The building blocks of a ‘Liveable Neighbourhood’: Identifying the key performance indicators for walking of an operational planning policy in Perth, Western Australia

ABSTRACT
Planning policy makers are requesting clearer guidance on the key design features required to build neighbourhoods that promote active living. Using a backwards stepwise elimination procedure (logistic regression with generalised estimating equations adjusting for demographic characteristics, self-selection factors, stage of construction and scale of development) this study identified specific design features ($n=16$) from an operational planning policy (“Liveable Neighbourhoods”) that showed the strongest associations with walking behaviours (measured using the Neighbourhood Physical Activity Questionnaire). The interacting effects of design features on walking behaviours were also investigated. The urban design features identified were grouped into the “building blocks of a Liveable Neighbourhood”, reflecting the scale, importance and sequencing of the design and implementation phases required to create walkable, pedestrian friendly developments.

KEYWORDS
Planning policy; liveable neighbourhoods; walking; health; built environment
INTRODUCTION

A vast body of evidence demonstrates associations between the built environment and levels of walking and physical activity (Hooper et al., 2012; Saelens and Handy, 2008; Saelens and Papadopoulos, 2008; Sallis et al., 2009; Transportation Research Board Institute of Medicine, 2005). Government policy and planning initiatives determine the way cities and towns are developed and therefore play a vital role in shaping the neighbourhoods where residents can safely and conveniently be physically active.

Despite a proliferation of evidence and increased attempts by active living researchers to promote research findings to change urban planning policy and practice, there is a dearth of prescriptive evidence about ‘how much’, of ‘what types’ of urban design features and infrastructure are needed to support health and active living behaviours. Planning professionals and policy makers have indicated that to help progress the influence of health research and its translation into planning policy and practice there is an urgent need for practice-based evidence evaluating the effectiveness of existing planning policies - using policy-relevant measures, (Allender et al., 2009; Brownson et al., 2009; Durand et al., 2011; Koohsari et al., 2013). They also require clearer guidance from active living researchers on the ‘key’ or ‘essential’ design features that promote health outcomes and behaviours such as walking (Allender et al., 2009).

In 1998 the Western Australian State Government introduced the ‘Liveable Neighbourhoods Community Design Guidelines’ (LN). A key intended outcome of the LN policy was to reduce suburban sprawl and car dependence and encourage more walking, cycling and public transport use. LN consists of four general design ‘elements’ (community design; movement networks; lot layout; public parkland) that provide design guidance to assist in creating more compact, self-sufficient, pedestrian-friendly neighbourhoods, with destination hubs (i.e., neighbourhood centres) and public transport links. Each element contains a list of requirements of different design features with a range of responses or criteria outlining how planners or developers could meet the element objectives.
The introduction of LN provided a unique opportunity for a natural experiment. As such the RESIDential Environments project (RESIDE) commenced with the aim of assessing the impact of the new planning policy on local residents’ walking and cycling behaviours and health outcomes (Giles-Corti et al., 2008) and to provide longitudinal evidence to enhance the cross-sectional evidence that dominates this literature. As part of the RESIDE project a process evaluation was previously conducted to objectively measure the levels of on-ground policy implementation in in 36 housing developments across Perth using tailored spatial measures (Hooper et al., 2014). This study revealed that the greater the implementation the better the walking outcomes. Indeed, there was a dose-response relationship between overall levels of policy compliance and with each of its elements (i.e., community design, movement network and lot layout) and walking behaviours (Hooper et al., 2014).

The LN elements provide guidance on the built environment features considered to encapsulate good ‘New Urbanist’ design (Duany et al., 2000) and stimulate walking. A simple scoring system for quantifying levels of policy compliance was developed (Hooper et al., 2014). Additionally, a cluster analysis identified the different mix of design features that had been implemented in the developments and their associations with walking behaviour (Hooper et al., 2015). Both approaches also helped to identify the number and range of policy requirements implemented and the degree to which these had been implemented. However, these methods assumed that all of the design features were of equal importance to walking outcomes - which may not be the case.

The LN policy is complex and contains a large number of different design features (up to 25 within each of the four elements) for consideration. Western Australian planning policy-makers (including the custodians of the policy – the Department of Planning) and practitioners (i.e., those implementing the policy on-the-ground) have expressed interest in identifying whether any (and which) of the design features are more effective than others in promoting walking.

In response to this demand and building on earlier work investigating the levels of LN compliance and its associations with walking (Hooper et al., 2014), this paper sought to identify which of the
specific design features currently required under the policy are more, or less important in encouraging walking. Using a backwards stepwise elimination procedure this paper considered all of the design features within each of the four elements of the LN policy (i.e., community design, movement network, lot layout and public parkland) to identify a hierarchy of ‘key performance indicators’ of liveable suburban neighbourhood design that promote active living behaviours, such as walking. The LN elements and their respective design features were not intended to be implemented in isolation. It was therefore important to investigate combinations or interactions of design features across the elements that were required to encourage walking behaviours, and to represent these as ‘building blocks’ of a ‘Liveable Neighbourhood’, reflecting the sequencing required in the design and implementation phases.

The two specific objectives of this paper were to: 1) identify the LN requirements from each element that showed the strongest associations with walking behaviours; and 2) to investigate the interacting effects of selected policy requirements on different walking behaviours.

METHODS
Measuring implementation of policy requirements
This paper follows the process evaluation that objectively measured the implementation of the quantifiable requirements from the LN policy across its four elements for 36 new housing developments being built in Perth, Western Australia (Hooper et al., 2014). Measures specific to each of the LN policy requirements were developed and computed in a geographic information system (GIS). Detailed information on the specific policy requirements and development of the measures are reported elsewhere (Hooper et al., 2014). A brief description of the policy measures included in this study is outlined in Table 1.

Participants and self-reported walking behaviours
The RESIDE study population comprised people who purchased land and were building new homes in 73 greenfield developments across the metropolitan region of Perth, Western Australia. Participants completed a self-report survey before they moved house (2003/04) and on three
subsequent occasions after relocating to their new suburban home (2004-2006). Full details of the RESIDE recruitment protocols and study design are available elsewhere (Giles-Corti et al., 2008).

The process evaluation focused on a subset of RESIDE participants (n=664) who were resident in 36 of the RESIDE developments (Hooper et al., 2014), had completed a RESIDE survey in 2009 and had lived in that development for at least two years. Walking behaviours were measured using the Neighbourhood Physical Activity Questionnaire (NPAQ), which has been shown to have acceptable reliability (Giles-Corti et al., 2006). Participants reported the frequency and duration of walking for transport (WT) and recreation (WR) within their neighbourhood in a usual week (Giles-Corti et al., 2006). Dichotomous variables (yes/no) were computed for >0 (any) and ≥60 mins/week of any WR and WT in the neighbourhood. Minutes of total walking (TW) were also dichotomised (yes/no) at >0 (any), ≥60 mins/week and ≥150 mins/week. This upper threshold of total walking was used to investigate whether participants were meeting recommended levels of physical activity through any type of walking.

