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Built environment and children's travel to school

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ABSTRACT

The decline in children's active travel has significant implications for urban planning and sustainable mobility. This research explores the influence of built environment on children's travel to school across a range of typical urban environments in Australia. The analysis draws on a sample of children and their parents from nine primary schools across four urban regions: Brisbane, Melbourne, Perth and Rockhampton. The built environment features for each school neighbourhood are measured. An analysis of travel, socio-demographics and attitudes to travel is conducted. The findings indicate that children residing in built environments that are more dense and urban are significantly associated with more active travel to school and for other journey purposes. Distance to school is critical for active travel (AT) and many children lived beyond walking distance. While built environment is important, a decisive role for children's active travel to school and other places is seen in the combination of preferences and licences. Children who AT prefer to be more autonomous/independent travellers and have parents who foster their IM; conversely, children's preferences for being driven coincides with parents' fears for IM and lack of confidence in their children abilities to travel independently.

1. Introduction

Consistent with other countries in the developed world there has been a decline in the number of Australian children travelling by active modes (walking and cycling) to school and an increase in the numbers being driven to school (Van der Ploeg et al., 2008). This decline in active travel (AT) has been accompanied by a decline in the independent mobility (IM) of children. Along with a wide range of concerns, including health, social connectedness, and wellbeing, the reduction of AT has significant implications for sustainable mobility and urban planning policy.

There is now a wealth of empirical research emanating from North America associating the physical design and form of built environments with the travel behaviour outcomes of adults (see for example Rodriguez and Joo, 2004; Ewing and Cervero, 2002; Crane, 2000). The PLACE study (Cerin et al., 2007; University of Queensland Cancer Prevention Research Centre, 2005) and the RESIDE study (Giles-Corti et al., 2008) add Australian evidence to this research. Tempering the notion that built environment alone affects travel behaviour are a wealth of studies that demonstrate the contribution of socio-economic factors and attitudes to travel outcomes (Schwanen and Mokhtarian, 2005; Mokhtarian and Cao, 2008; De Vos et al., 2014).

The extent to which the design and form of built environments influences children's travel, as opposed to adult's travel, is under-researched (Van Goeverden and De Boer, 2013). That children's mobility is influenced by adults is not in question. Parental fears of ‘stranger danger’ and traffic safety are strong determinants of parent's restrictions of children's travel (Mackett, 2013). It is not enough, however, to simply assume children's attitudes and behaviours will mirror those for adults. Where children do get to travel independently their travel choices may not simply be determined by time or cost, the design of the built environment may have an influence. Of the limited evidence available, relationships have been observed between the absence of footpaths, presence of busy streets, long distances to schools and other destinations and children's travel (Sallis and Glanz, 2006, Panter et al., 2008).

Since the early 1990s there has been a key shift in town planning practise throughout the developed world. The rise of Smart Growth or New Urbanist policies (Congress for New Urbanism, 2001; Morris and Kaufman, 1998; Katz, 1994) together with sustainable mobility initiatives, across North America, the UK, Europe and Australasia, calls for a shift to higher densities, mixed land uses and replacing mobility with proximity to enhance accessibility by walking, cycling and public transport. Still, empirical evidence supporting ways in which this objective is achieved for

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various population groups is modest. In Australia, at least, there is a lack of evidence as to the role of varying physical built environments on children's travel. The purpose of this paper is to examine this question by looking at the range of factors that shape children's journey to school across four broad urban regions in Australia – inner urban, middle suburb, outer urban, and a regional country town.

2. Background: children's active travel, independent mobility and the built environment

For children, walking and cycling to and from school is important for a number of reasons. The routine nature of the journey to and from school provides potential benefits to children's health and wellbeing, contributing to the volume of children's everyday physical activity (Mackett and Paskins, 2008; Faulkner et al., 2009), affording them skills for independent travel (Tranter and Pawson, 2001), and providing opportunities for them to interact and engage with their natural and built local environments (Fusco et al., 2012). Despite the increasing recognition of benefits, however, studies are reporting a decline in the rates that children are participating in AT to school in many developed countries (see Fyhri et al., 2011 for Denmark, Finland, Great Britain and Norway; Buliung et al., 2009 for Canada; Peddie and Somerville, 2006 for Australia; Boarnet et al., 2005 for United States). Looking specifically at cycling, the reported decline in rates of travel to school is dramatic despite reported high bicycle ownership rates (Christie et al., 2011).

An important factor in determining children's AT is the *licence* to travel which parents provide children. Hillman et al. (1990) defined four licences children acquire in gaining their own independent mobility (IM): the licence to walk from school; cross roads; ride a bicycle; and catch public transport. The restrictions on children's licences are becoming stricter due to the increased concerns regarding the risk to children's safety in the public realm (Rudner, 2012). The licences to IM vary between children (O'Brien et al., 2000). The age of 10–11 years appears to delineate the transition between non-independent and independent mobility, although there are variations by gender, travel mode and journey purpose. Brown et al. (2008) reporting a UK study found a marked increase in IM when children reached 11 years of age, yet these licences were stricter for girls, particularly with regard to cycling. Zwerts et al. (2010) reporting a Belgian study of 10–13 year olds found that boys travelled more often than girls and a greater proportion of boys were independent travellers or IM. This transition point is not static, studies in the UK have shown a decline in the percentage of 10 and 11 year olds with IM from a reported 94% in 1970, 54% in 1990 and 47% in 1998 (Hillman, 1970; Hillman et al., 1990; O'Brien et al., 2000). Other studies (such as Fyhri and Hjorthol, 2009, in Norway) do not specify ages where major transitions occur; rather they note that age is an important influence on the level of independence.

The quality of the built environment around home and schools plays an important role in influencing children's rates of travel to school. Distance to school is one of the most consistently reported factors associated with children's active travel rates to school, with children more likely to walk or cycle to school the closer they live to the school (for example, Schlossberg et al., 2006 in Oregon, U.S.; Cole et al., 2007 in South East Queensland; McDonald, 2007 in a national U.S. study; and Ziviani et al., 2006 in Brisbane, Australia). Some researchers suggest that physical built environment elements influence children's IM, such as traffic calming on streets; safe paths and routes to school; secure end-of-trip facilities at schools; and monitored road crossings (Mackett, 2013; Johansson, 2006; Carver et al., 2005). Other scholars assert that perceptions of safety are more influential (Fyhri and Hjorthol, 2009).

