations such as journeys to work, to shop, to socialize, and so on; and third, movement in and around the locations where these activities occur (Golledge and Stimson, 1997). On the other hand, 'action spaces' describe an individual's total interaction with his or her environment and they contain all locations about which an individual is aware of or has some knowledge through both direct (e.g. travel) or indirect involvement (e.g. telephone, newspaper, magazines, radio, television, etc.) (Golledge and Stimson, 1997; Horton and Reynolds, 1971). The activity spaces of individuals, therefore, shape the boundary of alternative properties which individuals evaluate and ultimately choose as a new place of residence (Brown et al., 1977; Clark, 1970; Freeman and Sunshine, 1976; Huff, 2001).

The concepts of directional and sectoral biases in intra-urban residential mobility have respectively emerged from the two basic models of urban residential structure and growth: the concentric zone model (Burgess, 1925); and the sector model (Hoyt, 1939). Burgess (1925) observed that intra-urban mobility occurs outwards in annular fashion from the central business district (CBD). Therefore, a directional bias describes the levels to which a single mobility is more likely to end in a place that is in a particular direction from the origin (Brown and Holmes, 1971). Ideally, directional bias is defined in terms of another location (orientation node) that is relevant to the relocation decision and provides either an attractive or repulsive force (Brown and Holmes, 1971; Donaldson, 1973). The sector model also acknowledges an outward mobility of households but shows that such movement is confined within wedge shaped homogenous sectors (Hoyt, 1939). Therefore, sectoral bias describes the degree to which a single relocation is more likely to end in a place that is along a single axis through (or near) the origin (Brown and Holmes, 1971).

## 2.2 Measures of spatial biases

Residential relocation can result in a short distance intra-urban mobility, a long distance inter-city or inter-state migration (Clark, 1970; Gilliland, 1998; Quigley and Weinberg, 1977). Spatial biases in residential mobility have been observed in both inter-city (Brown et al., 1977) and intra-urban relocation decisions (Clark, 1970; Freeman and Sunshine, 1976; Johnston, 1969; Phipps, 1984). Intra-urban residential mobility has a larger share in the overall mobility patterns (Eaglstein and Berman, 1988; Kamruzzaman et al., 2013; Quigley and Weinberg, 1977). In addition, the methods applied to study spatial biases are fundamentally different for intra-urban from inter-city mobility. As a result, this review focuses on intra-urban mobility. Intra-urban mobility can be either voluntary or involuntary (forced), and the biases have been identified in both types of mobility behaviour (Adams, 1969; Clark, 1970). However, the average relocation distance of involuntary movers is relatively longer than voluntary movers.

Studies investigating spatial biases in residential mobility behaviour often applied an aggregated approach, and as result, it is difficult to identify the biased households among the movers. For example, the analysis of distance decay curve is a commonly applied method to identify distance bias in which the relocation distances of all movers are plotted and examined. If the plot exhibits a decay behaviour (i.e. not randomly distributed), then the behaviour is said to be biased at the population (movers) level as evident in Melbourne (Johnston, 1969), Minneapolis (Adams, 1969), Christchurch (Clark, 1970), Syracuse (Freeman and Sunshine, 1976), and Saskatoon (Phipps, 1984). Few studies have, however, generated group specific (e.g. African Americans, whites) distance decay curve to examine which group shows a stronger bias (Freeman and Sunshine, 1976; McPeake, 1998). Brown and Holmes (1971) have derived a different measure of distance bias. They have derived a standard deviational ellipse (SDE) based on the destination points (relocated residences) and the dispersion (standard radius) of the points was used to measure distance bias – i.e. the lesser the standard radius or dispersion, the greater the distance bias.

The sectoral bias in residential mobility was initially measured by the angle of move (angle forming the origin, CBD, and destination). Analysing data from 808 movers in Minneapolis, Adams (1969, p.323) concluded that the movement patterns exhibit ‘a narrow, perhaps wedge-shaped image of the city which is sharply in focus for places close to home and other parts of the home sector, and blurry or blank for distant places such as the other side of town’. This work, therefore, supports Hoyt’s (1939) wedge-shaped sector concept. However, the notion of wedge-shaped sector was not appreciated by the transport researchers; rather, based on the concepts of potential activity spaces (Hägerstrand, 1970) or actual activity spaces (Horton and Reynolds, 1971), they adapted an elliptical form of sector (Burns, 1979; Cullen and Godson, 1975; Dijst and Vidaković, 1997; Lenntorp, 1976; Parkes and Thrift, 1980). Recently, a number of studies used the SDE to study travel behaviour (Buliung and Kanaroglou, 2006; Buliung et al., 2008; Newsome et al., 1998) and to examine transport related social exclusion (Kamruzzaman and Hine, 2011, 2012; Schönfelder and Axhausen, 2003). However, none of these studies examined the spatial biases in residential mobility behaviour. Early work by Brown and Holmes (1971) used the ratio of the minor to major axis of SDE to indicate sectoral bias. If these axes are equal (i.e. a circle), no sectoral bias exists; if the minor axis is of zero length, complete sectoral bias occurs. Using this measure, the authors found a low degree of sectorality. In contrast, using a similar approach, Donaldson (1973) found that respondents’ mobility exhibited distinct sectoral bias in Christchurch.

Adams (1969) has operationalised directional bias by measuring the distance between origin (pre-move residence) and CBD, and between destination (relocated residence) and CBD. If the relocated distance is shorter (or longer) than the original distance, then a household is said to be biased towards (or away from) CBD. If the distance is about the same, the mobility is not subject to directional bias. Brown and Holmes (1971) have also used CBD as the orientation node but they have measured the orientation of SDE to represent directional bias. The angle to which the major axis of SDE is offset (angle of rotation) from a base axis has been employed to gauge directional bias. Thus, an angle of rotation of 0° or 180° is an indication of directional bias towards or away from the CBD respectively. Whereas Adams (1969) found a directional bias away from the CBD, Brown and Holmes (1971) as well as Bible and Brown (1980) reported a directional bias towards CBD.

**2.3 Residential mobility and travel behaviour**

A limited number of studies have analysed travel behaviour changes after a residential relocation due to a lack of pre- and post-move travel data (Aditjandra et al., 2016; Cao and Ermagun, 2017; De Vos et al., 2018; Krizek, 2003; Scheiner and Holz-Rau, 2013). Most of these studies again used quasi-longitudinal data. These studies found that a considerable travel mode switch occurs after a relocation. Findings from these studies show that residents moving to more compact, mixed-use neighbourhoods reduce car use and increase walking, cycling and public transport use. In contrast, relocating to a more suburban-style neighbourhood often results in an opposite mode switch pattern. These changes can be partly explained by decreasing travel distances and better public transport facilities when moving to an urban-style neighbourhood. Conversely, increasing distance and limited public transport facilities when relocating to a suburban-type of neighbourhood are the main reasons to switch to the car. Additionally, moving to urban neighbourhoods is often accompanied by a reduced car ownership (i.e., selling one or more cars), while people moving to suburbs often buy an additional car, further reinforcing the above-mentioned mode switch.

A few studies found that people change their travel mode after a relocation which is independent from the type of new neighbourhood (Fatmi and Habib, 2017; Klinger and

Lanzendorf, 2016; Scheiner, 2006). De Vos et al. (2018), for example, found that, on average, residents increased the use of active travel and public transport and reduced the car-based travel following a relocation. This can be explained by the fact that living closer to the job location is an important reason to relocate for a considerable number of people. This means that travel-related factors are an important reason for relocation. People move and self-select neighbourhood to satisfy their travel intention when existing residential neighbourhood fails to provide sufficient travel choices causing unsatisfying trips (De Vos et al., 2016). The self-selection of post-move neighbourhoods thus act as an enabler of trip satisfaction (Cao et al., 2009).

