Transport Policy 37 (2015) 1–10

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

School travel mode choice and the characteristics of the urban built environment: The case of Helsinki, Finland

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ARTICLE INFO

Article history:
Received 8 October 2013
Received in revised form
25 August 2014
Accepted 25 October 2014
Available online 11 November 2014

Keywords:
Children
Youth
Active transport
Independent mobility
GIS

ABSTRACT

As observed in several previous studies, the nature of the urban structure can affect children's mode of transportation to school. In this paper, we identify and investigate, in the Finnish context, the elements of the urban structure around homes and *en route* to school that promote children's ability to walk or cycle to school, using the conceptual domains proposed by Mitra (2013) to frame the work.

The associations discovered can, to a large extent however, be viewed as contrasting significantly with those identified in previous research, as an increase in the variables, essentially indicating urbanity, decreased the likelihood of the children walking or cycling to school. This is due to the existence of a well-functioning public transportation network in the Helsinki region. The associations were more significantly associated with the environment *en route* to school than with the environment around homes. This research improves our understanding of active school transportation behaviour in an environment that is already relatively supportive of active transportation and independent mobility by offering a well-functioning public transportation system.

1. Introduction

Because of the growing obesity epidemic, the possibility that different environments could promote greater physical activity in children is a subject that has attracted increasing research interest (Ding and Gebel, 2012; van Loon and Frank, 2011; Ding et al., 2011; Pont et al. 2009). As such, activity on school journeys has become the focus of an increasing research effort (see reviews by Stewart et al., 2012; Stewart 2011; Wong et al., 2011; Davison et al., 2008; Sirard and Slater, 2008), as the journey to school is something that children need to cover on most days, and active school journeys can thus promote a significant opportunity for physical activity. To better understand the linkages between the environment and children's active school transportation (AST), a number of conceptual frameworks have been proposed (McMillan, 2005; Panter et al., 2008; Mitra, 2013; Sirard and Slater, 2008; Pont et al., 2011). We discuss a few of these in more detail below and suggest a way to empirically analyse the school journey travel mode choices of children and young people living within 1–3 km of their school, using the model proposed by Mitra (2013).

The earliest attempt to build a comprehensive child-specific framework of the built environment's impact on transport was provided by McMillan (2005). In her framework the urban form was seen as having an indirect link to children's active transport, through the prism of parental perception and decision-making. The urban form clearly had an effect on parental perceptions of the neighbourhood through which the children had to travel and on parents' perceptions of traffic safety as well as on the transport options available to the household. Based on their perceptions, parents then decided whether their children could walk or cycle to school. Panter et al. (2008), however, were subsequently to criticise McMillan's framework for not incorporating the varied components of the environment that had been shown to influence parental decision making. In its place they suggested a conceptual framework composed of four domains of influence on children's active travel behaviour. These domains were the individual factors concerning the child, the physical environment, external factors (such as climate or policy), and the main moderating factors (age, gender, and distance). In this context, the diverse elements of the urban form were highlighted, focusing on relevant issues in relation to the creation of perceptions among both children and parents and their joint decision making processes, such as facilities, environmental factors related to personal and traffic safety, and route directness etc.

A further conceptual framework has been suggested by Mitra (2013). His critique of the framework proposed by Panter et al. is that the framework is not clear in explaining the behavioural

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http://dx.doi.org/10.1016/j.tranpol.2014.10.011
0967-070X/

processes that link the factors on these different levels of the ecological model to the choice of active transport modes. Trying to overcome this shortcoming, Mitra's framework is informed by research from three different research fields and multiple theoretical backgrounds where children's transportation has been in focus, namely, in transportation and urban planning studies, public health, and environmental psychology. Based on his review, Mitra builds a behavioural model of school transport (BMST) that is at its core a socio-ecological model, which looks at the associations between built environment and behaviour across multiple nested layers. In addition, the model also contextualises the intra-household interactions within the household activity-travel framework, and considers the perceived importance of an escorted trip, the mobility options available and the activity constraints on the family.

On the urban environment level, Mitra (2013) identifies five conceptual domains of relationship between the neighbourhood environment and school travel outcomes. These domains include the proximity to school, traffic and personal safety concerns, connectivity, comfort and attractiveness, and the possibility to maintain social capital on the school journey. Previously discovered evidence in respect of the environmental attributes associated with children's transport choices is then placed under these conceptual domains and discussed in detail by Mitra.