For policy makers, an evidence base is emerging regarding the built environment factors that shape decision-making and behaviour related to active modes of travel within adults. The potential built environment factors at play include functional aspects such as: the distance between places; street design and geometry; the connectivity of streets; path infrastructure, aesthetic qualities; safety; the mix of land uses; and the proximity and quality of destinations (Olaru and Curtis, 2015; Saelens and Handy, 2008; Pikora et al., 2003; Bagley and Mokhtarian, 2002; Crane, 2000; Kitamura et al., 1997; Cervero and Radisch, 1996). The relationship is likely more nuanced – moderated by journey purpose-for example, in a study in Adelaide, Owen et al. (2007) found that street connectivity was associated with walking for transport, but not for recreation, indicating that built environment factors are associated with different types of walking activities in different ways. A children's perspective may add a further dimension given they may not see even a utilitarian journey as just that; they may add a creative dimension to their journey. The provision of good physical infrastructure has been posited as a means of addressing such factors as gender inequities in travel to school (McDonald, 2012).

In addition to built environment factors, other socio-economic and attitudinal factors play a role in determining whether children are permitted to AT. At the household scale, the scheduling of activities and parent's travel to work (McMillan, 2005; McDonald, 2008; Yarlagadda and Srinivasan, 2008; Copperman and Bhat, 2010; Lang et al., 2011) is influential in shaping children's likelihood of walking or cycling to school. McDonald (2008) found in the US that child's travel mode to school was significantly associated with their mother's commute to work. In New Zealand, Lang et al. (2011) asserted that parents may choose to drive their children to school, even when residing in close proximity to school, due to the perceived convenience of car travel. Attitudes and preferences of parents in Austin, Texas with regard to their children's travel activity were influential on whether their children walked to school (Lee et al., 2013). Furthermore, parents who walked their children to school had more positive perceptions of the walkability of the built environment than those who drove their children to school McMillan et al., 2007; Panter et al., 2010a, 2010b; Trapp et al., 2011). Research has found that there are important differences between the factors influencing adults' and children's travel (McMillan, 2007; Mitra, 2012). For example a study from Belgium reported that parents' perceptions of land use mix are more influential on active travel than children's perceptions (De Meester et al., 2014). Social norms, the cultural aspects of walking (Mitra et al., 2010; Panter et al., 2010a, 2010b), and economic contexts (Valentine, 2004; Mitchell et al., 2007; McMillan et al., 2006; Mitra et al., 2010), as well as the presence of social support for active travel (Sallis et al., 2008) also play a major role in shaping children's daily travel activity. However, as Kerr et al.'s (2007) research from Atlanta, US, has shown, despite ethnic and socio-economic differences between households and neighbourhoods, built environment factors remain significantly associated with children walking to school.

Policy responses to concerns about declining rates of children's AT to school have seen the emergence of a range of initiatives. Responses such as the introduction of walking school buses have been popular and can have an influence on rates of active travel to school, but they have been criticised due to their resource intensity and tendency to be present mainly in higher socio-economic areas (Collins and Kearns, 2005). Alternatively, policies targeted towards building social trust and community connectedness, as well as the safety of neighbourhoods, could increase children's AT to school (Carver et al., 2013). Behavioural and education programmes (community walking bus and road crossing agents, walking and cycling days, co-curricular physical activities in the neighbourhood are likely to increase self-efficacy of children as AT's) can be integrated into all schools, with programmes adapted to school needs. The impact of policy change outside the transport domain can have adverse consequences for children's AT to school. The movement towards 'choice' policy in educational markets has provided greater freedom for parents to select schools in which to enrol their children, instead of simply attending the closest school. Greater choice can lead to an increased need to access schools outside feasible walking and cycling distances for children (Wilson et al., 2007). The rationalisation and merging of schools, in response to the relaxing of local enrolment policies and changing demographics, can lead to erosion in social cohesion and community identity (Witten et al., 2001). This can impact on parental attitudes where parents become less willing to allow their children IM.

It is clear from the above literature that both built environment and socio-demographic and attitudinal factors influence children's active travel. There is an increasing body of research in this respect (the reader is directed to the comprehensive review provided by Mitra, 2012), but very little is drawn from Australian cases. Notwithstanding this, two important questions remain for planners and policy-makers developing policy for increasing children's rates of active travel to school: (1) What aspects of the built environment are critical in facilitating children's active travel? (2) Are there any other moderators of children's independent mobility that policy making can influence/action upon?

3. Research design

3.1. Overview

This paper reports on an analysis of children, parents and built environment elements based in nine school neighbourhoods from varying urban environments. The purpose of this paper is to assess to what extent built environment matters to children's AT to and from school, compared to the attitudes of children and their parents towards active mobility.

A socio-ecological approach is used to address the two objectives (what policy approaches would be influential and what built environment factors could increase children's AT to school) and interpret findings. Conceptual frameworks have been developed by Panter et al. (2008) and Mitra (2012). These frameworks situate decision-making as nested within household, neighbourhood, institutional and broader socio-political domains (Fig. 1).

Drawing on McLaren and Hawe (2005), this research adopts a multi-level approach to IM and children's school travel activity, starting with the individual level characteristics to the social-political context. Age, gender and attitudes of children are important factors in how children prefer to go to school. Household factors include children's licence to travel (negotiation between parents and children) and social norms and values. It is the interplay between these two levels and within the context of neighbourhood, that also affects children's travel. For policy makers it is important to understand these multi-scale influences and how they are influenced by policy actions directed towards children's mobility.

3.2. Sample

Children aged 9–13, and their parents, were recruited from nine primary schools in three Australian cities – Brisbane (QLD), Melbourne (VIC) and Perth (WA) – and one regional centre – Rockhampton (QLD) (Fig. 2). This is the age range where children begin to transition to IM (see discussion above). Most schools are located in the metropolitan area of one of the three State capitals; three schools are located in the regional centre of Rockhampton. Rockhampton is akin to a country town, with a current population of 115,419 (ABS, 2012), functioning as an important service provider for economic activity in the broader region.

The schools were selected to represent a range of built environment types based on their location in the urban region: inner urban, middle suburb, outer urban and regional areas. In order to control for the impact of socio-demographic factors on travel, the Australian government Index of Community Socio-Education Advantage (ICSEA) was used to select schools. This index groups schools of similar socio-economic circumstance. Selection was restricted to those falling in the in the middle range of the index (with values between 900 and 1100) to avoid the extreme 10% lowest and highest schools. While it was anticipated that the majority of children attending the school would reside in the neighbourhood, education policy varied. WA required students to attend their closest school, VIC allowed more flexibility in the enrolment catchment, QLD had a policy of unrestricted choice.