Identifying important LN requirements for walking

All analyses were conducted in SPSS version 22. Logistic regression with generalised estimating equations (to control for clustering of participants within housing developments) was used to examine associations between the individual LN requirements and each of the walking outcomes. Variables (i.e. LN requirements) with potential associations (univariate \(p\)-value ≤0.1) were accepted into the next backwards elimination phase of analysis. This was run separately for requirements within each of the four elements to identify the specific requirements from each element that were associated with walking outcomes. At each stage of the backwards process the policy requirement with the highest \(p\)-value (and >0.05) was removed and the model re-fitted. This continued until all remaining LN requirements had \(p\)-values ≤0.05 which constituted the (final) multivariate model. All models adjusted for demographic characteristics (age; gender; education, children ≤18 years and under living at home) and neighbourhood-selection factors as well as the stage of construction and scale of development. The estimated odds ratios (and 95% confidence intervals) are presented for each requirement in the final multivariate models. The odds ratio
represents the relative increase in the odds of the walking outcome for that level of the requirement in comparison to the reference level - yes/no for categorical requirements and for a one unit increase in the level of the requirement for quantitatively measured requirements.

**Interaction effects of LN requirements and walking**

Interaction analyses assessed the interacting effect on walking of the movement network with the provision of community infrastructure (in the form of neighbourhood centres and public open space). All movement network requirements that remained in the final multivariate models (n=7), plus the two MN requirements removed in the penultimate stage (the connected node ratio and cul-de-sac street percentage) were examined with: 1) the community design requirement on the presence and configuration of neighbourhood centres that remained in the final multivariate model: and 2) the five public parkland requirements relating to the provision of and access to public open space that remained in the final multivariate models. Each of the requirements entered into models with interaction terms were first dichotomised (reflecting high vs. low levels of policy implementation of that requirement). All models adjusted for demographic characteristics (age; gender; education, children ≤18 years and under living at home) and neighbourhood-selection factors as well as the stage of construction and scale of development.

**RESULTS**

The full demographic characteristics of the study population (n=664) are reported elsewhere (Hooper et al., 2014). Briefly, the average age of participants was 43 years (SD 11.7), the majority were female (62%) and married or in a de-facto relationship (87%) and about one-half of participants had one or more children under the age of 18 years living at home.

Table 2 presents the estimated odds ratios (and 95% confidence intervals) results from the final multivariate models containing the significant LN requirements from the community design (CD), movement network (MN), lot layout (LL) and public parkland (PP) elements associated with each of the walking outcomes. Table 3 presents the estimated odds ratios (and 95% confidence intervals) results from the interactions analyses. Only those with significant associations are presented.
**Community design requirements and walking behaviour**

The configuration of the centre accessible within 1600m was associated with the odds of walking within the neighbourhood: Compared with having no centre accessible within 1600m, having a 'big-box' shopping centre was significantly associated with increased odds of undertaking ≥60mins WT (OR=1.7), as well as any TW (OR=3.1) and ≥60mins of TW (OR=1.4) within the neighbourhood. Having access to a main street configured centre was significantly associated with all walking outcomes and a higher odds of walking compared with having access to a big-box centre. Compared with having no accessible centre, the odds of doing any WT, WR and TW were more than double for participants with access to a main street configured centre. The odds of doing ≥60mins TW per week increased by a factor of nearly seven (OR=6.7), and were substantially higher for doing ≥60mins WT (OR=1.7) and WR (OR=2.4). A greater diversity of destinations provided within the centres was also associated with increased odds of doing any WT (OR=1.22 for every additional destination type), ≥60mins WT (OR=1.36) and ≥150mins TW (OR=1.16).

The presence of a primary school within 400m was, somewhat counter-intuitively, significantly associated with lower odds of doing any WT (OR=0.55).

**Movement network requirements and walking behaviour**

Three MN requirements were positively and significantly associated with WT (Table 1): Each additional external access point increased the odds of doing any WT by 35% (OR=1.35). For each additional kilometre of footpaths in the development, the odds of doing any and ≥60mins WT increased by 2%; and for each additional tree provided along the footpath network the odds of doing any WT increased by 4% (OR=1.04). Having a higher proportion of cul-de-sacs roads with linking routes more than doubled the odds of doing ≥60mins WT (OR=2.40).
Three MN requirements were significantly associated with WR (Table 1): Higher block densities were associated with a nearly seven-fold increase in the odds of doing any WR (OR=6.83) and five-fold increased odds of doing ≥60mins WR (OR=5.14). Each extra kilometre of footpath increased odds of doing ≥60mins WR by 1% (OR=1.01). Notably, higher proportions of cul-de-sacs with linking routes were associated with decreased odds of achieving ≥60mins WR (OR=0.64) (Table 2).

Four MN requirements were significantly associated with TW. Higher block densities were associated with a five-fold increased odds of doing ≥60mins TW (OR=5.05). A higher walkable block ratio (i.e., numbers of blocks that met the policy requirement for size i.e., ≤620m perimeter) was associated with increased odds of undertaking any TW (OR=4.38, 3.24-5.91) and ≥150mins TW (OR=2.27) per week. For every one unit increase in the sidewalk:road ratio the odds of doing ≥60mins TW increased threefold (OR=3.14, 1.89-11.1) and for every one unit increase in the density of trees positioned along the footpath networks the odds of doing ≥60mins TW increased by 2%.

Lot layout requirements and walking behaviour

The proportion of the residential land area occupied by small lots (≤350m²) was the only significant LL requirement. For every percentage increase in land area occupied by small lots the odds of doing any WT increased by 4% (OR=1.04).

Public Parkland requirements and walking behaviour

Four PP requirements were significantly associated with doing any WT (Table 1). The odds increased by 8% for every additional park (OR=1.08, 1.03-1.13), by 13% for every additional small park (>0.3 to ≤0.5ha), by 17% for each additional medium park (>0.5 to ≤1.5ha) (OR=1.17, 1.06-1.28) and increased four-fold with access to a regional park (>4ha in size) within 2.5km (OR=3.97, 2.46-6.41). Access to a regional park was also significantly associated with doing ≥60mins WT (1.99, 1.83-2.17).
Just two PP requirements were significantly associated with the WR and TW outcomes (Table 1): every additional medium-sized (>0.5 to ≤1.5ha) park was associated with a 6-9% increased odds of doing any and ≥60mins WR and TW. Access to a regional park was associated with a 60-80% increased odds of doing any and ≥60mins WR and TW.