Of the frameworks described above, we find Mitra's (2013) framework the most thorough in its reasoning and portrayal of the hypothesised links between urban environment and transport options in respect of children's journeys to school. In this paper, we seek to highlight the elements of the urban structure that promote children's transport to school by foot or by bike, using the conceptual domains proposed by Mitra to frame the work. We also ask whether the correlates of walking and cycling differ. It has been suggested that the correlates for walking and cycling in terms of school journeys may be different (Kemperman and Timmermans, 2014; De Vries et al., 2010) and hence we treat walking and cycling to school as two distinct outcome variables rather than looking at active versus passive travel modes.

Somewhat unusually, we only include subjects living within distances between one and three kilometres from their school. Increasing distance has consistently been shown to decrease the propensity of journeys taken actively (e.g. Su et al., 2013; Pont et al., 2009; Yeung et al., 2008). In the pupils studied from the Helsinki region, inactive modes of transport were almost nonexistent (2.8% modal share) on journeys shorter than one kilometre, while previous research shows notably lower shares of active transport in students living close to school. In the US, the share of walking was 48% for those living within 1 mile of their school (McDonald, 2008); while another study reported 32% walking, 14% cycling, and 54% using car or bus as their primary transport mode within the same distance (Schlossberg et al., 2006). In Australia, 23% of students living within 0.75 km of their school had no active commuting trips in a week (Merom et al., 2006). Meanwhile, a Dutch study found the share of inactive trips within 1 km of school to be 10% (Aarts et al., 2012). With regression analysis, the point is to explain the variance in the outcome variable (i.e. using inactive modes vs. walking or cycling) by the variance of the independent variables (i.e. the structure of the built environment). To be able to explain the variance in school journey transport modes, we need to concentrate on those trips where it is not only distance but also the environment that affects the mode chosen.

This article is, we believe, the first to operationalise Mitra's framework. We use, where available, variables related to the urban environment already utilised in earlier research and create new ways of operationalising the domains that have not previously been studied in detail. In their framework, Panter et al. (2008) recommended that the built environment relating to the neighbourhood, destination, and route environment should be considered. Research that has empirically studied the destination (i.e. school) environment and facilities has however shown no significant associations with children's active travel behaviour (Panter et al., 2010; Mitra et al., 2010). Thus we concentrate instead on analysing the urban environments of homes and school journeys in correlation with the transport modes of children and young people and leave the destination environment out of our analysis.

Finally, this study adds to the discussion on the associations between the built environment and AST by exploring this general theme in the Finnish context. Thus far, this field of research has largely been dominated by research from the US, Canada, Australia and the UK with occasional examples from other European countries such as Netherlands (e.g. Aarts et al., 2012; Kemperman and Timmermans, 2014).

2. Material and methods

Recent developments in GIS (Geographic Information Systems) and especially in public participation GIS (PPGIS) have created new opportunities for the use of location-based methodologies. The softGIS methodology is one example of a PPGIS method that enables the collection of large datasets of residents' experiential knowledge concerning various environments (Kyttä and Kahila, 2011). The main benefit of utilising location-based surveys in data collection concerning daily mobility and environmental experiences is the geographical dimension the data maintains. Based on the coordinates, the experiential knowledge gathered from residents can be simultaneously analysed with register-based GIS data, which provides new, location-based research possibilities (Kahila and Kyttä, 2009).

The data relating to this study was collected via a softGIS survey for children, where the respondents used the Internet interface to mark their home and daily routes to school, and to answer questionnaires concerning school journeys, perceived health and wellbeing as well as background details. The method has been tested in previous research among both children (Kyttä et al., 2012; Broberg et al., 2013) and adults. The user interface included a set of questionnaire pages where conventional survey question and mapping pages alternated (see Fig. 1)[1]. Additionally, the respondents were asked to mark places that were functionally, emotionally or socially meaningful, and to describe how accessible these places were, in terms of independent mobility and active transport. This article concentrates on children's school journeys, while the data relating to meaningful places will be reported elsewhere.

2.1. Subjects and communities

This article studies the school journeys of two select age groups in a small but rapidly growing metropolitan area, the capital region of Finland. The research data was collected in 16 comprehensive schools (in total 22 5th grade classes and 38 8th grade classes) during the autumn and early winter of 2011. The schools and their surrounding residential areas included represent different urban structures ranging from the inner city urban core to surrounding suburbs, and fringe areas dominated by single-family housing.