Questionnaires were completed by the children during class and a separate questionnaire was provided for their parents to complete. Ethics approvals were granted by each State Department of Education and University. A condition of the approval was that school names not be reported.

3.3. Analytic technique

Although not new to travel behaviour (Oppenheim, 1975; Neale and Hutchinson, 1981), cluster analysis has increasingly been applied in transport in the last decade, primarily for "classifying" locations (e.g., Kamruzzamann et al., 2014, proposed a typology of neighbourhoods based on density and accessibility features) or for contrasting behaviours and attitudes (Anable, 2005, identified travel segments using attitudes and Lin et al., 2009, distinguished

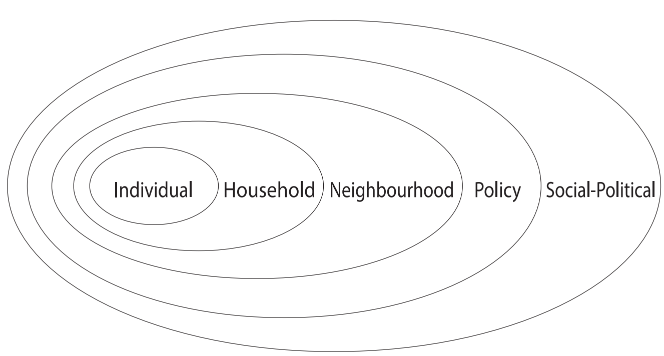

Fig. 1. Socio-ecological model.
Adapted from McLaren and Hawe (2005).

Fig. 2. Location (suburbs) of the nine school sites across Australia.

lifestyle categories based on socio-demographics and activity-travel data). Following the same line of enquiry, this research creates typologies of children and parents to explore children's travel to school and the perceived barriers in using AT and compares them with typologies of school neighbourhoods, based on their built-environment characteristics.

Cluster analysis is a multivariate technique applied to group objects based on their similarity within a set of user-selected characteristics. Here, the three separate cluster analyses (children, parents and the built environments around schools) were conducted in two steps: (1) first, a hierarchical clustering using Euclidean distances and the Ward method; and then (2) a quick-clustering using seeds from the first stage was refining the clusters' structure. In a successful analysis, clusters represent groups that are homogeneous/similar in their set of characteristics and quite different from the other clusters. Variables used in clustering were derived from the literature and explained below. To account for their different scales, standardisation was applied prior to calculating the dissimilarity measures. Different solutions (2–4 clusters) were compared based on their measures of heterogeneity, their interpretability, and size of the clusters. The solutions presented in Section 4 were tested for their validity using multivariate analysis of variance (MANOVA) and cross-tabulations. Variables not included in the cluster analysis, but for which it was expected there would be variation across the clusters, were also interrogated in this final stage of analysis.

4. Empirical setting

4.1. Built environment characteristics of school neighbourhoods

Nine items, found in prior scholarly work as influential for AT (Ewing and Cervero, 2002; Giles-Corti et al., 2011; McMillan, 2005; McDonald, 2008; Panter et al., 2008; Mitra, 2012; Schlossberg et al., 2006), were selected to assess the built environment features of each school neighbourhood (Table 1).

Each of the variables was based on commonly used built environment measures identified in the literature and in some cases applied by planning practitioners in designing or assessing new development. The 400 m and 800 m ped-shed were calculated as the developed area within 400 m or 800 m street network distance from the school – the higher the ratio, the larger the developed urban area within a 400 m or 800 m walkable distance to the school. The 400 m and 800 m street connectivity ratio was calculated by dividing the number of intersections of 3 or more segments, by the total number of segments within the catchment (determined by 400 m or 800 m Euclidean distance from school)- the higher the ratio, the greater the street connectivity and so the more permeable the area so likely to reduce potential walking or cycling distances. Following Slater et al. (2010), density measures were also applied as proxies for land-use mix. Population density was measured by total number of persons divided by total ha within an 800 m (Euclidean) distance from school (population numbers were those reported in the Australian Bureau for Statistics 2011 Census), while the residential density was measured by total number of dwellings divided by total area in ha within an

Table 1
Built environment measures.

Built environment variable	Measure
Distance to CBD	Euclidean distance (kilometres) from school to nearest CBD
Ped-shed[a] ratio	Ratio of residential area within 400 m and 800 m catchment
Street connectivity ratio	Number of three and four street intersections/number of street segments within 400 m and 800 m catchment
Population density	Number of persons/ha within 800 m catchment of the school
Dwelling density	Number of dwellings/ha within 800 m catchment
Presence of railway	Presence of a railway within an 800 m catchment
Presence of major road	Presence of a major road within an 800 m catchment

[a] A Ped-shed is a term used to describe the potential walking catchment of the school. Contours are drawn at 400 m and 800 m from the school centroid by measuring precisely along footpaths. The distances selected are assumed to equate to a 5 and 10-min walk respectively for an able bodied person.

Table 2
Built environment characteristics.

Site #	BE type	Distance from CBD (km)	400 m Ped-shed	800 m ped-shed	400 m Street connectivity	800 m Street connectivity	Population density-persons/ha (800 m catchment)	Dwelling density-dwellings/ ha (800 m catchment)	Railway	Major road
1	Outer suburb (QLD)	25	0.431	0.578	0.66	0.76	26.65	7.62	n	y
2	Middle suburb (QLD)	5.5	0.665	0.629	0.54	0.56	35.4	17.8	n	y
3	Outer suburb (QLD)	16.5	0.154	0.085	0.33	0.50	0.64	0.22	n	n
4	Inner urban (VIC)	5.5	0.482	0.411	0.58	0.58	33.54	15.75	n	y
5	Middle suburb (VIC)	13	0.364	0.389	0.50	0.57	18.85	7.21	y	n
6	Inner Urban (WA)	5.5	0.763	0.608	0.53	0.6	20.83	9.5	n	y
7	Regional (QLD)	4	0.477	0.374	0.63	0.53	14.26	5.61	n	n
8	Regional (QLD)	3	0.527	0.533	0.60	0.63	15.16	7.32	y	y
9	Regional (QLD)	2	0.307	0.233	0.62	0.46	8.25	3.32	n	n

800 m (Euclidean) distance from school. The choice of 400 and 800 m buffers around the schools was based on the literature suggesting that 400 m represented a child's five minute walk distance (Mitra et al., 2010) and 800 m represented a ten minute walk distance (Panter et al., 2010a, 2010b). Distance to the CBD provides an indicator for parent's journey-to-work (since Australian cities retain a dominant mono-centric form) in relation to 'time budgets' and the likelihood of using the car, which in turn impacts on children's journey to school (for further discussion see Burke et al., 2013).