Interacting effects of CD and MN requirements with walking behaviour

Table 2 presents the estimated odds ratios (and 95% confidence intervals) of the interaction analyses – many of which revealed that the effect of implementation of the MN requirements on walking differed according to whether or not a neighbourhood centre was accessible within 1600m. There were significant interactions between the presence and type of a neighbourhood centre and street network connectivity with doing ≥60min WR and TW, and ≥150mins TW. Significant interactions were also observed between the presence and type of a neighbourhood centre and both cul-de-sac and sidewalk provision for ≥60min of weekly WR and TW. There were no significant interactions with WT as the outcome variable.

INSERT TABLE 2 ABOUT HERE

Access to a neighbourhood centre and street connectivity

Having access to a main street or big box centre had a major effect on walking (Table 2). However, the association between connectivity of the street network, measured by the connected node ratio, and the WR and TW outcomes was modified by the presence or absence of a centre within 1600m (interaction terms p<0.001). For people with no access to a centre within 1600m, having a highly (versus low) connected street network had a large effect on the odds of doing ≥60mins WR (OR=9.96), ≥60mins TW (OR=29.83) and ≥150mins TW (OR=3.87) per week. For people with access to a big-box configured centre, having high (versus low) street connectivity increased the odds of achieving ≥60mins WR by about 50% (OR=9.12/6.29 =1.45), of achieving ≥60mins TW by 70% (OR=36.37/21.46 =1.69) and achieving ≥150mins TW by 60% (OR=5.07/3.23 =1.57). Similarly, for participants with access to a main street centre, having a highly connected street network provided 30% increased odds of achieving ≥60mins WR (OR=20.42/15.94 =1.28),
40% increased odds of achieving ≥60mins TW (OR=69.40/50.46 =1.38) and 30% increased odds of achieving ≥150mins TW (OR=6.03/4.62 =1.31).

However, having access to a main-street configured centre within 1600m provided the most benefit to increasing walking behaviour, regardless of the connectivity of the street network. The 'best case scenario' for residents was living in developments with a main street centre and high street connectivity. These residents had the highest odds of achieving walking; with a 20-fold increased odds of doing ≥60mins WR (OR=20.42), a 70-fold increased odds of doing ≥60mins TW (OR=69.40) and a six-fold increased odds of doing ≥150mins TW (OR=6.03) compared with those with no centre and low street connectivity (i.e., ‘worst case scenario’).

**Access to a centre and cul-de-sacs street percentage**

The association between cul-de-sacs street percentage with doing ≥60mins WR and TW outcomes was also modified by the presence or absence of a centre within 1600m (interaction terms p<0.002) (Table 2). For people with no access to a centre, having low (versus high) cul-de-sacs street percentages had a large effect on the odds of doing ≥60min WR (OR=9.18) and ≥60min TW (OR=29.27) per week. For people with access to a big-box configured centre, having a low (versus high) cul-de-sacs street percentage made little difference to the odds of doing ≥60mins WR (OR=6.53/6.76 =0.97) or doing ≥60mins TW (OR=27.34/24.21 =1.13). For participants with access to a main street centre, having a low (versus high) cul-de-sacs street percentages increased the odds cul-de-sacs of doing ≥60mins WR by 25% (OR=18.56/14.85 =1.25) and increased the odds of doing ≥60mins TW by 36% (OR=67.12/49.20 =1.36)

**Access to a centre and sidewalk provision**

The association of high (versus low) provision of sidewalks (i.e., the proportion of the road network with footpaths adjacent to / running parallel to the road pavement) with the ≥60mins WR and TW outcomes was modified by the presence or absence of a centre within 1600m (interaction terms p<0.001) (Table 2). For people with no access to a centre, high (versus low) provision of sidewalks increased the odds of doing ≥60mins WR three-fold (OR=3.12) and ≥60mins TW six-fold
(OR=6.09). For people with access to a big-box configured centre, high (versus low) provision of sidewalks made only a small difference to doing ≥60mins WR (OR=2.94/2.25 = 1.31) and doing ≥60mins TW (OR=7.42/5.64 = 1.32). For people with access to a main street centre, having high sidewalk provisions made a moderate difference to doing ≥60mins TW (OR=12.04/7.16 = 1.68). Participants with no centre but high provision of sidewalks had similar levels of WR and TW to those with access to a big box centre (regardless of provision of sidewalks) whilst those with access to a main street configured centre had the highest odds of walking.

**Interacting effects of PP and MN requirements with walking behaviour**

There were significant interactions between two PP requirements (the total number of parks and the number of medium-sized parks) and the footpath:road ratio in their effects on achieving ≥60mins WR (p=0.022 and p=0.023, respectively). Compared with having low numbers of all parks/medium-sized parks and low footpath provisions, participants living in housing developments with higher total numbers of parks/medium-sized parks and high levels of footpath provision had an increased odds doing ≥60mins WR (OR=2.47 and 2.47 respectively). Participants living in housing developments with higher total numbers of parks/medium-sized parks or a high level of footpath provision (but not both) did not have a significantly increased odds doing ≥60mins WR.

There was also a significant interaction between the presence of a larger regional-sized park (≥4ha) and high levels of footpath infrastructure for ≥60mins WT (p=0.040), ≥60mins WR (p=0.001) and ≥60mins TW (p<0.001). Compared with participants with no access to a park ≥4ha in size within 2.5km and low footpath:road ratio, participants with access to a park ≥4ha in size plus high footpath:road ratios had significantly higher odds of achieving ≥60mins WR (OR=2.04), ≥60mins WT (OR= 2.46) and ≥60mins TW (OR=1.80). Additionally, access to a regional park, even with low footpath provision was also associated with an increased odds of doing ≥60mins WT (OR=2.42) – and similar to that with high footpath provisions, suggesting that the provision of the footpath network offered little increased benefit for achieving ≥60mins WT when a regional-sized park was accessible within 2.5km. Further, participants with no access to regional park but with high provision of a footpath network had significantly lower odds of ≥60mins WT (OR= 0.27),
≥60mins WR (OR=0.35), and ≥60mins TW (OR=0.19) than participants with no access to regional park and low provision of a footpath network.

DISCUSSION

A particular focus of the Western Australian ‘Liveable Neighbourhoods’ (LN) policy is to promote walking (particularly transport walking). There has been much interest amongst local planning policy makers and practitioners in the key components or policy requirements and design features that promote walking. This study is unique in its attempts to provide practice-based evidence and to begin to identify ‘key performance indicators’ representing a hierarchy of requirements for encouraging or supporting residents’ walking behaviours, from an operational planning policy in Perth, Western Australia.