[1] See http://www.softgis.fi/children. Similar datasets were gathered in Finland, Australia and Japan. For ease of understanding, in Fig. 1 the Australian version of the questionnaire is depicted instead of the one in Finnish.

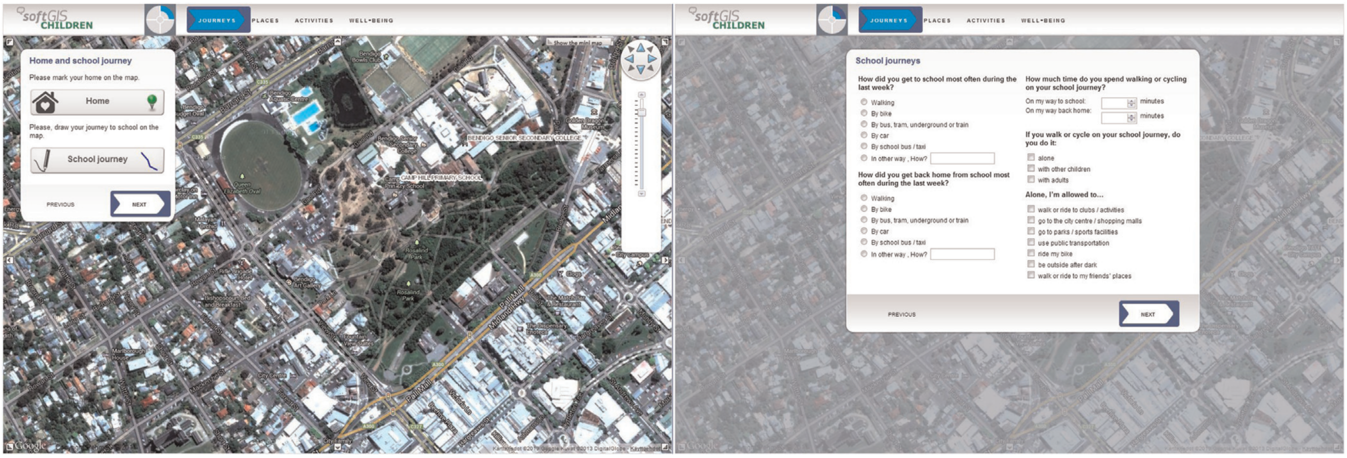

Fig. 1. Interfaces for mapping and ordinary questionnaire pages.

In Finland, every pupil is assigned to the nearest school, or the nearest school where the chosen first foreign language is being taught. Pupils are also free to choose other schools, but going to the nearest school available is still fairly common: 70% of the primary school pupils go to their nearest school, the respective figure for lower secondary schools being 60% (Bernelius, 2011).

In the Helsinki region, the school network is still relatively dense, though smaller schools have been closed and education centralised into bigger units. The density of the network is visible in the relatively short school trips of the studied pupils (mean 1.8 km, SD 2.2 km, and maximum 14.2 km). Finnish law requires the municipalities to grant free school transportation for pupils whose school journey to the nearest designated school is over 5 km. The municipalities of Espoo and Vantaa offer a free public transportation ticket that is valid on school days for these pupils. Helsinki city offers these tickets, but the journey length limits are 2 km for 5th-graders and 3 km for 8th-graders.

Data collection was organised in computer equipped classrooms and led by a research assistant. The ethics board from the Education Board of the Cities of Helsinki and Vantaa approved the research, and informed consent was gathered from the respondents and their parents. The total number of pupils in the classes that participated in the study was 980, although 80 pupils were absent for various reasons. In some schools problems were encountered with the Internet connection, but in these cases the pupils were instructed to fill in the questionnaire at home. After incomplete answers were excluded, the final dataset included the answers of 828 pupils, of whom 35% were from the 5th grade (approximately 11 years old), and 65% from 8th grade (approximately 14 years old).

In this article, only a subsample of these 828 respondents is included. Based on the transport mode shares of the respondents in different distance bands from schools (see Table 1), we narrowed our final dataset down to children who lived between one and three kilometres from school. Nelson et al. (2008) have suggested applying a 2.5-mile criterion within which active commuting to school is achievable, while others have used 2 mile cut-off based on the low levels of AST beyond that limit (McDonald, 2008; Mitra and Buliung, 2014). Including only children living in the range 1–3 km from school thus allows for variance in the transport modes chosen and makes modelling the correlates of the environment meaningful.