In summary, extensive research on spatial biases in intra-urban residential mobility was conducted in the 1970s. However, less attention has been paid on this topic lately. Rather, researchers have recently paid more attention to understanding the socio-spatial factors affecting residential mobility (see, Helderman et al., 2004; Hui and Yu, 2009a, b; Jones et al., 2004; van der Klis and Karsten, 2009; Wu, 2006; Zenou, 2009). This could be due to the fact that spatial biases have been rooted permanently in the literature. For example, recently, Sun and Manson (2010) used spatial biases as essential properties in developing an agent based model to predict residential mobility in the Twin Cities of Minnesota. Nevertheless, significant technological changes have occurred since the identification of spatial biases residential mobility in the 1970s. These changes have the capacity to alter the biases. For example, the knowledge of people about a city (as well as direct contacts) has expanded dramatically due to increase in automobile ownership and consequent increase in the mobility level (Frändberg and Vilhelmson, 2011; Giuliano and Dargay, 2006). Development of spatially segregated employment or shopping centres in a city reduces the dependency on CBD as has been described in other urban spatial structure models e.g. multiple-nuclei model, White's model of the twenty-first century city (Brown and Holmes, 1971; Harris and Ullman, 1945; White, 1987). The advancement in information and communication technologies (ICT) helped to disseminate vacancy information to any potential movers located anywhere in the world (Ford et al., 2005). This, therefore, necessitates validating whether spatial bias in residential mobility behaviour exists in today's society. In contrast, research on the effects of residential mobility on travel behaviour gained popularity recently. However, there exists a little cross-over between two aspects (spatial bias and travel behaviour) of residential mobility. As a result, this research is timely to address the two research objectives to understand the effects of urban spatial structure and urban form.

## 3. Data and methods

### 3.1 Data and context

This study was conducted in the context of Brisbane, Australia (Figure 1). It is the state capital of Queensland and the third largest city in Australia with a population of 2.2 million in 2016. According to the Australian Bureau of Statistics, 49.2% and 50.8% of the population were male and female respectively. The median age of people was 35 years with children (aged 0 - 19 years), young (aged 20-39 years), baby boomers (aged 40-64 years), and ageing (65 years and over) cohorts respectively made up 26.1%, 29.5%, 31%, and 13.4% of the population. The city is centred along the Brisbane River, and its eastern suburbs line the shores of Moreton Bay (Figure 1). The city experiences subtropical climate with hot and wet summers, but dry and moderately warm winters.

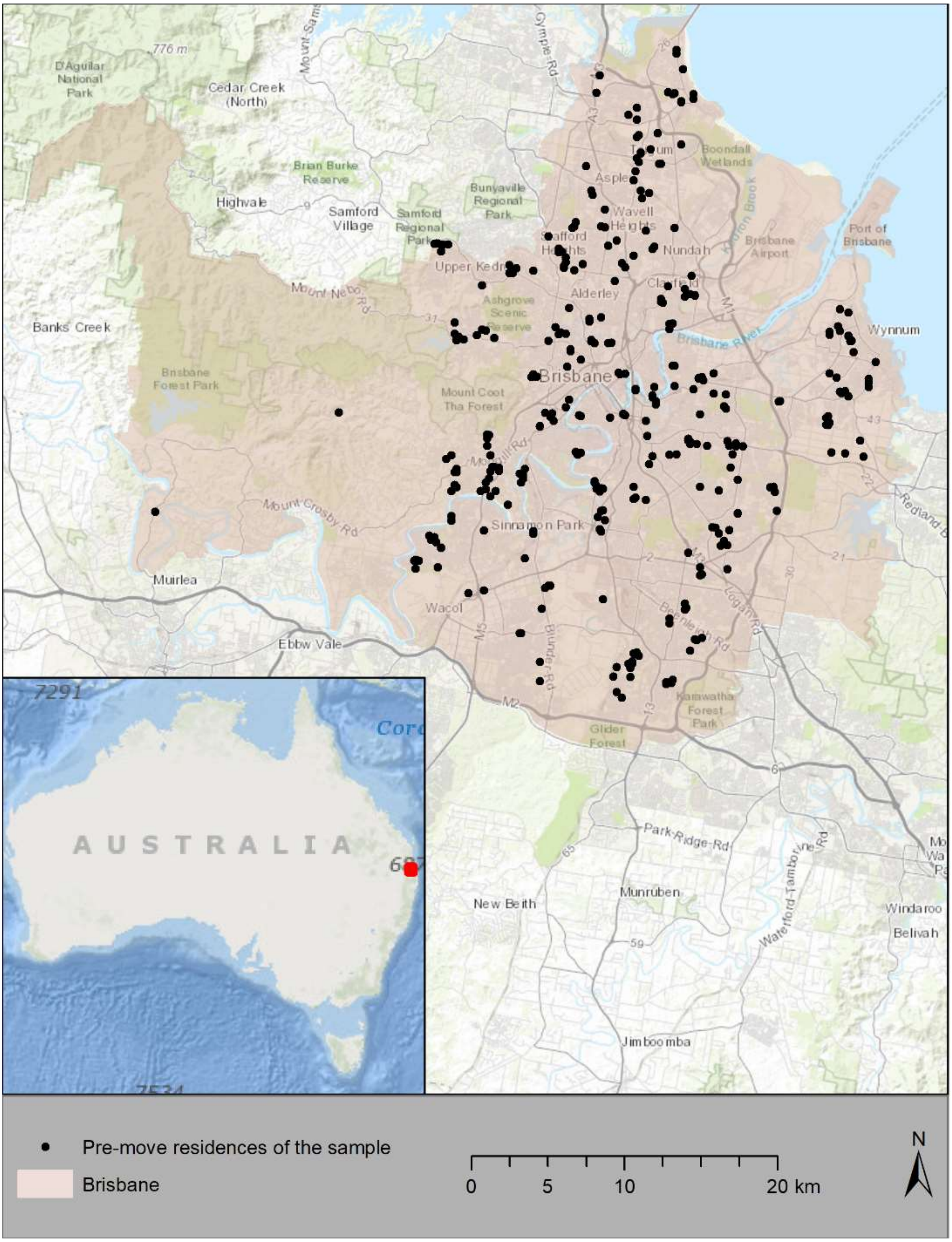


**Figure 1: Location of the study area in wider geographic context and the distribution of samples**

This research used the HABITAT (*H*ow *A*reas in *B*risbane *I*nfluence Heal*t*h and *A*ctivi*t*y) panel survey data to address the two research objectives. The survey collected data in five waves (2007, 2009, 2011, 2013, and 2016) with a baseline sample of 11,035 individuals. A two-stage probability sampling procedure was applied: first, 200 CCDs (census collection districts) were randomly selected from Brisbane stratified by socio-economic status – CCDs were the smallest sized administrative unit used to collect census data prior to 2011 in Australia; and second, households were randomly selected within each CCD. The survey draws a purposeful sample of baby boomers cohorts (aged 40 – 65 years at baseline). This research used data from the 2007 and 2009 versions of the survey. Other periods were not considered in this study because respondents' home and work locations data were not accessible to the researcher. These location data were needed to derive indicators for spatial biases in residential mobility as discussed in Section 3.2.

The sample comprised of individuals who moved residences between 2007 and 2009. Out of 7,866 respondents who participated in the 2009 version of the survey, 568 respondents moved home (referred to as movers in this paper) between the periods. However, 196 of the movers relocated outside out of Brisbane (inter-city mobility), and as a result, they are not considered in this research. Moreover, 15 movers indicated that they had moved home due to a change in job location. These individuals were also not considered in this research. This exclusion resulted in a preliminary sample of 357 movers, which were subsequently reduced to 274 analytical samples after excluding movers with missing data. The home locations of these respondents in 2007 is shown in Figure 1. They were evenly distributed across the city. This sample size was found to be representative of previous studies investigating spatial biases in residential mobility. For example, sample sizes used in some well-known studies on this topic are: 141 in Phipps (1984), 150 in Bible and Brown (1980), 174 in Donaldson (1973), 203 in Brown and Holmes (1971), 209 in Horton and Reynolds (1971), 384 in Barrett (1976), 394 in Clark (1970), and 808 in Adams (1969).