This paper builds on the previously reported process evaluation findings examining compliance with the LN policy (Hooper et al., 2014) and different mixes or combinations of the design features stipulated within the policy associated with different walking outcomes (Hooper et al., 2015). This study has identified a smaller number (n=17) of specific policy requirements across the four elements that (when implemented) accounted for the greatest association with walking outcomes. The current findings also illustrates that the policy requirements interact with one another and thus their implementation in isolation will likely not result in optimal conditions to support local walking.

These analyses have allowed the development of an empirically derived, refined list of the “key” LN design features that showed the strongest associations with walking behaviour. These features have been grouped into three ‘building blocks of a liveable neighbourhood’ (Figure 1). These represent a hierarchy of design features related to: their scale (i.e., micro or macro); suggested sequencing of the design and implementation phases in order to create walkable, compact, pedestrian friendly developments; and their relationship with walking behaviour. All three blocks are supported, by a consideration of density – whether that is the ‘overall density’ of the development area, the ‘targeted density’ around centres and public transport hubs, and the ‘design and quality’ of the density provided (Giles-Corti et al., 2012).
Building Block One: Structure and Connectedness

This first building block represents the macro design features that create the foundation or ‘footprint’ of the development, setting out how it will be configured and connected for movement within, throughout and across the development. The first building block facilitates walking within the neighbourhood by determining the connectivity of the street networks, which in turn determines the proximity to destinations. Both of these design features have consistently been associated with walking behaviours (Oakes et al., 2007; Owen et al., 2007; Owen et al., 2004; Saelens et al., 2003).

The importance of the movement network as the foundation building block is highlighted by this study’s interaction analyses which revealed that good street connectivity was significantly associated with walking, even in the absence of a neighbourhood centre. This is also supported by our previous work which indicated that compliance with the MN element was associated with the greatest odds of WT in the neighbourhood (Hooper et al., 2014).

As an alternative measure of connectivity, and consistent with New Urbanist theory and the requirements of LN, increased street block densities (reflective of smaller and a larger number of blocks and more compact and denser developments) were associated with increased odds of both recreational and total walking, although none of the transport-related walking outcomes. This latter finding may be due to the generous provisions of LN allowing for block perimeters of up to 620m (The Planning Group WA 2003). By international standards this block size is still large, and suggests that the LN developments are meeting the letter but not spirit of this principle which aims to reduce the size and increase the number of blocks to create more compact developments. A large proportion of blocks at the upper limit of this threshold may reduce a development’s connectivity and overall neighbourhood density. However, Oakes et al. (Oakes et al., 2007) also found larger block sizes to be associated with increased odds of recreational walking. This may be
because the proximity of local destinations – particularly shops and services - is less important to recreational walkers, provided the neighbourhood environment is pleasant (Sugiyama et al., 2012).

**Building Block Two: Activities and Mix**

The current results indicated that access to and diversity of destinations within community centres and the provision of public open spaces were essential community design requirements for encouraging both walking for transport and recreation behaviours in the neighbourhood. This second building block therefore represents the installation of a mix of land uses and activities (i.e., other than residential) within the neighbourhood, providing public open spaces and places or destinations for residents to visit and use. This building block provides residents with a ‘reason’ to walk within their neighbourhood.

The importance of destinations for walking has been consistently observed in the literature (Cerin et al., 2007; Cervero and Kockelman, 1997; Chanam and Moudon, 2006; Durand et al., 2011; Transportation Research Board Institute of Medicine, 2005) and in other New Urbanist neighbourhoods (Boer et al., 2007; Lund, 2003). Longitudinal evidence from the RESIDE project further supports these cross-sectional findings providing evidence of a dose-response relationship between transport walking and access to a mix of local neighbourhood destinations (Giles-Corti et al., 2013; Knuiman et al., 2014).

Indeed, previous analyses that included all four of the LN policy elements in a multivariate model highlighted that the community design element remained important for walking for transport (Hooper et al. 2014). Furthermore, recent findings indicated that above and beyond the implementation of the MN and LL requirements, the added combination of implementation of the CD and PP requirements through the provision of neighbourhood centres and public open spaces was associated with greater odds of walking for transport, recreation and meeting recommended levels of physical activity through any walking (Hooper et al., 2015). Providing incentives that facilitate the early installation and establishment of mixed-use centres or implementing business
development in specific areas to ensure residents have access to a mix of recreational and utilitarian destinations to which to walk is therefore warranted.

McConville et al (McConville et al., 2011) have noted that previous measures and classification of ‘retail’ land uses incorporate shops in different configurations which may have widely varying influences on pedestrian activity. A key principle of the CD element relates to the configuration of the neighbourhood and town centres. Conventional big-box style centres tend to cater generously for cars (Naess, 2005) and can be hostile, unwelcoming and unsafe environments for pedestrians. The LN policy emphasises the installation of more traditional main-street mixed-use centres where pedestrian-scaled, street-fronting retail layouts that encourage walking and cycling access predominate. This study revealed that in addition to having destinations to walk to, the configuration of the centre in which these are located is highly important for encouraging walking behaviour. Whilst having a big box configured centre provided some benefit in terms of increasing walking, the provision of the main-street centres was associated with greater odds of doing any TW and ≥60mins per week of transport, recreational or any walking within the neighbourhood.

This supports previous findings by Cervero and Kockelman (Cervero and Kockelman, 1997) who found that neighbourhoods with more on-street parking in commercial areas, and thus a greater pedestrian emphasis, had fewer single-occupant car travel for non-work purposes. Similarly, Pikora et al (Pikora et al., 2006) found that respondents living in neighbourhoods with more off-street, large car parking facilities at destinations had lower odds of walking for transport. A recent ‘Good for Business’ report by the Australian Heart Foundation (Tolley, 2011) also concluded that creating town centres in more attractive, pedestrian orientated main-street formats significantly increases pedestrian activity and is important in helping to create a modal shift from the car to walking trips.

The association of WR with the main street configured centres may be explained by Handy (Handy, 1996). She suggests that whilst the primary motive for recreational walking is the act of walking itself (i.e., for pleasure or exercise), individuals may still set out with a particular destination in mind. Additionally, work by Moudon and colleagues (Moudon et al., 2006) suggests that whilst...
destinations such as supermarkets are usually associated with necessary spending and utilitarian trip purposes, the presence of a diverse mix of destinations associated with discretionary spending (such as cafes, restaurants and retail) and community or civic uses and spaces, located in pedestrian-orientated main street centres, may provide both destinations and an interesting route for recreational walking (Sugiyama et al., 2012).