In all, 224 children lived within the specified range, and 202 of them provided their actual school journey taken. These 202 children will constitute the final subjects of this article. Of these children, 18.3% were 5th graders, while for the data as a whole the percentage was 35.4. This is due to the secondary school network being sparser and thus producing longer school journeys for the older age group. The school trip distances were fairly similar throughout the study region, although longer distances were a little more prominent in the more sparsely populated fringe areas. Nevertheless, the children selected for the study represent the 16 schools where the initial dataset was gathered. The percentages for girls were 53.7% and 51.8%, respectively, and regarding gender the modelling dataset is representative.

Subjects typically lived with both parents (72.6%), had their own room (86.1%), a bicycle (96.5%), and spoke Finnish at home (93.5%). Of the families of the respondents 43.1% lived in single family housing, while the proportions living in apartment buildings or semi-detached houses were roughly the same. Owning two or more cars was typical (55.4%), with only 6.9% of the families not having a car.

2.2. Measures

2.2.1. Outcome variables

The mode of school travel was studied by asking how the respondent had most often travelled to and from school during the current week: on foot, by bicycle, by public transportation, by school bus or taxi, by car, or other mode. There was little difference between the transport modes to and from school, and as it has been shown that the urban environment plays a more significant role on journeys to school than from school (Mitra et al., 2010), the stated mode on the journey to school was used in the analysis. Walking (17%), cycling (43%), and public transport (34%) were the main modes in the final sample, while private car was used on the remaining 6% of the trips[2]. There were no significant differences in modal shares between genders or age groups.

The level of independence in respect of mobility in relation to school journeys was studied by asking with whom the respondent normally travels to school: alone, with other children, or with adults. Journeys were predominantly taken with other children (53%) or alone (47%), with only one respondent reporting that they travelled with an adult. There was a slight difference between age groups in terms of the proportions of trips taken alone and with other children, but these differences were not statistically significant. The studied children enjoyed high levels of independence in their mobility relating to school journeys, and thus this variable was not used as an outcome variable, as suggested by Mitra (2013),

[2] In modelling, transport mode was recoded as (1) walking, (2) cycling, and (3) other modes.

Table 1
Mode shares on school journeys in different distance bands from school, and descriptive statistics for the independent variables

	Walking	Cycling	Motorised modes	N
Within 1 km from school	74.4%	22.8%	2.8%	430
From 1 to 3 km from school	18.8%	40.2%	41.1%	224
Beyond 3 km from school	0.6%	2.3%	97.1%	174

INDEPENDENT VARIABLES[a]	Mean	Std. deviation
Traffic or personal safety		
LIGHT_DTY_H: number of street lights divided by total road length in buffer	0.38	0.71
LIGHT_DTY_SJ: number of street lights within 100 m of route divided by route length	2.58	5.55
LIGHT_PROP_H: ratio of signalised intersections to total number of street intersections	5.45	9.18
LIGHT_PROP_SJ: ratio of signalised intersections to total number of street intersections	8.04	14.65
MAJOR_RD_PROP_H: length of primary roads divided by total road length	27.69	19.97
MAJOR_RD_DTY_H: length of major roads[b] normalised by sq km of area	3.01	2.78
MAJOR_RD_DTY_SJ: length of major roads[b] normalised by sq km of area	1.07	0.77
MAJOR_RAIL_INT_SJ: 1 if major road or railroad intersects the school journey	0.47	0.50
BUILD_DTY_H: summed floor space in all the buildings divided by buffer area	0.18	0.24
BUILD_DTY_SJ: summed floor space in all the buildings divided by buffer area	0.27	0.31
PUBLIC_BUILD_PROP_H: proportion of land covered by public buildings	4.94	5.47
BUILD_USE_MIX_H: mix in the main uses of buildings[c]	0.67	0.50
BUILD_USE_MIX_SJ: mix in the main uses of buildings[c]	0.96	0.35
Connectivity		
FOURWAY_PROP_H: ratio of 4-way intersections to total number of street intersections	16.25	12.59
FOURWAY_PROP_SJ: ratio of 4-way intersections to total number of street intersections	19.60	15.96
ROAD_DTY_H: total road lengths divided by buffer area	9.26	3.68
ROAD_DTY_SJ: total road lengths divided by the drawn school journey length	2.56	0.74
INTERSECT_DTY_H: number of all intersection divided by buffer area	40.22	23.19
INTERSECT_DTY_SJ: number of all intersection divided by buffer area	57.58	26.46
PUBL_TRANS_DTY_H: number of transportation stops near home divided by buffer area	14.21	10.38
PUBL_TRANS_DTY_SJ: number of transportation stops near home divided by route length	6.21	3.68
Comfort and attractiveness		
RECR_PROP_H: proportion of parks and recreation areas	4.73	7.00
RECR_PROP_SJ: proportion of parks and recreation areas	4.16	7.06
FOREST_PROP_H: proportion of forests	22.89	15.48
FOREST_PROP_SJ: proportion of forests	18.30	12.62
SINGLE_FAM_PROP_H: proportion of land covered by single family housing	14.89	13.59
SEPAR_WALK_SJ: summed length of separate walk or bikeways divided by route length	1.71	0.81
Maintaining social capital		
SJ_WITH_FRIENDS: 1 if school journey is travelled in company of friends	1.99	0.83
POP_DTY_H: number of residents per sq km	2.39	2.47
POP_DTY_SJ: number of residents per sq km	3.63	3.60
HOUSING_DTY_H: number of housing units per hectare	12.85	17.08
HOUSING_DTY_SJ: number of housing units per hectare	20.62	25.69
Household		
MOB_LICENCE_COUNT: count of items respondent is allowed to do independently	5.64	1.87