Table 1 shows both the pre-move and post-move socio-demographic characteristics of the sample. Note that gender and education data were collected only once because they are unlikely to change. Naturally, the age increased equally for all respondents. To examine whether the sample experienced a significant change in socio-demographics over the period, the Stuart-Maxwell test of symmetry was conducted for the categorical factors (e.g. employment status). For similar reason, paired-sample *t*-test was conducted for the continuous factors (e.g. household size). The test results show little changes between pre- and post-move characteristics (except for vehicle availability and living arrangement factors).

**Table 1: Socio-demographic characteristics of the sample**

| Variables | Pre-move characteristics | Post-move characteristics |
|---|---|---|
| % Male | 43.3 | - |
| Average age | 49.9 | 51.9 |
| Average household size | 2.8 | 2.8 |
| Health status (1-Poor to 5-Excellent) | 3.5 | 3.4 |
| Vehicle availability | | |
| Yes, always (%) | 89.4 | 85.4 |
| Sometimes or not available (%) | 10.6 | 14.6 |
| Employment status | | |
| Full-time employment (%) | 62.0 | 60.9 |
| Part-time/casual employment (%) | 23.0 | 21.5 |
| Other/not-employed (%) | 15.0 | 17.6 |
| Education | | |
| Up to year 12 (%) | 34.3 | - |
| Diploma/certificates (%) | 27.4 | - |
| Bachelor or higher (%) | 33.3 | - |
| Living arrangement | | |
| Living alone with no children (%) | 14.6 | 13.6 |
| Single parent living with one or more children (%) | 12.4 | 8.2 |
| Single and living with friends or relatives (%) | 7.7 | 6.6 |
| Couple (married/defacto) living with no children (%) | 25.9 | 29.6 |
| Couple (married/defacto) living with children (%) | 39.4 | 38.9 |
| Other (%) | - | 3.1 |
| Household income before tax per year | | |
| Up to $36,399 (%) | 11.0 | 11.7 |
| $36,400 – $72,799 (%) | 31.9 | 25.4 |
| $72,800 – 129,999 (%) | 26.7 | 27.6 |
| $130,000 or more (%) | 23.1 | 28.3 |
| Not known (%) | 7.3 | 7.0 |
| N | | 274 |

## 3.2 Deriving spatial bias indicators of residential mobility

### *3.2.1 Generation of distance bias*

Two indicators of distance bias were generated in this research: a) move distance; and b) whether individuals moved outside of their activity spaces (Figure 2).

Move distance was measured by the network distance between pre- and post-move homes (Figure 3b). The network dataset contained all road types in Brisbane. To protect the privacy of the respondents, this research used the centroid of home CCDs to calculate the move distance rather than using specific home locations. The activity spaces were derived based on SDE (2-standard deviation) of the activity locations (Figure 2) (Golledge and Stimson, 1997; Horton and Reynolds, 1971). The activity location data were collected from the sample during the 2007 version of the HABITAT survey. In the survey, respondents were asked to indicate the locations (suburbs) if they had undertaken/used the following activities/facilities: work, public swimming pool, indoor recreation facility (e.g. gym, indoor sports, yoga centre), oval or sporting field, outdoor recreation facility (e.g. golf course, tennis court), public park, and public recreation area. The centroids of these activity suburbs were used as activity locations. In addition, respondents' pre-move home and Brisbane CBD were included in the set of activity locations. These activity locations were then used to derive the SDEs.