As per sample design, the nine school neighbourhoods display significant variation in built environment features (Table 2). The wide ranges confirm distinct differences in the extent that the neighbourhood would be conducive to AT: population density (from 35.4 to 0.64 persons/ha), dwelling density (from 15.75 to 0.22 dwellings/ha), distance from the central business district (CBD) (from 25 km to 2 km), 400 m ped-shed (from 76% in a 5-min walk to school to 15%), 800 m ped-shed (from 63% in a 10-min walk to school to 8%), two sites were severed by a railway and five sites had a major road running through the neighbourhood.

These profiles are further supported by the street and lot layouts and pedestrian catchment areas, presented in Fig. 3. Site 1 (Springfield) is in a master planned community on the urban fringe, but part of a planned satellite city in the South East Queensland metropolitan region. The suburban layout follows the New Urbanist principles with roads following a modified grid design where a hierarchical street system is in place. Site 2 (Greenslopes), located in middle suburban area has a high residential density, grid pattern streets and high connectivity. The school is located on a main road. Site 3 (Rochedale) is a new suburb, large parts of which are still under construction, located on the urban fringe, 17 km from the CBD. It has primarily large rural lots, with pockets of urbanised residential lots. The school will service a predominantly urbanised area, but at present there is very little developed land within the 800 m pedestrian catchment. Site 4 (East Brunswick) is an inner city suburb, characterised by high residential density, mixed land use, reasonably well connected streets but with long blocks and alley connectors to improve permeability. Site 5 (Glenroy) is a middle suburb of medium residential density. The street system follows a grid layout. There are few main roads within the 800 m pedestrian catchment, but part of the residential catchment is separated by a railway line. Site 6 (Melville) is an inner-urban suburb located 11 km from the Perth CBD and 5.5 km from a large secondary city in the Perth metropolitan region. The street system follows a grid layout. The neighbourhood is bordered by two regionally significant highways, one that links the City of Fremantle to the City of Perth, and the other that serves as an important regional freight distributor between the airport and port. The three remaining sites (7. Mt Archer, 8. Allenstown, and 9. Taranbanga) are part of large regional centre. Sites 7 and 8 have a grid street system, site 9 a curvilinear street system and residential densities are low.

4.2. Sample characteristics

A total of 1534 children from classes where the predominant age was between 10 and 13 were invited to participate in the study. From this 375 children were recruited with an average response rate of 24% (Table 3). During the course of the research, eight of these children dropped out of the study and after data validation the number of children further reduced to 273.[1]

[1] Both child and parent surveys needed to be complete for inclusion in this analysis, where they could not be matched this reduced the sample size to 257 valid cases. Sixteen cases were added using imputed values for 'distance to school' increasing the valid cases to 273. The imputed values were used for children who

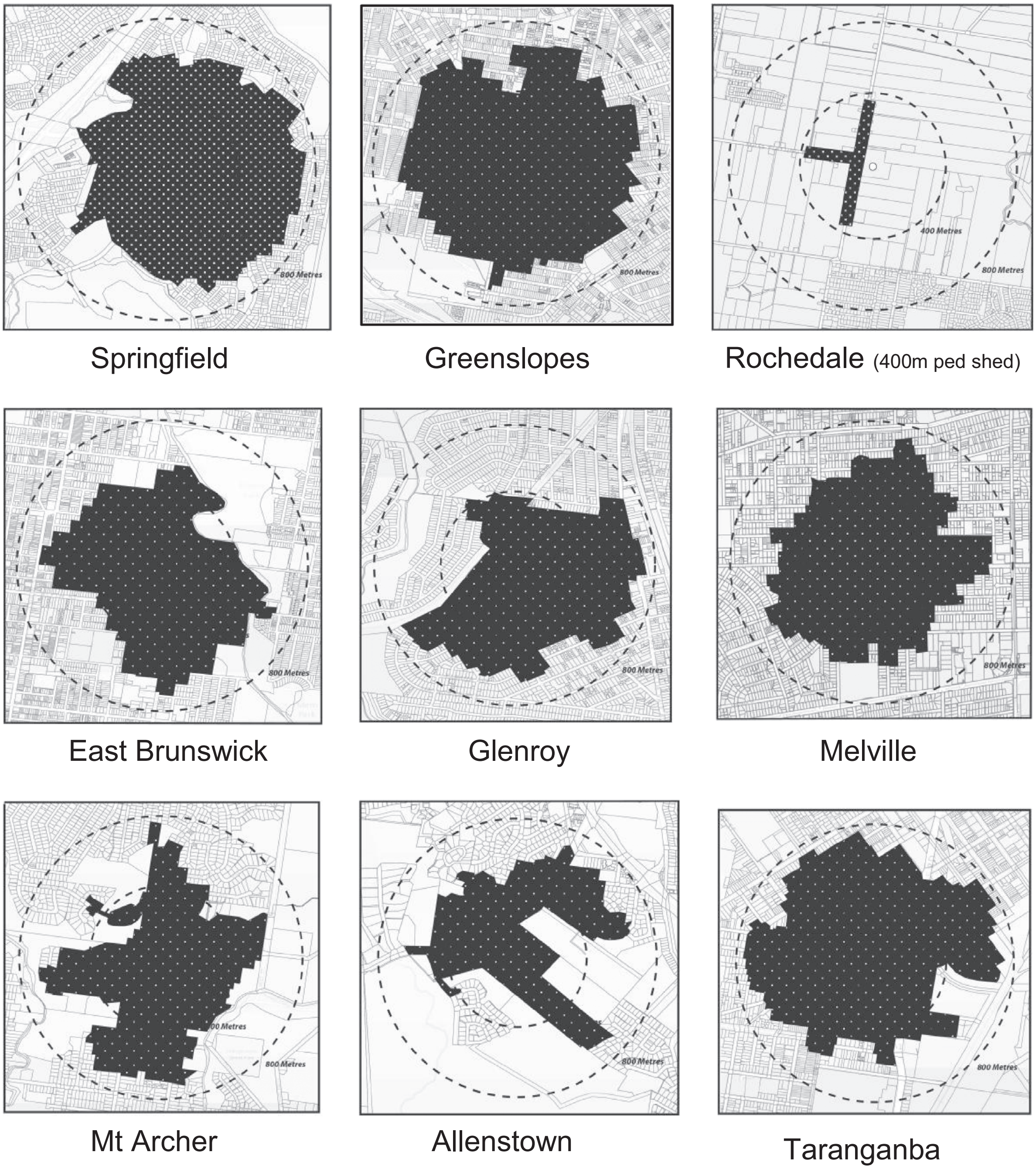

Fig. 3. 800 m Pedestrian catchments for the nine sites.