[a] The built environment was estimated separately for 500-metre buffer around home (*variable_name*_H) and 100-metre buffer around drawn school journey (*variable_name*_SJ).
[b] Expressways, arterials and collector roads; length in km.
[c] The evenness between proportions of floor area for residential, commercial, office and institutional uses.

but as an independent variable operationalising the conceptual domain of maintaining social capital[3].

2.2.2. Physical environmental variables

GIS-based measures t of the built environment were calculated for 500 m buffers around each respondent's home (Kyttä et al., 2012) and within 100 m of the drawn school journeys (Panter et al., 2010). Detailed descriptions of the variables and their summary statistics are provided in Table 1.

2.2.2.1. Proximity-related variables. The distance, as the crow flies (DIST_CROW), from home to school was calculated and used in adjusted models[4]. Rather than treating distance as a measure of environment in itself, we included it in the partly adjusted models, for densities of different measured urban structures and distance are closely interlinked. Wong et al. (2011) have outlined how distance can be viewed as an operational measure of the concept of 'density'.

2.2.2.2. Variables related to traffic safety and personal safety. Numerous variables concerning the traffic environment have been used in previous research on children's transportation. In this study, streetlight density (Panter et al., 2010) and proportion of intersections with street lights were used (Mitra and Buliung, 2012).

The presence of primary roads was operationalised as their proportion of total roads (Panter et al., 2010) and as the length of major roads by area near home and along school journey (Mitra and Buliung, 2012). We also analysed whether or not a major road or railroad intersects the school journey (Schlossberg et al., 2006).

Mitra (2013) hypothesizes that large retail centres or employment districts may discourage AST. Previous research in relation to Helsinki has shown that environments dominated by high building densities discourage active and independent mobility (Broberg et al., 2013). Building density was calculated as the summed floor space in all the buildings within a buffer divided by the area (Lin and Yu, 2011). The proportion of land covered by public buildings near home (Su et al. 2013) was also calculated.

[3] We dichotomised the accompaniment on school journey to a new variable SJ_WITH_FRIENDS (alone (0), with friends (1), recoding one respondent taking the journeys in adult company as a missing value.

[4] Also the distance of the drawn journey (DIST_DRAWN) was calculated, but as these measures were highly correlated (r=.84), the first was used, it being more objective and less sensitive to differences between respondents in the meticulousness of drawing the route.

It has been suggested (Mitra, 2013; Ding et al., 2011) that a mixed design and associated presence of street-level retail and 'eyes on the street' could encourage AST. We calculated the mix in the main uses of buildings (as defined for land use mix by Frank et al., 2004).