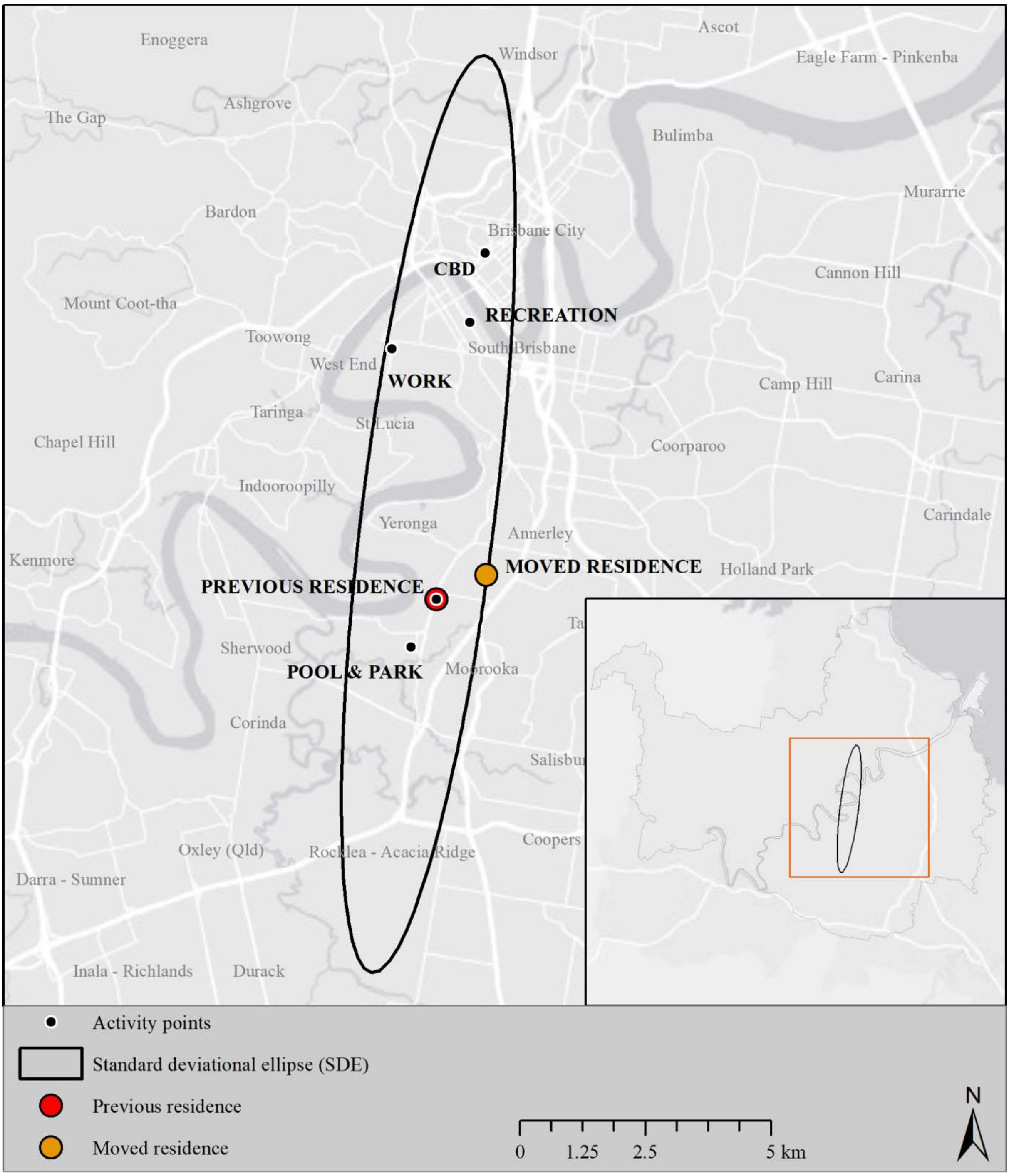


**Figure 2: Derivation of activity spaces (standard deviational ellipse) based on the activity locations**

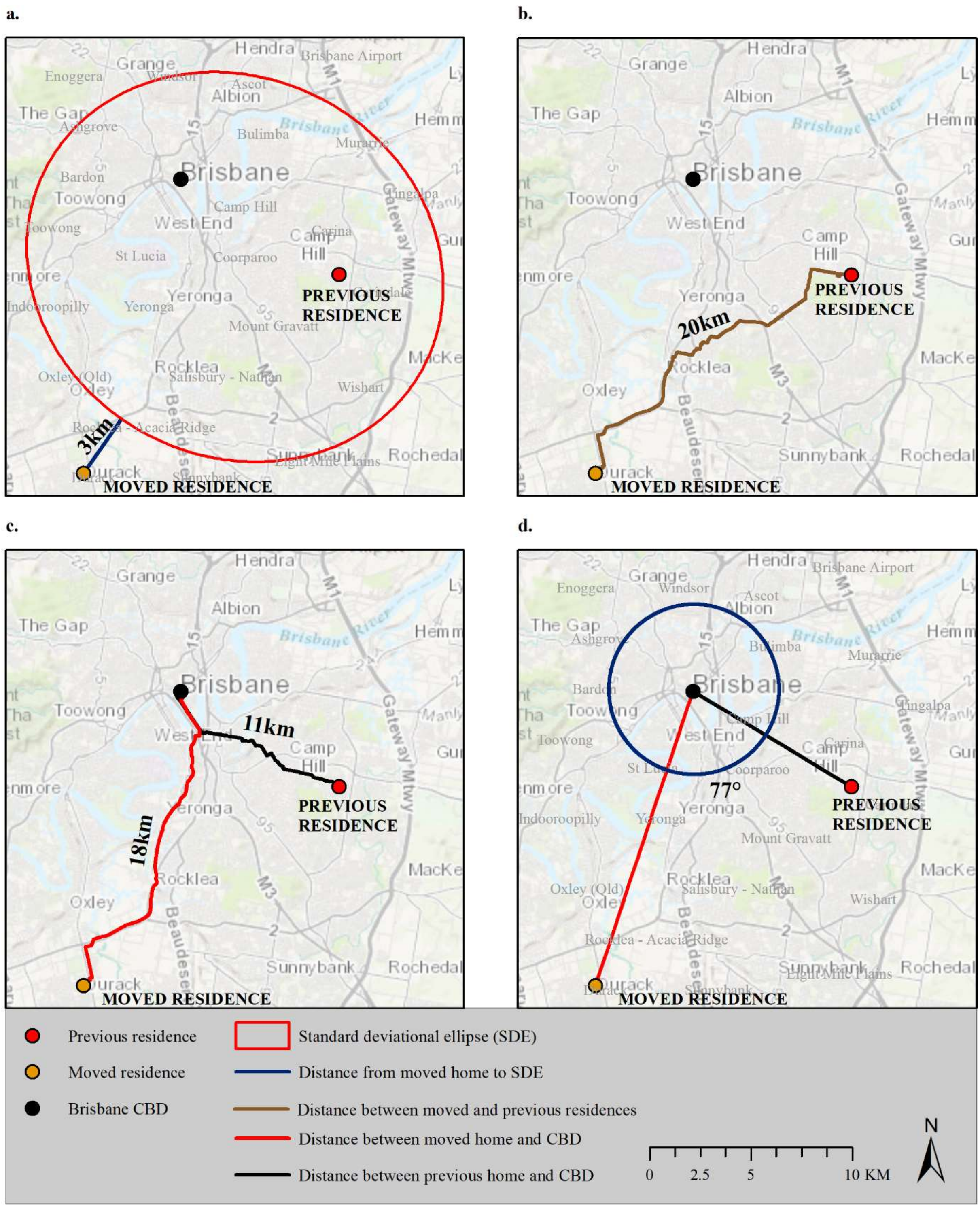


**Figure 3: Derivation of indicators of spatial biases in residential mobility: a) whether the move home is located outside of the activity spaces; b) distance of move; c) directional bias – measured by the distance from Brisbane CBD; and d) sectoral bias – measured by the angle of move**

The move distance has commonly been applied to identify distance bias as discussed previously. However, a move distance does not specify whether a mover is biased or not. In other words, how far does an individual need to move to be labelled as unbiased? To address this weakness, the research generated activity spaces of each individual and examined the locations of moved homes with respect to their activity spaces. If the moved homes of individuals are outside of their pre-move activity spaces, then the individuals can be considered to have overcome the distance bias. Figure 3a shows that an individual moved 3km away from his activity spaces.

### *3.2.2 Derivation of directional bias*

Network distance from Brisbane CBD to post-moved home was derived in ArcGIS. Similarly, network distance from Brisbane CBD to pre-move home was also derived. The latter distance was then subtracted from the former to obtain directional bias indicator. A positive difference indicates that an individual moved away from the CBD (Figure 3c) whereas a negative difference outlines a directional bias towards the CBD. Like distance bias, a problem with this measure is that it does not specify a cut-off distance to be considered as unbiased towards/away from the CBD. To address this issue, the differences were converted into a '% difference' measure (i.e. difference in distance / pre-move distance * 100). If the % difference lies between -10% and +10%, the difference was considered as unbiased. A similar approach has been adopted in the route choice literature – i.e. if the shortest path distance of an individual lies within ±10% of the actual route distance, then the individual is said to have taken the shortest path route (Buliung et al., 2013; Zhu and Levinson, 2015).

### *3.2.3 Determining sectoral bias*

Following Adams (1969), the sectoral bias of residential mobility was measured by the angle of move (Figure 3d). However, despite the expectation that movers would prefer familiar but distant neighbourhoods within their home sector over unknown but proximate alternatives in neighbouring sectors, the notion of home sector is not clearly defined. In other words, what angle of move is to be considered as a move beyond the home sector? Theoretically, the angle of move can range from $0^\circ$ to $180^\circ$. Like directional bias, this paper used a 10% cut-off of $180^\circ$ (i.e. move angle $<=18^\circ$) to define a move as sectoraly biased (i.e. a move within the home sector).

## 3.3 Outcome variable

One of the objectives of this research is to examine how spatial biases in residential mobility affect travel behaviour outcome following residential relocation. The outcome is assessed by examining the mode choice behaviour of the movers in this research. In the HABITAT survey, respondents were asked to indicate 'on most weekdays (Monday to Friday), which type of transport do you mainly use to get to and from places?' in both 2007 and 2009. Respondents were requested to select one of the following five options: a) public transport; b) car or motorcycle; c) walk; d) bicycle; and e) other. The public transport, walk, and bicycle modes were combined together to represent active transport (AT). The 'other' category was excluded due to low response rate which resulted in a two-category outcome (AT and car/motorcycle). To investigate whether the movers had changed their behaviour following relocation, a new 'mode switch' variable was created. The 'mode switch' variable was populated by comparing mode choice behaviour between 2007 and 2009. This resulted in a three-category outcome (unchanged, switched from car/motorcycle to AT, and switched from AT to car/motorcycle).

## 3.4 Exposure to changed urban form following relocation

As discussed previously, in the absence of true BE intervention, transport researchers have utilised residential relocation as an opportunity of natural interventions to understand their effect on travel behaviour. This research derived six urban form indicators for each respondent in both pre- and post-move periods as shown in Table 2. These indicators have been identified to have a significant effect on mode choice behaviour in this context (Kamruzzaman et al., 2015). The indicators were derived at the level of respondents' home CCD. The differences between the periods in each of these indicators highlight the BE interventions that the respondents experienced. Based on a paired-sample *t*-tests, Table 2 shows that, on average, the respondents experienced a significant increase in all of the urban form factors considered in this research (except distance to bus stop).