Table 3
Recruitment of children.

School	No. of children			Response rate (*n*/%)
	Invited	Recruited	Dropped out	
1 S	162	57	0	57/35
2 G	100	38	0	38/38
3 R	160	70	0	70/44
4 EB	104	32	0	32/31
5 G	111	48	2	46/41
6 P	172	52	0	52/30
7 MA	266	20	1	19/7
8 A	151	29	3	26/17
9 T	308	29	2	27/9
TOTAL	1534	375	8	367/24

Descriptive statistics of the sample are provided in Table 4. Out of the 273 children, 70.7% are children between 10 and 11 years of age, and 64.8% are girls. Depending on the geographical setting, children have shorter or longer distances to school (distance range = 3.4 km; std. dev. = 1.44 km), and different modes to travel to and from school. Two of the sites, located in Melbourne (Glenroy and East Brunswick), have a much higher proportion of children using AT modes to school than the other sites.[2] As shown

(*footnote continued*)
had reported street name only and their street was less than 500 m in length. In these cases we took the street centroid as their place of residence. For streets greater than 500 m we assumed the error associated with using the street centroid was too great and these were omitted.

[2] Children who reported that they usually walked or cycled to school were identified as active travellers. Children who reported they usually were driven or

Table 4
Sample characteristics.

School	1	2	3	4	5	6	7	8	9	Total
N	48	18	36	21	36	49	16	26	23	273
Ages										
< 10	0	0	0	5	7	27	0	0	0	39
10	20	9	13	12	8	15	7	7	12	103
11	24	6	16	3	9	6	5	11	10	90
12+	4	3	7	1	12	1	4	8	1	41
Gender										
Boy	18	6	7	12	15	18	4	9	7	96
Girl	30	12	29	9	21	31	12	17	16	177
Distance to school (km)										
Mean	1.90	1.68	4.60	1.69	1.86	1.31	3.48	4.47	4.71	2.85
% AT to school	40	39	17	76	72	41	44	15	39	42

Table 5
Profile of school clusters.

Variable	Cluster centres		*F*	Significance level *p*
	1	**2**		
Distance to CBD (km)	6.38	10.90	0.742	0.418
400 m Ped-shed ratio	0.37	0.54	2.396	0.166
800 m Ped-shed ratio	**0.31**	**0.52**	**4.503**	**0.072**
400 m Street connectivity ratio	0.55	0.56	0.137	0.722
800 m Street connectivity ratio	0.56	0.61	1.250	0.300
Population density (per ha)	**9.58**	**27.05**	**13.472**	**0.008**
Dwelling density (per ha)	**4.12**	**10.92**	**7.526**	**0.029**
Presence of railway	0.75	0.80	0.025	0.879
Presence of major road	0.75	0.20	3.036	0.125

further in Section 4.3, this may be due to a combination of higher proportion of boys (50%) with a higher population density (24.77 persons/ha) and further distance from the major road (1.6 km). Although the pedshed ratios are lower (0.41 and 0.40 respectively), the street connectivity ratios are lower too (0.53 and 0.57), which may be perceived as safer from the viewpoint of the exposure to traffic.

4.3. *Cluster analysis findings*

The presentation of the clustering solutions starts with the analysis of the schools, followed by children's travel and circumstances and parent's attitudes.

4.3.1. *Built environment clusters*

The cluster analysis conducted for the nine built environments (BE) included nine variables that describe the neighbourhood type of each of the school sites (Table 1). They referred to: the connectivity of streets and the density of the urban area around the school; key factors that are linked to the walkability of neighbourhoods (Giles-Corti et al., 2009); the presence of a major road or railway within 800 m of the primary school (based on the hypothesis that major roads and railways create potential barriers to children's active travel – Schlossberg et al., 2006); and density, as a proxy for land-use mix (Slater et al., 2010).

Two clusters (profiled in Table 5) emerged out of this analysis. They are significantly different from each other on only three out of the nine characteristics, as indicated by the ANOVA tests (Table 5). F Tests shows that population and dwelling densities contribute the most to the description of clusters, followed by the 800 m ped-shed. This result does not suggest that street connectivity and severance by rail or road are unimportant for children's travel, but rather indicates that the variation across the nine sites examined in this research was limited (e.g., the 400 m connectivity ratio varied only between 0.5 and 0.66). In addition, the result should be interpreted with caution, as it may be an effect of the low sample size. However, the nine schools appear to be located in areas with similar street connectivity or disruption by rail and major roads (the larger the observed significance level the less the variable contributed to the classification of clusters). Cluster 1 BE includes the three schools in the lower density areas of the regional town Rockhampton and the Brisbane outer urban fringe site (Mount Archer; Taranganba; Allenstown; and Rochedale), whereas cluster 2 BE includes the metropolitan suburbs of inner (Brunswick, Melville), middle (Glenroy, Greenslopes) and the outer suburban New Urbanist (Springfield).

When comparing the children living in the two BE clusters by age, gender, and the distance they have to travel to school, we observe that children in cluster 1 are older (10.83 years on average compared to 10.3 years on average for cluster 2), they include fewer boys (28% compared to 42% in cluster 2) and children travel further to school (4.72 km on average compared to 1.81 km on average in cluster 2). We note that a 1.81 km would amount to about a 25 min walk. These differences are statistically significant at 0.05 level.

4.3.2. *Children clusters*

The cluster analysis for children considered their active travel, but also socio-demographic characteristics key in determining their independent mobility:

- Preferred travel mode to school
- Active travel to school
- Active travel to locations other than school
- Year level
- Age
- Gender
- Distance to school

Children's self-reported usual travel to other locations (local shops, parks, friends' houses, organised activities and places outside the neighbourhood area) was also included as an indicator of the child's overall AT. Children who usually travelled (more than half of the time) to other locations by AT were considered active travellers. While school catchment areas may be an outcome of planning or education policy, the decision to include distance to school in children's clusters (rather than BE clusters) was based on the important role that school location plays in households' relocation decisions (as also pointed out by Mitra, 2012). Multiple studies have shown that children living closer to school are more likely to walk or cycle to school as their parents are less concerned with safety issues, more confident in their children abilities to travel alone, and hence more supportive of active travel (Schlossberg et al., 2006; Faulkner et al., 2009; Fyhri and Hjorthol, 2009; Panter et al., 2010a, 2010b; Mitra, 2013; Ziviana et al., 2004). Likewise, girls and younger children (Brown et al., 2008; McDonald, 2008, 2012) are more likely to be accompanied (and most often driven) to activities.