This study also revealed the important interactions between the ‘structure and connectedness’ and ‘activities and mix’ building blocks and the need to align them for optimal walking outcomes. The interaction results revealed that having access to a main-street configured centre within 1600m provided the most benefit to increasing walking behaviour, regardless of the connectivity of the street network. Conversely, over and above a highly connected street network, the provision of a ‘big-box’ configured centre provided little or no additional benefit in terms of encouraging walking. However, the provision of a main street centre in combination with a connected underpinning street network provided the optimal conditions for encouraging walking behaviour.

Parks and areas of public open space provide another form of destination for residents to walk to and within (Sallis et al., 2009; Sugiyama et al., 2010; Ulrich and Addoms, 1981). Indeed, the provision of more parks throughout the neighbourhood was associated with increased odds of doing any transport walking and any and ≥60 mins per week of recreational and total walking. However, the presence of a larger ‘destination’ (regional) park was associated with greater odds of doing both any and ≥60 mins per week of transport, recreational and total walking. Longitudinal results from RESIDE also showed for each type of recreational destination (i.e., park, playing field or beach) gained after relocation participants recreational-walking increased by around 18 minutes/week (Giles-Corti et al., 2013). Parks also facilitate social interactions and play a role in increasing social capital by providing places where people to gather and develop social ties (Bedimo-Rung et al., 2005; Kuo et al., 1998) (Chiesura, 2004; Wolch et al., 2014) and another intended objective of the LN policy.
The interaction results also revealed that where there were a high number of parks with footpaths, people were almost 2.5 times to walk achieve ≥60 mins walking for recreation each week. However, participants with access to a larger (regional) park were more likely to undertake ≥60 mins transport, recreation or total walking irrespective of the footpath provisions. When no large park was accessible, participants were less likely to walk even with good footpath provisions. These findings are consistent with other elsewhere that has found access to larger, more attractive parks to be associated with walking for recreation (Giles-Corti et al., 2005; Sugiyama et al., 2010).

After controlling for the presence of children living at home and the provision of a neighbourhood centre, the presence of a primary school within 1600m was negatively associated with walking for transport. This was contrary to expectations, however consistent with other findings suggesting that large land parcels allocated for school sites and offices were “deterrent” land uses and negatively associated with walking in adults (Moudon et al., 2006). Indeed, the LN policy recognises that “the trend towards larger primary schools and their large site area (some 4 ha) may interfere with walkability and a reduction in the potential catchment of the neighbourhood centre” (Western Australian Planning Commission 2000), pg.15). This is important, given recommendations to co-locate schools with town centres, which may decrease the potential for adults to walk to the town centre, and children to walk to school (Giles-Corti et al., 2011).

Nevertheless, 11 of the 13 regional-scaled developments in this study of sufficient size to require the provision of a primary school, did so. Schools were constructed early in the development phase, perhaps to encourage young families to buy into the development. However, only seven of these developments had installed a neighbourhood centre at the time of evaluation. Thus it is possible that it was not the presence of the school per se that discouraged walking for transport but rather the absence of utilitarian destinations. Whilst the provision of school sites is an important community destination, particularly for increasing the likelihood of children using active modes to school, reliance on a primary school alone to generate walking trips is insufficient as an attractor or anchor destination for creating walkable neighbourhoods. The presence of a primary school is only likely to be a destination for primary aged children and their parents, not for other adult
residents. Moreover, the trend towards larger primary schools may deter children from walking and cycling to school and encourage parents to chauffeur their children by car (Trapp et al., 2013).

**Building Block Three: Design Details and Quality**

The third ‘building block’ relates to the detail and quality of the neighbourhood design and micro features that enhance the walking experience and make walking within the neighbourhood an attractive, safe and desirable option. Quality design contributes to creating walkable and enjoyable places, buildings, streets, and parks. This includes the provision of footpaths along the connected street networks (providing a safe alternative to driving) and trees to provide shade from the hot climatic conditions of WA (Cervero and Kockelman, 1997) and a buffer between the sidewalk and traffic – creating a safer walking environment (Burden, 2006; City of Melbourne, 2011), as well as the building design and frontage to streets and the road design (widths and intersections) to create slower vehicular movements.

This study highlight the importance of footpaths for walking and are consistent with those found elsewhere (Duncan and Mummery, 2005; Hess et al., 1999; Pikora et al., 2006; Saelens et al., 2003). Two footpath variables remained in the multivariate models with full adjustment. The first (total footpath length) reflected the total footpath provisions throughout the development. This included all footpaths that were positioned alongside roads (i.e., sidewalks) as well as those through parks and areas of open space and pedestrian access-ways or laneways linking cul-de-sac terminations or road reserves, reflecting a higher connectivity of routes for pedestrians.

The importance of pedestrian infrastructure alongside the road network (i.e. sidewalks) was also important, as called for in the LN policy, as it positively moderated interactions with the access to neighbourhood centres for recreational and total walking – again highlighting the need to align and install in combination design features from the different building blocks.
Supporting Block: Density

An important supporting characteristic for each block in the hierarchy, and an essential consideration at each stage of the design process is residential density. Alone, there have been mixed results and relatively weak relationships between residential density and walking. Density by itself does not increase walking and cycling for transport. However, higher densities tend to result in the creation of more compact development thereby decreasing the distances between housing and destinations. The ‘overall density’ of a development is thus an important consideration when designing its ‘footprint’ or structure and connectedness. The level of density influences the provision of local destinations and public transport services that encourage active modes of travel making them both viable and accessible (Ewing and Cervero, 2010; Handy and Clifton, 2001; Transportation Research Board Institute of Medicine, 2005). Consideration of higher density development ‘targeted’ around community centres and public transport hubs is thus an important consideration to support provision of a mix of land uses and activities. Finally, the ‘design and quality’ of higher density development is another important consideration. This will ensure the quality of the design of ‘liveable’ higher density residential dwellings (Giles-Corti et al., 2012; Udell et al., 2014). It includes consideration of its appearance and amenity, form, size or scale, and relationship with the streetscape.

Strengths and Limitations

A limitation of this study is the relatively small sample size of residents, which most likely accounts for the large confidence intervals for the interaction results. The lack of significant associations with walking for transport in the interaction analyses is likely to be a result of the relatively small number of participants who reported using active modes of transport to and from their place of work. However, the use of precise, policy-specific GIS measures of the new developments on greenfield sites is a particular strength. The results are directly applicable to suburban areas throughout Australia and the United States (US), that have typically followed conventional design principles, as well as European settings as new towns are developed on greenfield sites. A strength of this study was the inclusion of self-selection factors in models. Notably, the associations observed persisted after controlling for self-selection, measured as participants’
preferences for particular neighbourhood features. This suggests that regardless of residents’ preferences for ‘walkable’ or ‘liveable’ features, implementation of the 16 policy requirements encouraged walking within the neighbourhood. This finding is consistent the longitudinal results from RESIDE (Giles-Corti et al., 2013; Knuiman et al., 2014) and suggest that creating more walkable neighbourhoods would increase local walking, even in those who chose their neighbourhood for reasons other than its walkability.