**Table 2: Urban form characteristics and their changes between pre- and post-move periods**

| Urban form | Pre-move characteristics | Post-move characteristics | Differences |
|---|---|---|---|
| Residential density (dwellings/ha) | 20.02 | 23.63 | 3.61* |
| Land use mix | 0.40 | 0.43 | 0.03* |
| Street connectivity | 13.18 | 16.05 | 2.88** |
| Length of bikeways (m) within home neighbourhood | 328.37 | 497.44 | 169.06** |
| Network distance (m) to bus stop from home | 416.58 | 501.73 | 85.15 |
| Network distance (m) to train station from home | 3043.40 | 3313.78 | 270.38* |
| N | | | 274 |

* Significant at the 0.1 level (paired-sample t-test results)

** Significant at the 0.05 level (paired-sample t-test results)

## 3.5 Residential self-selection

As discussed earlier, previous studies have used residential relocation as an opportunity to address the residential self-selection effect on travel behaviour outcome. However, a problem with this conceptualisation is that "the relocating households are themselves a self-selected group" (Bhat and Guo, 2007, p.511). Therefore, it is important to control the self-selection effect even though travel data are collected from the relocating households. This research controls the two sources of self-selection effect (socio-demographics, and attitude and preference) to understand the true effects of urban structure and urban form on travel behaviour (Mokhtarian and Cao, 2008). First, respondents' socio-demographic characteristics as outlined in Table 1 were used as controlling factors. The pre-move characteristics (2007) were only considered given the little changes between the periods. Second, respondents' living preferences data were also controlled. In 2009, the movers were asked to indicate the reasons for choosing their current address in a 20-item question measured on a 5-point Likert scale (1- Not at all important to 5- Very important). A factor analysis was conducted using the responses in these items to extract the fundamental dimensions spanned by these items based on the literature (Cao et al., 2007; Giles-Corti et al., 2013; Handy et al., 2005; Handy et al., 2006). Four factors were extracted based on 14 items after refinement of initial results (exclusion of items with low communalities and complex structure) (Table 3). The extracted factors suggest that respondents choose a particular neighbourhood because of their: a) accessibility and mobility options; b) ease of commuting; c) green environment and safety; and d) child centric facilities. The scores associated with these factors were included in the analysis in order to control for self-selection effect.

## 3.6 Habit

Research has shown that individuals' changed behaviour is a function of not only changed circumstances (e.g. changes in the BE) but also related to their 'base' values (BE in the pre-move neighbourhood) including travel behaviour in the base year (Krizek, 2003). As a result, this research controls habitual active transport uses. In the 2007 version of the survey, respondents were asked "What do you estimate was the total time that you spent walking for transport in the LAST WEEK?" The answer to this question was used to identify habitual active transport user based on whether they walked 35 minutes in the week (5 min a day) or not (Heinen et al., 2018).

**Table 3: Pattern matrix showing main reasons for choosing the current address**

| Items | Factors | | | |
|---|---|---|---|---|
| | Accessibility and mobility of places | Ease of commuting | Green environment and safety | Child centric facilities |
| Wanted to live close to shops | **.859** | .033 | -.127 | -.024 |
| Closeness to restaurants and cafes | **.741** | .053 | -.002 | -.033 |
| Access to freeways or main roads | **.641** | .012 | .025 | .010 |
| Close to health care facilities | **.623** | -.040 | .076 | .105 |
| Closeness to public transport | **.390** | .068 | .218 | -.047 |
| Closeness to work | .015 | **.856** | .070 | .032 |
| Cheaper to travel to work | .081 | **.730** | .000 | .010 |
| Closeness to open space (e.g. parks) | .035 | .013 | **.924** | -.064 |
| Near to green-space or bushland | -.053 | .045 | **.921** | -.092 |
| Quiet location | -.042 | .078 | **.518** | .107 |
| Safety from crime | .120 | .180 | **.379** | .108 |
| Sense of community | .144 | -.144 | **.332** | .048 |
| Closeness to schools | -.001 | -.095 | .022 | **.884** |
| Closeness to childcare | -.004 | .082 | -.025 | **.518** |
| % Of variance explained | 33.16 | 10.96 | 10.26 | 9.24 |
| Total variance explained (%) | | | | 63.62 |
| Kaiser–Meyer–Olkin measure of sampling adequacy | | | | 0.78 |
| Extraction method: Principal axis factoring | | | | |
| Rotation method: Oblimin with Kaiser normalisation | | | | |
| N | | | | 274 |

## 3.7 Analytical strategy

Descriptive analyses were conducted to identify the extent of spatial biases in residential mobility behaviour in this study (objective 1). To address the second objective (i.e. to examine the effects of spatial biases on travel behaviour), three multinomial logistic (MNL) regression models were estimated: a) Model 1: estimates the relative effects of urban form and mobility biases on mode switch behaviour; b) Model 2: estimates the effects of urban form on mode switch behaviour for those who had shown biases in residential mobility behaviour; and c) Model 3: estimates the effects of urban form on mode switch behaviour of residents with biased mobility behaviour. To avoid model over-specification problem (a large number of explanatory factors with a relatively small sample size) (Wilson et al., 2006), this research applied the purposeful selection method of explanatory factor for Model 1 as outlined by Hosmer et al. (2013). First, a bivariate/simple (unadjusted) model was estimated separately for each of the explanatory factors on the outcomes to identify factors that have a significant association with the outcomes (Appendix A). Second, only factors that were found to be significant at the $p<0.1$ level in the unadjusted model were entered into an adjusted model (Bursac et al., 2008) (Appendix A). Finally, a parsimonious model (maximally adjusted) was estimated by step-wise exclusion of factors with statistical insignificance. Hosmer et al. (2013, p.90) stated that "the rationale for minimizing the number of variables in the model is that the resultant model is more likely to be numerically stable, and is more easily adopted for use". The multicollinearity among the selected explanatory factors was tested by estimating an ordinary least squares (OLS) regression model (Piya et al., 2013; Shatu et al., 2019). However, given that Model 2 and Model 3 were estimated to compare the effects of urban form on mode switch behaviour between biased and unbiased respondents, all explanatory factors were kept in the model. All analyses were conducted in Stata (version 15).

## 4. Results

### 4.1 Nature and extent of spatial biases in residential mobility

#### *4.1.1 Distance bias*

Figure 4 outlines the distribution of move distances. It clearly shows a distance decay pattern (e.g. the move distances are not random over the entire distance range) at the population level. On average, the movers moved 6929m away from their pre-move home with a relatively high standard deviation (6045m). This means that not all movers are biased in terms of move distance. This is verified using the binary indicator of distance bias (i.e. whether moved inside their activity spaces). Analysis shows that about 70% of the movers moved within their activity spaces – i.e. within the areas that they had direct contact. Therefore, only 30% of the movers overcame the distance bias in residential mobility. However, on average, these individuals moved only 983m away from their SDE – again suggesting that they tended to be located closer to their activity spaces.