Two clusters (profiled in Table 6) emerged out of this analysis. They are significantly different from each other as confirmed by the parametric and non-parametric tests (all tests statistically significant at 0.05 level). Children in cluster 1 are slightly younger, less likely to be girls, and they are using more AT for all purposes.

(*footnote continued*)
caught public transport were identified as non-active Travellers. However, most non-active travellers at these two sites were driven (94.2%, $n = 16$).

Table 6
Profile of children clusters.

Variable	Level/attribute	Cluster 1 'active traveller'		Cluster 2 'NA traveller'		Total (*n*)	Significance *p* (X^2, likelihood ratio, ANOVA)
		n	% Total	*n*	% Total		
School Year	Year 3	4	100.0	0	0.0	4	
	Year 4	15	62.5	9	37.5	24	
	Year 5	38	40.4	56	59.6	94	
	Year 6	49	44.1	62	55.9	111	
	Year 7	7	17.5	33	82.5	40	
							< 0.001
Age		10.36		10.59		10.49	0.05
Gender	Boy	47	49.0	49	51.0	96	
	Girl	66	37.3	111	62.7	177	
							< 0.001
How would you most like to travel to school?	Walk alone	21	72.4	8	27.6	29	
	Walk with other children	37	39.8	56	60.2	93	
	Walk with an adult	6	60.0	4	40.0	10	
	Public transport alone	2	33.3	4	66.7	6	
	Public transport with other children	6	72.4	9	27.6	15	
	Public transport with an adult	1	40.0%	0	60.0	1	
	Cycle alone	11	100.0	10	0.0	21	
	Cycle with other children	19	52.4	34	47.6	53	
	Cycle with adults	0	35.8	5	64.2	5	
	Be driven	7	0.0	30	100.0	37	
	Scooter / ripstick	3	18.9	0	81.1	3	
							< 0.001
Mode of usual travel to school	Active travel	113	99.1	1	0.9	114	
	Car-based travel	0	0.0	159	100.0	159	
							< 0.001
Mode of usual travel to non-school destinations	High active travel levels (50–100% of non-school trips)	68	53.5	59	46.5	127	
	Low active travel levels (< 50% of non-school trips)	45	30.8	101	69.2	146	
							< 0.001
Distance to school		2.06		5.23		4.05	< 0.001

Remarkably, clusters 1 and 2 separated children perfectly in terms of their active travel to school.

As indicated, by far the most significant variable that defined each of the clusters was whether the child usually walked or cycled to school, or whether they were driven. The almost perfect association between the clusters and the mode of travel to school can be partly explained by the average distance home to school. Children in cluster 1 ('active traveller, AT) live at an average distance of 2.04 km from school, whereas those in cluster 2 ('not-active traveller, NAT) at an almost double distance (3.84 km). This is consistent with findings in UK (Mackett, 2013), where one of the reasons for the shift from walking to car for the journey to school is due to the increasing distance (more than doubling from 1.8 km in 1985/1986 to 3.7 to 5.4 km in 2009). Similarly, van Goerverden and de Boer (2013), highlighted that modal choice is related to the "relative quality of the available travel modes" (p. 76), which in turn depend on distance. In their study comparing Flemish and Dutch students', primary school students were more likely to the chauffeured to school if the distance was greater than 3 km. Moreover, children in cluster 2 (NAT) show a significantly higher preference for being driven, whereas children in cluster 1 would like better to be IM (walk and cycle alone).

4.3.3. *Parent clusters*

The variables that made up the parent's cluster were organised according to the licences parents grant on their children's travel and their attitudes towards their children and other children's AT and IM. Six questions from the parent survey were used to reflect children's licences to travel. These included four questions regarding the licences provided to children for IM – the licence to travel TO school, FROM school, to cross roads, and cycle on main roads unaccompanied by an adult – and two questions regarding the range children can travel independent of adults – alone, and with friends or siblings.

Three clusters emerged from the analysis of variables from the parents' surveys. The profiling of parent clusters is separated into two tables. Table 7 presents the variables related to the licences that parents provide for their children to travel independently and the range of independent travel children are permitted by their parents, whereas Table 8 indicates the values and perceptions of social norms the parents held with regard to children's independent mobility.

Cluster 1 ('free range'[3]) includes parents who allow their children to travel to school, to cross roads, or to cycle without an adult. They also permit their children to travel by themselves within the

[3] 'Free range' and 'bubble wrapped' are terms coined by Whitzman (2006) and Malone (2007) respectively.

Table 7
Profile of parent clusters (licences).

Variable	Attribute	Cluster 1 'free range'		Cluster 2 'home zone'		Cluster 3 'bubble wrapped'		Total	Significance p (X^2, likelihood ratio, ANOVA)
		n	% Total	*n*	% Total	*n*	% Total		
Is your child allowed to travel TO school without an adult present?	No, not allowed to travel TO school without an adult	5	8.5	0	0.0	54	91.5	**59**	
	Yes, allowed to travel TO school without an adult	25	27.2	66	71.7	1	1.1	**92**	
									< 0.001
Is your child allowed to travel FROM school without an adult present?	No, not allowed to travel FROM school without an adult	5	9.6	1	1.9	46	88.5	**52**	
	Yes, allowed to travel FROM school without an adult	25	25.3	65	65.7	9	9.1	**99**	
									< 0.001
Is your child allowed to cross main roads without an adult present?	No, not allowed to cross main roads without an adult	1	1.4	29	41.4	40	57.1	**70**	
	Yes, allowed to cross main roads without an adult	29	35.8	37	45.7	15	18.5	**81**	
									< 0.001
Is your child allowed to cycle on main roads without an adult?	No	4	3.3	63	51.6	55	45.1	**122**	
	Yes	26	89.7	3	10.3	0	0.0	**29**	
									< 0.001
How far is your child allowed to travel from home? By himself or herself	Within your street or next street	7	7.6	40	43.5	45	48.9	**92**	
	Within your neighbourhood (1 km)	19	35.8	25	47.2	9	17.0	**53**	
	Adjacent neighbourhood	2	50.0	1	25.0	1	25.0	**4**	
	City centre	2	100.0	0	0.0	0	0.0	**2**	
	Anywhere in the city								< 0.001
How far is your child allowed to travel from home? With friends or siblings but without adults	Within your street or next street	1	2.5	16	40.0	23	57.5	**40**	
	Within your neighbourhood (1 km)	9	12.0	40	53.3	26	34.7	**75**	
	Adjacent neighbourhood	10	41.7	9	37.5	5	20.8	**24**	
	City centre	4	80.0	1	20.0	0	0.0	**5**	
	Anywhere in the city	6	85.7	0	0.0	1	14.3	**7**	
									< 0.001