CONCLUSION

This study aimed to identify a shortlist of policy requirements from an operational state planning policy that showed the strongest associations with walking behaviours in order to begin to identify a hierarchy of design features that are important for encouraging or supporting residents’ walking behaviours. Sixteen policy requirements were identified across the four elements and grouped under three different “building blocks of a liveable neighbourhood” supported by appropriate densities, to represent a hierarchy of requirements related to their scale (i.e., micro or macro), and suggested ordering of consideration in the design and implementation phases in order to create walkable, compact, pedestrian friendly developments and neighbourhoods.

The impact of micro-design elements such as street trees and landscaping (i.e., the detail and desirable features) although more easily implemented, is likely to be too small on their own to exert any fundamental influences on travel and recreational behaviour in a low density, homogenous residential neighbourhood. In contrast, the implementation of macro urban planning features such as street connectivity with sufficient residential densities provide the foundation of walkable communities and result in more compact neighbourhoods that support the provision of neighbourhood centres and quality public open spaces. Together these are the principal underlying determinants of walking within the neighbourhood, and the most difficult to retrofit. Implementation of these macro features should therefore be the first to be considered, incentivised and enforced in the design and development processes of new suburban neighbourhoods, to which other micro features can be added. The interaction analyses has also highlighted that each
block of design features is essential in its own right, but to bring about optimal walking outcomes these need to be aligned vertically and implemented in combination.

Evidence-based planning requires information on thresholds relating the design features (e.g., the optimal distance to a neighbourhood centre or the mix of destinations within it to promote walking or the level of density for positive health outcomes) to incorporate into planning guidelines or policies. There is also a lack of studies examining the cost-effectiveness of creating more walkable and liveable neighbourhoods or planning policies. Further research in these is required to advance evidence-based planning.
REFERENCES


Table 1: Objective measures of the community design, movement network, lot layout and public parkland requirements from the Liveable Neighbourhoods policy that were entered into the multivariate analyses

**COMMUNITY DESIGN**

**Access to Neighbourhood Centres**
- Distance to the nearest neighbourhood/town centre
- Centre accessible within 400m (Yes/No)
- Centre accessible within 800m (Yes/No)
- Centre accessible within 1600m (Yes/No)

**Configuration of Neighbourhood centre accessible within 1600m**
- Main street layout
- Big-box layout

**Diversity of Destinations within Neighbourhood Centres**
- Destination diversity score - number of different destination types present within the centre (score 1-8):
  1. Number of convenience goods stores: Supermarkets; deli’s; specialty food stores (i.e., butchers, greengrocers, fishmongers); liquor stores and bottle shops; newsagents and confectionary retailers; service station shops
  2. Number of retail goods stores: Fashion and apparel stores, footwear and accessories shops; jewellery stores; books, games, music, DVD/video stores; cards, souvenirs and gift stores; personal electronic and telecommunications; variety and discount stores
  3. Number of general services: Hair and beauty; banks and finance; personal health (e.g., pharmacies); video/DVD rental; laundry and tailoring
  4. Number of medical and health care services: Medical centres; other medical and health services (e.g., dentist, physiotherapist)
  5. Number of places of worship: Churches, mosques, temples and synagogues
  6. Number of community services and facilities: Community centres; day care centres / crèches; libraries
  7. Number of eating and drinking out establishments: Restaurants, bars, fast food outlets, hotels, taverns, pubs, bars, nightclubs
  8. Number of entertainment and amusement places: Cinemas; theatres; convert halls; museums, art galleries; gaming and gambling venues; sporting (spectator) venues

**Access to Public Transport**
- Distance to the nearest bus stop
- Bus stop accessible within 400m (Yes/No)
- Number of bus routes through the development
- Number of bus services to/from the development
- Distance to the nearest train station
- Train station accessible within 800m (Yes/No)

**Access to Primary Schools**
- Distance to the nearest primary school
- Primary school accessible within 1600m (Yes/No)

**MOVEMENT NETWORK**

**Connectivity of the Street Networks**
- Connected node ratio (number of 3 + 4 way intersections ÷ total number of all intersections including cul-de-sacs)
- Mean block perimeter
- Block density = number of blocks ÷ constructed land area within the development
- Walkable block ratio = number of blocks ≤620m perimeter ÷ total number of blocks

**External Connectivity**
- Number of external access points = number of pedestrian-friendly access points along the development perimeter ÷ perimeter of development boundary (km)

**Cul-de-sac provision and design**
- Cul-de-sac length ratio = number of cul-de-sacs ≤120m in length ÷ total number of cul-de-sacs
- Cul-de-sac link ratio = number of cul-de-sacs with a pedestrian cut through ÷ total number of cul-de-sacs
- Cul-de-sac lot ratio = number of cul-de-sacs serving ≤20 residential lots ÷ total number of cul-de-sacs
- Percentage of residential lots on cul-de-sacs (≤ / > 15%) = number of residential lots served by a cul-de-sacs ÷ total number of residential lots
- Cul-de-sac street % = length of all road network segments terminating in a cul-de-sac ÷ total length of all road centrelines

**Total footpath provision**
- Footpath length per unit area (ha) = length of all footpaths ÷ constructed land area of housing development
- Footpath to road ratio = length of all footpaths within the development ÷ length of all roads within the development

**Footpaths on both sides of the street?**
- % of road length with sidewalks (i.e., footpath segments that ran alongside the road)
- Sidewalk to road ratio = length of all footpath segments alongside/adjacent to roads ÷ length of all roads
Streetscapes – Trees along footpaths
- Tree density along footpaths = number of trees along footpaths (within a 5m buffer) ÷ length (km) of footpaths within the development
- Tree canopy cover = area of footpath shaded by tree canopy cover ÷ total footpath area within the development

LOT LAYOUT

Residential lot size
- Mean residential lot size
- Median residential lot size
- Number of different lot sizes present (categories: ≤350m²; >350 - ≤550m²; >550 - ≤750m²; >750 - ≤950m²; >950m²)
- Residential land areas occupied by different lot sizes
- % of lots ≤350m² (i.e., “small” lots for medium density housing)

Housing diversity development-wide
- Number of dwellings by type (n=9) as a % of the total number of dwellings
- Residential land area occupied by different (n=9) dwelling types = the total number of different dwelling types present within each development (score = 1-9):
  1) Single detached houses; 2) Semi-detached houses; 3) Duplex unit; 4) Triplex unit; 5) Town house; 6) Terrace house; 7) Group house; 8) Villa house; and 9) Flat or apartment. Housing types 3-8 (inclusive) represent medium density housing models.