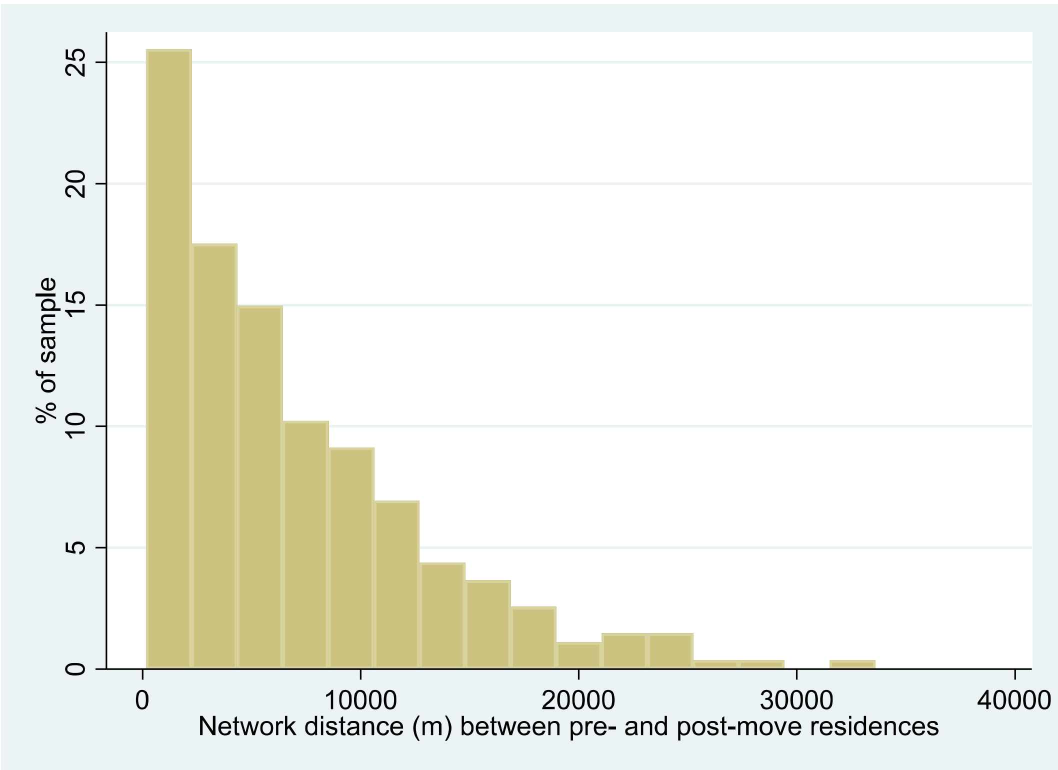


**Figure 4: Distribution of move distances**

### *4.1.2 Direction bias*

Directional bias reflects the extent to which the movers move towards or away from the CBD. Figure 5 shows the distribution of directional biases with respect to Brisbane CBD. In the strictest sense, all movers are to some extent directional biased as shown in Figure 5 because they either move towards the CBD or away from the CBD (unless the pre- and post-move distances from CBD are identical). Using this strict criterion, 51% of the movers moved away from the CBD and the remaining 49% moved towards the CBD. Therefore, the biases are not strongly pronounced in either direction, similar to what has been found in prior studies e.g. 57% outward movement in Adams (1969). However, when the criterion is relaxed to ±10% as unbiased, a different picture of directional bias appears. 32% of the movers are not directional biased at all – i.e. they moved only a shorter distance from their home either towards or away from the CBD (i.e. they made a lateral move). Irrespective of the criteria, the findings suggest that a strong directional bias exists in residential mobility behaviour in Brisbane – 68% respondents made a move towards/away from the CBD.

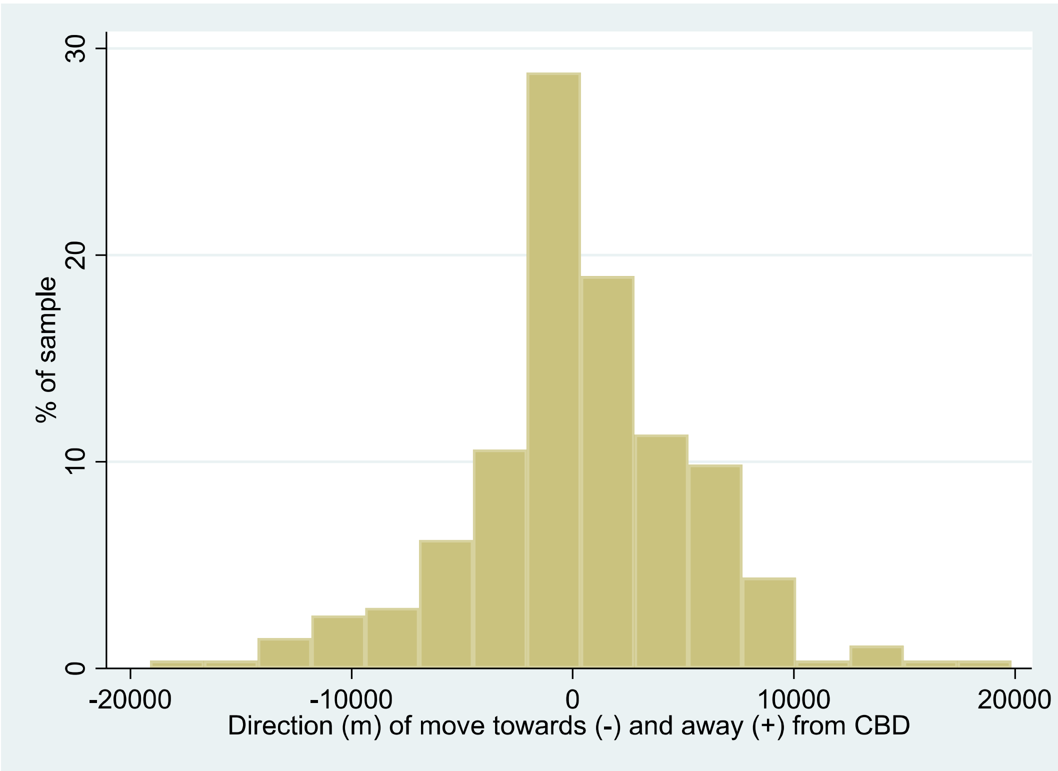


**Figure 5: Distribution of direction of move with respect to Brisbane CBD**

### *4.1.3 Sector bias*

The distribution of the degree of move as shown in Figure 6 clearly illustrates the presence of sectoral bias in residential mobility behaviour in Brisbane – i.e. the distribution of angles are far from random and they show a strong decay behaviour. Clearly, the distribution supports a wedge-shaped urban image hypothesis. For example, using the 10% criterion, 62% of the movers had a move angle less than 18°. Further analysis shows that about 73% and 83% of the movers had a move angle of less than 30° and 45° respectively. Only a few movers (6%) moved through the city to destinations on the opposite side of their pre-move home (move angle >90°).

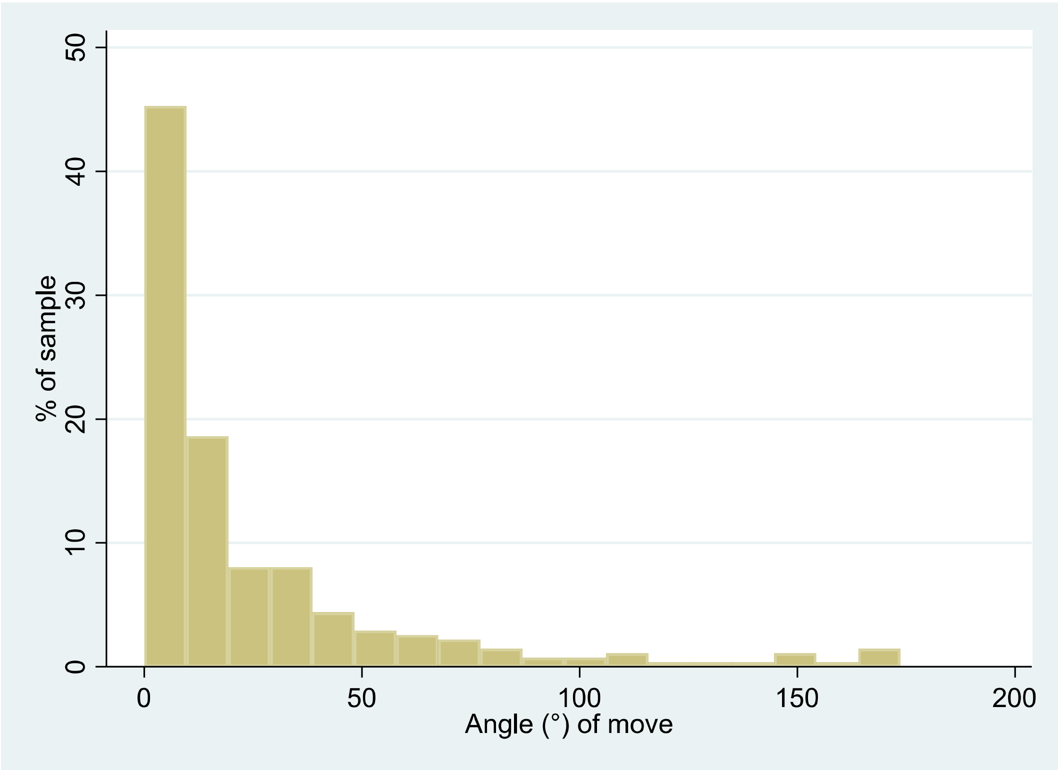


**Figure 6: Distribution of move angle**

### 4.2 Residential biases and travel behaviour

On average, movers experienced a significant change in their urban form after their residential relocation as shown in Table 2. Nevertheless, the movers had exhibited a strong spatial bias in their residential relocation decision as discussed in Section 4.1 – i.e. the movers experienced little change in the urban structure. Hence, this section presents results on the effects of these two aspects of the built environment on travel behaviour change.