neighbourhood and if accompanied by a sibling or friend to travel outside the neighbourhood (including the city). Parents in cluster 2 ('home zone') allow their children to walk to school without an adult (which is translated in the highest AT proportion – 37 out of 61), but they are more reluctant when it comes to crossing roads and completely opposed to cycling. These parents are comfortable letting their children wander within their neighbouring streets only, even if accompanied friends or siblings. Although not significant, these parents live closest to the schools of their children (2.68 km). By contrast, Cluster 3 ('bubble wrapped') includes parents who do not provide any IM licence to their children. They are the most restrictive group and require the presence of an adult, sibling, or friend when any of their children travel. These parents only allow their children to travel by themselves within the street and accompanied within the neighbourhood. They are most likely to drive their children to school (27 out of 35). This may also be explained by the distance to school, which is further in this cluster, compared to 'Free range' and 'Home zone' clusters (Fig. 4).

Table 8 presents interesting results. Although all clusters show strong agreement of parents in regard to developing children's skills for IM, cluster 3 parents are less confident in their child's ability to travel without an adult. This cluster also feels that licences to travel may be seen as an act of irresponsibility and other parents would be concerned to see children travelling by themselves in the neighbourhood. This attitude may seem to be at divergence to their own travel as children, as this cluster walked and cycled the most in their school years. Cluster 1, of 'free range' parents, had different travel experiences in their childhood and none of them thinks that it is irresponsible to allow their children to travel without an adult within the neighbourhood. They primarily walked and cycled to school in their childhood and they have confidence in their children abilities to become independent travellers. Similar attitudes are observed for the parents in cluster 2 'home zone'.

4.4. Measures of association

Further analysis was conducted to see whether there are significant associations between the three series of clusters (built environment, children and parents). The results suggest a statistically significant association between the built environment clusters and the clusters of children ($p < 0.001$). Table 9 further confirms the role of built environment in shaping travel: three quarters of cluster 1 (lower density, towards the fringes) includes children in cluster 2 (NAT), who usually go to school by car. Cluster 1 of children (AT and living closer to school) is significantly associated with Cluster 2 BE (metropolitan, denser, and more walkable).

Table 8
Profile of parent clusters (attitudes).

Variable	Attribute	Cluster 1 'free range'		Cluster 2 'home zone'		Cluster 3 'bubble wrapped'		Total	Significance p (X^2, likelihood ratio, ANOVA)
		n	% Total	n	% Total	n	% Total		
When you were the age your child is now, how did you usually travel to school?	Walked	13	14.3	40	44.0	38	41.8	**91**	
	Local bus, train or other PT	2	28.6	3	42.9	2	28.6	**7**	
	Cycled	7	30.4	10	43.5	6	26.1	**23**	
	Car	4	23.5	8	47.1	5	29.4	**17**	
	School bus	4	36.4	3	27.3	4	36.4	**11**	
	Other	0	0.0	2	100.0	0	0.0	**2**	
									< 0.001
It is irresponsible for parents to allow their children to walk or cycle in our neighbourhood without an adult	Strongly disagree	11	37.9	16	55.2	2	6.9	**29**	
	Disagree	12	18.2	32	48.5	22	33.3	**66**	
	Neutral	7	15.6	15	33.3	23	51.1	**45**	
	Agree	0	0.0	1	11.1	8	88.9	**9**	
	Strongly agree	0	0.0	2	100.0	0	0.0	**2**	
									< 0.001
I think other parents would be concerned if I allowed my child to walk and cycle by themselves in my child's neighbourhood	Strongly disagree	8	47.1	6	35.3	3	17.6	**17**	
	Disagree	14	20.6	35	51.5	19	27.9	**68**	
	Neutral	6	14.3	14	33.3	22	52.4	**42**	
	Agree	2	8.3	11	45.8	11	45.8	**24**	
									< 0.001
I am confident that my child has the ability to walk or cycle in the neighbourhood without an adult	Strongly disagree	1	16.7	4	66.7	1	16.7	**6**	
	Disagree	0	0.0	3	23.1	10	76.9	**13**	
	Neutral	1	7.1	5	35.7	8	57.1	**14**	
	Agree	11	13.8	39	48.8	30	37.5	**80**	
	Strongly agree	17	44.7	15	39.5	6	15.8	**38**	
									< 0.001
I think it is important that my child develop skills to travel alone	Strongly disagree	0	0.0	3	100.0	0	0.0	**3**	
	Disagree	0	0.0	3	60.0	2	40.0	**5**	
	Neutral	2	15.4	4	30.8	7	53.8	**13**	
	Agree	15	19.5	30	39.0	32	41.6	**77**	
	Strongly agree	13	24.5	26	49.1	14	26.4	**53**	
									< 0.001

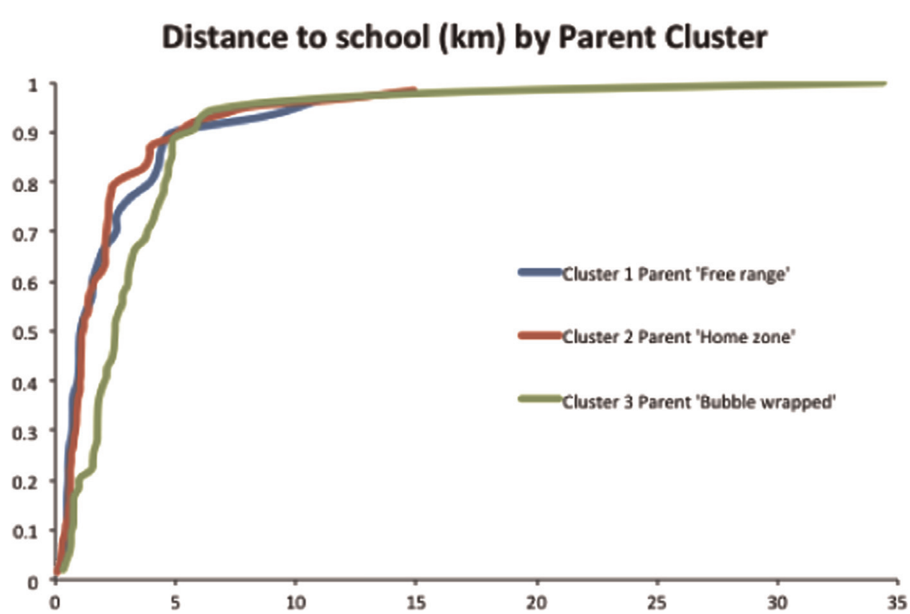

Fig. 4. Distance to school by parent cluster.