PUBLIC PARKLAND

Amount and type of parks
- Area (ha) of all parks + publicly accessible school grounds
- % provision of parks = area of all parks + publicly accessible school grounds ÷ gross constructed land area of housing development (< / ≥ 10%)
- Total number of parks within the development
- Number of local parks
- Number of neighbourhood parks
- Number of district parks
- Number of regional parks (>4ha)

Access to parks
- Any park accessible within 400m (Yes/No)
- Local park (≤0.3ha) accessible within 200m (Yes/No)
- Small neighbourhood park (0.3-0.5ha) accessible within 400m (Yes/No)
- Medium neighbourhood park (0.5-1.5ha) accessible within 400m (Yes/No)
- Large neighbourhood park (1.5-2.5ha) accessible within 400m (Yes/No)
- District park (2.5-4ha) accessible within 600m-1km (Yes/No)
- Regional park (≥4ha) accessible within 2.5km (Yes/No)

Park surveillance and safety
- Park perimeter frontage ratio = % of the park perimeter bordered by lots facing the park
- Park perimeter roads ratio = % of the park perimeter bordered by adjacent roads

\[1 \text{ Distance computed along the road network from all residential dwelling points (n=31,102) to the nearest centre, bus stop, train station, primary school and parks. For each development the mean distance to each of these destinations was computed.} \]
\[2 \text{ Deemed accessible if ≥10% of the dwellings within a development had access to a centre within the specified distance.} \]

*This is an abridged version of a Table previously published by the authors (Hooper et al., 2014)*
Table 2  Odds ratios (OR) of LN requirements significantly associated with walking outcomes in the multivariate models (n=664)†

<table>
<thead>
<tr>
<th>Liveable Neighbourhoods</th>
<th>Walking for transport</th>
<th>Walking for recreation</th>
<th>Total walking</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy Requirement</td>
<td>Any</td>
<td>≥60 mins</td>
<td>Any</td>
<td>≥60 mins</td>
</tr>
<tr>
<td>Community Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configuration of neighbourhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>centre ≤1600m*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Big Box</td>
<td>1.38</td>
<td>(0.82-2.31)</td>
<td>1.68</td>
<td>(1.12-2.36)</td>
</tr>
<tr>
<td>Main St</td>
<td>2.10</td>
<td>(1.38-3.16)</td>
<td>1.70</td>
<td>(1.05-2.68)</td>
</tr>
<tr>
<td>Destination diversity of centre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for every additional destination type present]</td>
<td>1.22</td>
<td>(1.01-1.49)</td>
<td>1.36</td>
<td>(1.11-1.68)</td>
</tr>
<tr>
<td>Primary School ≤400m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR vs. reference group no school ≤400m]</td>
<td>0.55</td>
<td>(0.35-0.86)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movement Network</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block density*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in block density = no. of blocks per ha]</td>
<td>6.83</td>
<td>(3.6-13.1)</td>
<td>5.14</td>
<td>(1.99-13.2)</td>
</tr>
<tr>
<td>Walkable block ratio*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in walkable block density]</td>
<td>2.40</td>
<td>(1.09-5.26)</td>
<td>0.64</td>
<td>(0.47-0.86)</td>
</tr>
<tr>
<td>Cul-de-sacs Link Ratio ≥50%*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR vs. reference group &lt;50% cul-de-sacs Link Ratio]</td>
<td>1.35</td>
<td>(1.06-1.73)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of external access points*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in number of access points]</td>
<td>1.02</td>
<td>(1.01-1.03)</td>
<td>1.02</td>
<td>(1.00-1.02)</td>
</tr>
<tr>
<td>Length of footpaths (km) *</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in length of footpaths]</td>
<td>0.97</td>
<td>(1.01-1.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sidewalk : road ratio*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in sidewalk : road ratio]</td>
<td>1.04</td>
<td>(1.03-1.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree density along footpaths*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in number of trees per km of footpath]</td>
<td>1.04</td>
<td>(1.01-1.09)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lot Layout</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% residential land area occupied by small lots (≤350m²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in % residential land area]</td>
<td>1.04</td>
<td>(1.01-1.09)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public Parkland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium neighbourhood park (&gt;0.5 to ≤1.5ha) ≤400m*</td>
<td>1.09</td>
<td>(1.05-1.12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR Yes vs. reference group no park ≤400m]</td>
<td>1.08</td>
<td>(1.03-1.13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of parks*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in number of parks present within the development]</td>
<td>3.97</td>
<td>(2.46-6.41)</td>
<td>1.99</td>
<td>(1.83-2.17)</td>
</tr>
<tr>
<td>Regional park (≥4ha) ≤2.5km*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR Yes vs. reference group no regional park ≤2.5km]</td>
<td>1.13</td>
<td>(1.02-1.25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of small neighbourhood parks (&gt;0.3 to ≤0.5ha) *</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in number of parks present within the development]</td>
<td>1.17</td>
<td>(1.06-1.28)</td>
<td>1.09</td>
<td>(1.06-1.13)</td>
</tr>
<tr>
<td>Number of medium neighbourhood parks (&gt;0.5 to ≤1.5ha) *</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in number of parks present within the development]</td>
<td>1.26</td>
<td>(1.18-1.34)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of parks with sports surfaces, marking or equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OR for 1 unit increase in number of parks present]</td>
<td>1.09</td>
<td>(1.05-1.12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Policy requirements that were included in the interaction analyses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3

Results of multivariate models showing adjusted interactions between requirements of the community design, movement network and lot layout elements and associations with doing ≥60 minutes of total, transport and recreation walking within the neighbourhood in a usual week and meeting recommended levels of total walking (≥150 minutes) in a usual week.