Table 4 shows that, on average, there were only minor changes in the choice of transport mode. Car or motorcycle use increased by 2% at the expense of active transport uses. However, changes in mode choice behaviour were evident for about 15% of the movers. While 85% of the movers did not change their mode, about 6% of drivers switched to active transport whereas 9% of active transport users switched to the car. The question remains then: what influences the movers to make this mode switch?

The results from the unadjusted MNL model, as shown in Appendix A, show that a range of factors in all five broader categories (spatial bias, urban form, residential preferences, socio-demographics, and habit) considered in this research are potential contributor to these changes in mode choice behaviour. However, the parsimonious model (Model 1), as presented in Table 5, shows that only five factors had a statistically significant contribution to the mode switch behaviour of the movers.

Table 5 shows that a one degree increase in sector increases the propensity of switching to active transport by one percent. This means that the movers who overcame the sectoral bias were more likely to switch to active transport. Similarly, movers who chose post-move addresses because of the accessibility of places and the availability of public transport options were twice as likely to switch to active transport. This finding, therefore, support the previous findings of strong residential self-selection effect on travel behaviour (Boarnet and Sarmiento, 1998; Cervero and Duncan, 2008; Kamruzzaman et al., 2016). Respondents who were healthy were half as likely to switch to the car. Movers were more likely to switch to the car as they aged. Pre-move walking habit was found to be a stronger predictor of mode switch. Notably, although they were four times more likely to switch to active transport (probably because of their habit), they were 10 times more likely to switch to the car (perhaps they were all ageing).

**Table 4: Mode choice behaviour and their changes following residential relocation**

| Main mode of transport | Pre-move (%) | Post-move (%) | Changes in travel mode | % of movers |
|---|---|---|---|---|
| Active transport (AT) | 21.53 | 19.34 | No Change | 84.67 |
| Car or motorcycle | 78.47 | 80.66 | From car/motorcycle to AT | 6.57 |
| | | | From AT to car/motorcycle | 8.76 |
| N | | | | 274 |

**Table 5: Multinomial logistic regression analysis results (relative risk ratios – RRR) showing the effects of the spatial biases in residential on changes in mode choice behaviour (maximally adjusted model)**

| Explanatory variables | Model 1: Outcome variable: Changes in main mode of transport (ref: unchanged) | |
|---|---|---|
| | Changed to AT | Changed to car/motorcycle |
| ***Indicators of spatial biases*** | | |
| Sectoral bias (° of move) | 1.015** | 1.005 |
| ***Residential self-selection indicators*** | | |
| Accessibility and mobility of places | 2.117** | 1.269 |
| ***Socio-demographics*** | | |
| Health status | 1.069 | 0.528** |
| Age | 1.018 | 1.102** |
| ***Pre-move habit*** | | |
| Walked >35min/week: yes (ref: no) | 4.173** | 10.211** |
| ***Constant*** | 0.007** | 0.002** |
| Log likelihood | | -120.29 |
| LR $Chi^2$ | | 51.52** |
| Pseudo $R^2$ | | 0.18 |
| N | | 274 |

** Significant at the 0.05 level

Sector bias, as shown in Table 5, is the only statistically significant factor among the three biases of residential mobility as considered in this study. As a result, the samples were stratified into two groups (biased and unbiased) to compare the effects of urban form on mode switch behaviour between the groups. Model 2 in Table 6 shows that none of the urban form variables had a significant effect on mode switch behaviour for those respondents who had shown sector bias in residential mobility. This means that despite changes in urban form, respondents who relocated within their home sector were unlikely to switch travel mode. In contrast, as shown in Model 3, two of the urban form factors (changes in residential density and changes in street connectivity) significantly affected mode switch behaviour for those who overcame the sector bias. The RRR values in Model 3 suggest that respondents who experienced an increase in residential density were less likely to switch to the car. However, respondents who experienced an increase in street connectivity level were more likely to switch to active transport.

**Table 6: Effects of changes in urban forms on mode switch behaviour stratified by unbiased (sector) and biased residential mobility behaviour (RRRs are reported from multinomial logistic regression models)**

| Explanatory variables | Outcome variable: Changes in main mode of transport (ref: unchanged) | | | |
|---|---|---|---|---|
| | Model 2: Residential mobility biased (sector) | | Model 3: Residential mobility unbiased (sector) | |
| | Changed to AT | Changed to car/motorcycle | Changed to AT | Changed to car/motorcycle |
| ***Changes in urban form*** | | | | |
| Residential density (dwellings/ha) | 1.014 | 1.024 | 1.003 | 0.969* |
| Street connectivity | 0.880 | 0.977 | 1.103* | 1.023 |
| Land use mix | 0.690 | 2.261 | 0.692 | 10.794 |
| Length of bikeways (m) | 1.000 | 1.000 | 1.000 | 1.000 |
| Distance to bus stop (m) | 1.000 | 1.000 | 0.998 | 1.001 |
| Distance to train station (m) | 1.000 | 1.000 | 1.000 | 1.000 |
| ***Residential self-selection indicators*** | | | | |
| Accessibility and mobility of places | 1.168 | 1.003 | 7.950** | 1.481 |
| Ease of commuting | 2.058 | 0.528 | 1.456 | 1.538 |
| Green environment and safety | 1.018 | 1.343 | 0.771 | 0.221* |
| Child centric facilities | 1.294 | 1.692 | 0.464 | 1.117 |
| ***Socio-demographics*** | | | | |
| Female | 1.075 | 1.680 | 0.456 | 1.335 |
| Age | 0.940 | 1.120* | 1.195* | 1.130 |
| Household size | 1.174 | 0.873 | 1.249 | 1.464 |
| Health status | 0.611 | 0.598 | 1.638 | 0.318* |
| ***Pre-move habit*** | | | | |
| Walked >35min/week: yes (ref: no) | 4.141 | 13.353** | 20.896** | 10.080** |
| ***Constant*** | 0.798 | 0.000 | 0.000 | 0.000 |
| Log likelihood | | -59.830 | | -38.090 |
| LR Chi$^2$ | | 41.02* | | 51.87** |
| Pseudo $R^2$ | | 0.255 | | 0.405 |
| N | | 170 | | 104 |

** Significant at the 0.05 level
* Significant at the 0.1 level

## 5. Discussion and conclusion

Much of the research on spatial biases in residential mobility behaviour was conducted in the late sixties and seventies. At that time, researchers found that the biases are the results of both supply (residential vacancy information is not available to all potential movers) and demand (people have a narrow view of the city based on their current activity spaces) side effects. This research suggests that similar biases still exist in this ageing cohort when gaining access to the availability of properties is no longer likely to be a deterrent in finding a property. Therefore, any biases in residential mobility observed in this study are likely to be fully attributable to the demand side effect i.e. people have preferences about the locations to which they want to live either because of friends, families or current activities and their current activity spaces determine their preferences. In this study we found evidence of a clear distance bias, as 72% of the movers moved within their current activity spaces. Furthermore, 68% of the respondents made a move along the line of pre-move home and CBD, suggesting a strong directional bias. Finally, a sector bias was found, since 73% and 83% of the movers had an angle of less than 30° and 45°, respectively.