Table 9
School (built environment) and children clusters.

	School (BE) cluster 1	School (BE) cluster 2	Total	Significance p (X^2, likelihood ratio, ANOVA)
Cluster children				
AT 1	25	**88**	113	
NAT 2	**76**	84	160	
Total	101	172	273	< 0.001

Table 10
Parent and children clusters.

	Cluster parents			Total	Significance p (X^2, likelihood ratio, ANOVA)
	'Free range'	'Home zone'	'Bubble wrapped'		
Cluster children					
AT 1	19	**37**	5	61	
NAT 2	11	24	**48**	83	
Total	30	61	53	144	< 0.001

Clusters of children are also significantly associated with clusters of parents ($p < 0.001$). Children in cluster 1, 'active travellers', tend to have parents from cluster 2 of parents 'home zone' (37 out of 61), whereas children in cluster 2, 'not-active travellers', are more likely to have parents in cluster 3 'bubble wrapped' (Table 10). As a result, active travel children of 'free range' and 'home range' parents have 55% of their travel by active modes whereas the 'bubble wrapped' only 26%. Similarly, in the NAT2 group of children, those with 'free range' and 'home range' parents used 37% active transport, and only 14% in the 'bubble wrapped' sub-group.

There were no significant associations between parents' clusters and the school (BE) clusters, suggesting that social norms and values may be more influential determinants of attitudes to children's travel.

5. Discussion and conclusion

Independent mobility has been measured in a number of ways, using 'licences' provided by parents and alternatively, travel characteristics self-reported by children (Page et al., 2009). This research responds to the call for deepening the understanding of independent mobility and provides additional evidence on the relationships between children's travel, urban characteristics and parents' attitudes and 'licences' provided to their children. This study has applied cluster analysis to group children according to their most distinguishing travel characteristics and compared them with the built environment and the parents' values and travel-related norms imposed on their children. Our aim has been to explore whether built environment has an influence on children's travel.

This is the first study, to our knowledge, that has used cluster analysis to explore a range of factors linked to children's travel to and from school. We have found that:

(1) Distance to school has a strong influence on IM and it is related to: built environment (density), availability or quality of school (not investigated here, but it may explain the distances above 20 km), and 'licences' (perceived fear of parents to leave their kids to travel independently).
(2) In addition to densities, the 800 m ped-shed ratio was the only significant BE indicator, albeit marginally; other indicators, although important, were less relevant because the sample was quite homogeneous.
(3) Despite of its marginally significant effect (the sample does not have substantial differentiation) age of children matters; as expected, older children are allowed to (have more licences) to walk, cycle in their neighbourhood.
(4) Gender again seems related to the licences and boys can travel more freely than girls.
(5) Parents' perceptions and attitudes towards BE and IM are associated with children's AT; children with fewer licences are likely to be less active than children without barriers.
(6) It appears that a combination of preferences and licences lies behind children's active travel to school and other places; children AT prefer to be more autonomous/independent travellers and have parents who foster their IM by limiting the number of licences; conversely, children's preferences for being driven coincides with parents' fears for IM and lack of confidence in their children abilities to travel independently.

Returning to the socio-ecological approach our findings indicate the need for policy action in several domains. At the socio-political level, parental attitudes of those in the 'bubble-wrapped' cluster are clearly influenced by how they perceive others would view their granting of licences for IM. At the neighbourhood level, objective measures of the physical environment, especially 800 m ped-shed ratio, densities, and distance to school are key discriminators between children who are active travellers versus those who are not. At the household level we return to the need for parents to change 'licences', reflecting on their own early AT and IM experiences which were less restrictive. At the level of the individual child there may be latent support for children's active and independent travel, highlighting the importance of education and skills development programmes in schools. In all of this there are important implications for health, well-being and liveability.

The distance children have to travel to school is critical and in this case study extends beyond the standard five to ten minutes understood to be comfortable walking time. The average distance of households to school in school cluster 1 (metropolitan, walkable) is 1.69 km, whereas the walkable distance for children has been defined as ranging from 800 m (Panter et al., 2010a, 2010b; Zhu and Lee, 2008, 2009) and 1 km (Kerr et al., 2007). Reflecting findings in other research (Schlossberg et al., 2006; Cole et al., 2007; McDonald, 2007) distance of households to school is the most discernible factor associated with children's active travel rates to school. Policies that locate schools in proximity to new residential developments are already in place in Australia. Education policy, however, allows for more choice regarding school enrolments and results in children living beyond distances amenable for AT. This provision of greater choice in education enrolment in Australia (perceived quality of education) has the potential to further exacerbate children's active travel rates by increasing the enrolment catchments for schools.

Travel behaviour change policies and infrastructure programmes such as Safe Routes to School (SRTS) may have some potential to address declining rates of children's active travel. SRTS is an international programme using education, advocacy and infrastructure improvements to address unsafe walking and cycling environments and declining rates of children's active travel to school (Stewart, 2011). While many children in our sample now live beyond walking distance to school, they are located within a comfortable cycling distance. Bicycle ownership is high (92% of the sample owned a bicycle), yet less than 4% rode to school, and this despite a desire to do so. In Australia, cycling proficiency training is no longer offered and many urban environments have poor cycling infrastructure and it is here that policy makers must direct attention.

Aside from the journey to school, there may be an argument for policy makers to increase the focus on travel to non-school destinations in the neighbourhood. The results indicate that in the AT children's cluster there is a less definite membership-base of children who walked or cycled to non-school locations which supports this argument. Even regular active travellers to school were not usually walking or cycling to other places in the neighbourhood. Such policy responses would require attention paid to providing a more diverse range of activities within proximity to children's households.

On a final note, the association between the AT children's cluster and the inner metropolitan, dense and walkable school cluster suggests that built environment factors are important for policy makers to consider. In addition to densities, the 800 m pedshed ratio was the only significant BE indicator, albeit marginally; other indicators, although important, were less relevant because the sample was quite homogeneous.

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