<table>
<thead>
<tr>
<th>Liveable Neighbourhoods Requirements</th>
<th>≥ 60 minutes of walking for transport per week</th>
<th>≥ 60 minutes of walking for recreation per week</th>
<th>≥ 60 minutes of total walking per week</th>
<th>≥ 150 minutes of total walking per week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR 95% CI  p value</td>
<td>OR 95% CI  p value</td>
<td>OR 95% CI  p value</td>
<td>OR 95% CI  p value</td>
</tr>
<tr>
<td>Configuration of neighbourhood centre within 1600m × movement network requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Interaction Term</td>
<td>0.677 0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>No centre × connected node ratio (Low)</td>
<td>1.00 1.00</td>
<td>1.00 1.00</td>
<td>1.00 1.00</td>
</tr>
<tr>
<td></td>
<td>No centre × Connect. Node Ratio (High)</td>
<td>1.98 0.65-6.04 0.232</td>
<td>9.96 2.83-35.07 0.000</td>
<td>29.83 5.65-157.65 0.000</td>
</tr>
<tr>
<td>Big Box (Yes) × Connect. Node Ratio (Low)</td>
<td>5.77 2.49-13.37 0.000</td>
<td>6.29 1.86-21.33 0.003</td>
<td>21.46 4.16-110.86 0.000</td>
<td>3.23 1.22-8.59 0.019</td>
</tr>
<tr>
<td>Big Box (Yes) × Connect. Node Ratio (High)</td>
<td>6.49 1.87-22.53 0.003</td>
<td>9.12 2.67-31.21 0.003</td>
<td>36.37 6.95-190.43 0.000</td>
<td>5.07 1.85-13.90 0.002</td>
</tr>
<tr>
<td>Main St. (Yes) × Connect. Node Ratio (Low)</td>
<td>7.73 3.33-17.95 0.000</td>
<td>15.94 4.71-53.95 0.000</td>
<td>50.46 9.87-257.98 0.000</td>
<td>4.62 1.76-12.18 0.002</td>
</tr>
<tr>
<td>Main St. (Yes) × Connect. Node Ratio (High)</td>
<td>9.59 4.21-21.82 0.000</td>
<td>20.42 5.89-70.77 0.000</td>
<td>69.40 13.33-361.42 0.000</td>
<td>6.03 2.18-16.65 0.001</td>
</tr>
<tr>
<td>Configuration Of Centre 1600m (No centre/Main Street/Big Box) × Cul-De-Sac Street Percentage (High/Low)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Interaction Term</td>
<td>0.551 0.002</td>
<td>0.000</td>
<td>0.000</td>
<td>0.074</td>
</tr>
<tr>
<td></td>
<td>No centre × High cul-de-sacs st. % (Bad)</td>
<td>2.14 0.71-6.43 0.174</td>
<td>9.18 2.43-34.77 0.001</td>
<td>29.27 5.03-170.38 0.000</td>
</tr>
<tr>
<td></td>
<td>No centre × Low cul-de-sacs st. % (Good)</td>
<td>2.14 0.71-6.43 0.174</td>
<td>9.18 2.43-34.77 0.001</td>
<td>29.27 5.03-170.38 0.000</td>
</tr>
<tr>
<td>Big Box (Yes) × High cul-de-sacs st. % (Bad)</td>
<td>5.58 2.36-13.17 0.000</td>
<td>6.76 1.84-24.81 0.004</td>
<td>24.21 4.23-138.66 0.000</td>
<td>3.50 1.25-9.84 0.035</td>
</tr>
<tr>
<td>Big Box (Yes) × low cul-de-sacs st. % (Good)</td>
<td>7.60 2.38-24.21 0.001</td>
<td>6.53 1.69-25.27 0.007</td>
<td>27.34 4.43-168.85 0.000</td>
<td>4.16 1.25-13.90 0.021</td>
</tr>
<tr>
<td>Main St. (Yes) × High cul-de-sacs st. % (Bad)</td>
<td>8.58 3.81-19.36 0.000</td>
<td>14.85 4.03-54.67 0.000</td>
<td>49.20 8.71-277.82 0.000</td>
<td>4.37 1.54-12.39 0.006</td>
</tr>
<tr>
<td>Main St. (Yes) × low cul-de-sacs st. % (Good)</td>
<td>10.25 4.42-23.79 0.000</td>
<td>18.56 4.92-70.00 0.000</td>
<td>67.12 11.44-393.8 0.000</td>
<td>4.79 1.62-14.16 0.005</td>
</tr>
</tbody>
</table>
### Liveable Neighbourhoods Requirements

- **≥ 60 minutes of walking for transport per week**
- **≥ 60 minutes of walking for recreation per week**
- **≥ 60 minutes of total walking per week**
- **≥ 150 minutes of total walking per week**

<table>
<thead>
<tr>
<th>OR</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>1.25</td>
<td>0.33-4.79</td>
<td>0.001</td>
</tr>
<tr>
<td>4.01</td>
<td>1.21-13.56</td>
<td>0.001</td>
</tr>
<tr>
<td>4.47</td>
<td>1.81-11.04</td>
<td>0.001</td>
</tr>
<tr>
<td>6.19</td>
<td>2.45-15.65</td>
<td>0.000</td>
</tr>
<tr>
<td>16.23</td>
<td>0.64-131.23</td>
<td>0.001</td>
</tr>
</tbody>
</table>

### Configuration Of Centre 1600m (Main Street/Big Box) × Sidewalk : Road Ratio (High/Low)

<table>
<thead>
<tr>
<th>OR</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>1.25</td>
<td>0.33-4.79</td>
<td>0.001</td>
</tr>
<tr>
<td>4.01</td>
<td>1.21-13.56</td>
<td>0.001</td>
</tr>
<tr>
<td>4.47</td>
<td>1.81-11.04</td>
<td>0.001</td>
</tr>
<tr>
<td>6.19</td>
<td>2.45-15.65</td>
<td>0.000</td>
</tr>
<tr>
<td>16.23</td>
<td>0.64-131.23</td>
<td>0.001</td>
</tr>
</tbody>
</table>

### Public Parkland × Movement Network Requirements

#### Footpath : road ratio (High/Low) × Number of Park within the Development (High/Low)

<table>
<thead>
<tr>
<th>OR</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.97</td>
<td>0.54-1.74</td>
<td>0.022</td>
</tr>
<tr>
<td>2.28</td>
<td>1.54-3.39</td>
<td>0.097</td>
</tr>
<tr>
<td>1.97</td>
<td>0.91-4.27</td>
<td>0.232</td>
</tr>
</tbody>
</table>

#### Access to a large/regional park (>4ha) within 2.5km (Yes/No) × footpath to road ratio (high/low)

<table>
<thead>
<tr>
<th>OR</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.27</td>
<td>0.10-0.73</td>
<td>0.000</td>
</tr>
<tr>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>2.46</td>
<td>1.40-4.32</td>
<td>0.000</td>
</tr>
<tr>
<td>2.42</td>
<td>1.47-3.97</td>
<td>0.000</td>
</tr>
</tbody>
</table>

1 Adjusted for demographic characteristics (age; gender; education; children ≤18 years and under living at home) and self-selection factors as well as the stage of construction and scale of development; Reference group; Bold denotes p<0.05; OR = odds ratio; 95%CI = 95% confidence intervals
Figure 1  The building blocks of a Liveable Neighbourhood: Key policy requirements from the community design (CD), movement network (MN), lot layout (LL) and public parkland (PP) elements for walking.
Author/s:
Hooper, P; Knuiman, M; Foster, S; Giles-Corti, B

Title:
The building blocks of a 'Liveable Neighbourhood': Identifying the key performance indicators for walking of an operational planning policy in Perth, Western Australia

Date:
2015-11-01

Citation:

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http://hdl.handle.net/11343/115350