Using the theoretical construct of BE and travel, this research, for the first time, empirically tested the effect of spatial biases on travel behaviour and how these affect the findings as reported in previous studies using residential mobility as a BE intervention. In addition, unlike previous studies that often used urban form and urban structure interchangeably, this study defined these two terms as two separate levels of the BE. This separation enhanced our understanding of the effects of BE on travel. In particular, by conceptually linking urban structure with spatial biases it is now possible to understand why significant changes in urban form did not influence mode switch behaviour. Strong spatial biases in residential mobility mean that most individuals moved within their home sector. This means that their perceived spatial structure of Brisbane city remained unchanged. As a result, despite the changes in urban form, respondents failed to differentiate such changes. A shift in mode choice behaviour was evident when individuals overcome the biases. This research conducted further analysis to compare the effect of urban form changes on mode switch behaviour between those individuals who overcame the biases and those who did not. The findings clearly show that changes in residential density and street connectivity level promoted more sustainable travel behaviour for those who moved beyond their home sector. Such effects were not observed for those who experienced biased in residential mobility.

The above findings bear significant implications for both research and policy. It questions the findings of studies investigating the link between urban form and travel behaviour that used residential mobility as a BE intervention in research design. Given that such studies have not distinguished between biased and unbiased residential mobility, it is consequently possible that the reported effects of urban form on travel behaviour are not as pronounced as they should be because of the insignificant effects of urban forms for the biased respondents. The findings from this study clearly indicate that the sampling strategy (e.g. selection of residents with unbiased mobility) could play a vital role in studies examining the causal effects of urban form on travel that rely on residential mobility as a BE intervention.

Given the significance of urban structure and the dependency of urban form on structure in influencing travel behaviour, it is critical that policies aiming to change travel behaviour should prioritise changing structural settings. However, urban form has the potential to alter travel behaviour within a particular structural context, and therefore, they should not be left alone.

Although a residential relocation creates a new context that has the potential to disrupt travel habits, the aggregated data show limited changes in the movers' travel mode choice. This might suggest that previous studies – using quasi-longitudinal data – overestimated changes in travel mode after a relocation. A recent Chinese study using true longitudinal data (pre- and post-move) also found no major changes in movers' travel mode choice (Wang and Lin, 2017). We found that about 6% of the respondents made a switch from the car to active transport, while slightly more respondents (9%) switched from active transport to car use. This is rather surprising as density and diversity were on average higher – and more public transport and cycling facilities were present– in post-move neighbourhoods compared to pre-move neighbourhoods. Clearly this is largely due to the mix of respondents with biased and unbiased movers in Model 1. The analysis using these mixed groups in Model 1 shows that changes in mode choice are significantly affected by the angle of move (i.e., sectoral bias), a preference for living in a well-accessible, mixed use neighbourhood, health status, and past travel behaviour. In sum, results from this study indicate that travel behaviour is more strongly affected by past behaviour (i.e., travel habits), than by changes in the built environment (due to a residential relocation). Furthermore, outcomes suggest self-selection effects as people indicating that the proximity of various facilities (including public transport) were important reasons for choosing the current residential location are twice as likely to switch to active travel and public transport compared to other respondents.

Findings from this study might complicate the idea that sustainable travel patterns can be realised by changes in urban form. Results found that movers' travel behaviour is more strongly affected by their past travel behaviour (in their previous residential neighbourhood) than by a new type of BE. On the other hand, the found self-selection effects (i.e., respondents choosing a mixed-use neighbourhood with public transport facilities nearby likely to switch to active transport) indicate that the BE is still important. Travel-related residential self-selection can be seen as a demonstration of the effect of the BE on travel behaviour (Næss, 2009). If there were no such influence, people preferring active transport, for instance, would not have a preference for living in a compact, mixed-use neighbourhood.

This study provides a first evidence of the impacts of spatial biases on travel behaviour. However, such evidence is confined to a sample who are older in age, and therefore, less likely to move residences (Kamruzzaman et al., 2013). For this reason, they are also less likely to overcome the biases when they move. Further studies using a representative sample of all ages can reinforce the findings presented in this research. In addition, this research made a conceptual link between spatial biases and urban structure. Future research should seek to use alternative indicators to identify the relative effects of urban form and urban structure on travel behaviour. This research used the centroids of activity area (CCD, suburb) to denote activity locations (home, work, pool). These locations were subsequently used to derive both move distance and activity spaces (e.g. SDE) of individuals. Although the use of centroids (instead of actual location) affected all respondents, they are not a precise measure of activity locations, and may have the potential to affect respondents disproportionately, particularly those who lived in outer-suburb areas where the size of CCDs is larger than inner city areas. A major limitation of this study is the use of a rather crude measure of outcome variable (mode switch). The variable was derived from the main mode of travel used in weekdays using five categories as discussed in Section 3.3. The problem with this categorical variable is that it does not capture minor changes in mode switch behaviour. For example, respondents could have reported the car as their main mode irrespective of whether they used it 21% or 100% of the time. Other quantitative indicators (e.g. number of trips, VKT) could be useful to conduct more in depth analysis and offer additional insights not provided here. These limitations mean that the results provided in this study are conservative, and that potential changes could be larger than those observed in this study.


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## 6. Appendix

**A: Predictors of changes in main mode of transport**

| Outcome | Variables | Adjusted model | | Unadjusted model | |
|---|---|---|---|---|---|
| | | RRR | 95% CI | RRR | 95% CI |
| | ***Spatial biases*** | | | | |
| Changed to AT | % of difference in distances of moved and pre-moved homes from CBD (direction bias) | 0.99 | 0.98-1.01 | 0.99* | 0.98-1.00 |
| | Move angle (°) (sector bias) | 1.01* | 0.99-1.02 | 1.01** | 1.00-1.02 |
| | ***Urban form and changes*** | | | | |
| | Changes in distance to train station (m) | 0.99 | 0.99-1.00 | 0.99** | 0.99-0.99 |
| | Residential density (dwellings/ha) (pre-move) | 0.98 | 0.95-1.02 | 0.99 | 0.96-1.03 |
| | Distance (m) to bus stop (pre-move) | 0.99 | 0.99-1.00 | 0.99 | 0.99-1.00 |
| | ***Residential self-selection*** | | | | |
| | Accessibility and mobility of places | 1.79* | 0.97-3.31 | 2.21** | 1.27-3.86 |
| | Ease of commuting | 1.48 | 0.77-2.83 | 2.01** | 1.16-3.47 |
| | ***Socio-demographics*** | | | | |
| | Health status (Poor-Excellent) | 0.91 | 0.48-1.72 | 1.04 | 0.61-1.75 |
| | Age | 1.02 | 0.94-1.11 | 0.99 | 0.92-1.07 |
| | ***Pre-move habit*** | | | | |
| | Walked >35min/week: yes (ref: no) | 4.41** | 1.47-13.18 | 4.02** | 1.51-10.69 |
| Changed to car/motorcycle | ***Spatial biases*** | | | | |
| | % of difference in distances of moved and pre-moved homes from CBD (direction bias) | 1.00 | 0.99-1.01 | 1.00 | 0.99-1.01 |
| | Move angle (°) (sector bias) | 1.00 | 0.99-1.01 | 1.18 | 0.55-2.51 |
| | ***Urban form and changes*** | | | | |
| | Changes in distance to train station (m) | 0.99 | 0.99-1.00 | 0.99 | 0.99-1.00 |
| | Residential density (dwellings/ha) (pre-move) | 1.01 | 0.99-1.03 | 1.02** | 1.00-1.03 |
| | Distance (m) to bus stop (pre-move) | 0.99 | 0.99-1.00 | 0.99* | 0.99-1.00 |
| | ***Residential self-selection*** | | | | |
| | Accessibility and mobility of places | 1.34 | 0.80-2.27 | 1.27 | 0.79-2.02 |
| | Ease of commuting | 0.68 | 0.36-1.30 | 0.75 | 0.46-1.22 |
| | ***Socio-demographics*** | | | | |
| | Health status (Poor-Excellent) | 0.57** | 0.32-0.98 | 0.58** | 0.37-0.91 |
| | Age | 1.10** | 1.01-1.19 | 1.06* | 0.99-1.12 |
| | ***Pre-move habit*** | | | | |
| | Walked >35min/week: yes (ref: no) | 9.73** | 3.31-28.57 | 6.43** | 2.61-15.84 |

** Significant at the 0.05 level
* Significant at the 0.1 level

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