2.2.2.3. Connectivity-related variables. Previous research highlights the existence of contrasting evidence in relation to the associations between pedestrian connectivity or intersection densities and children's active transportation (e.g. Wong et al., 2011). Nevertheless, we calculated the ratio of 4-way intersections to total number of street intersections (Mitra and Buliung, 2012). Two variables concerning the overall availability of roads to walk or cycle and the connectivity of these roads were calculated. Road density (Panter et al., 2010) and intersection density (Schlossberg et al., 2006) were calculated for both home and route environments.[5]

Connectivity relates not only to the transport network, but also to the functional connectivity of the urban environment. We analysed the availability of public transportation by calculating the number of transportation stops in proximity to home and along the school journey.

2.2.2.4. Variables related to comfort and attractiveness. The presence of open space or parks (Ding et al., 2011; Mitra, 2013) and smaller neighbourhood blocks (Mitra, 2013) could enhance the comfort of walking and cycling. The greenness of the environment was analysed as the proportion of parks and recreation areas as well as that of forests near home and along the route. The presence of small neighbourhood blocks was operationalised as the proportion of land covered by single family housing.

Sidewalks are nearly omnipresent in the Helsinki area and are, probably for this reason, not included in any of the geographical datasets available. In reality, there is little to be gained from analysing sidewalks in relation to mobility statistically, as there would be no variance between subjects. Nevertheless, taking into consideration the notion of comfort in respect of pedestrian and bicycle mobility, we analysed the summed length of separate walk or bikeways along the school journey divided by route length.

2.2.2.5. Variables related to maintaining social capital. As Mitra (2013) notes, little research has been done on the connections between the social environment and AST. Thus, in order to analyse the possibility of meeting others on the school journey, we included variables concerning population size and residential densities near home and along the route of the school journey. Increasing population density has also been hypothesized as having a positive association with transport-related physical activity (Ding et al., 2011).

Moreover, accompaniment on the school journey SJ_WITH_FRIENDS (as described above) was used as an independent variable operationalising the conceptual domain of maintaining social capital.

2.2.2.6. Variables related to household and child. Household access to private automobiles was interrogated by asking if the respondent's family owned one, two or more cars, or no car at all (OWN_CAR). Car-ownership was included in all the partially adjusted regressions.

Parents' general attitude towards their child's mobility options can be seen in the mobility licences, i.e. permission to move around independently granted to the child. Children granted a greater level of independence were more likely walk or bike to school in an Australian study (Merom et al., 2006). We operationalised the licences with a set of questions concerning those things the child is allowed to do independently (Hillman et al., 1990), revising some of the items to better reflect the Finnish context. The children answered whether they were allowed to do a list of seven things alone (MOB_LICENCE_COUNT): go to leisure activities, go to parks or sports facilities, use public transportation, ride their bike, be outside after dark, go to the city centre or shopping malls, and walk or ride to their friends' places.

Finally, age group and gender were included in all the models, as they have been shown to be closely associated with both independence and the mode choice of children's travel (see e.g. Mitra et al., 2014; Fyhri and Hjorthol, 2009; Johansson et al., 2010).

2.3. Analysis

The environmental variables were extracted from register-based geographical datasets using ESRI ArcMap 10.1 and MapInfo Professional 11.5. The main geoprocessing techniques used were buffering the homes and the school journeys, overlaying and intersecting different layers of analysis with each other, and calculating statistics concerning the individual buffers from these intersections as well as the building points within buffers. Different raster calculation and focal statistical methods were used to calculate variables concerning land use.

Three geographical datasets were used in the analysis. The land use –related variables were calculated from the SLICES dataset[6]. Population and building density-related variables were drawn from a building centroid dataset[7], and the Digiroad[8] dataset was used to build the traffic-related variables.

The statistical analyses were performed with IBM SPSS Statistics 21. The significances in the differences of means between genders and age groups were studied with T-tests and the differences of frequencies across groups with the chi-squared test. The connections between the urban environment and the transport mode were studied with multinomial regression analysis. Multinomial outcomes were specified in the models with a three category outcome of walking, cycling, or motorised travel (used as the reference category).

A set of partially adjusted regressions (all adjusted for the confounding effects of age, gender, household car-ownership, and distance from home to school) were run to filter the initial set of variables down to those that showed correlation with the transport mode choice on a confidence level of 95% ($p < 0.05$). Another set of multivariate fully adjusted regressions were estimated separately for the environment surrounding the home and school journey. When variables showed strong correlations ($r > 0.75$), these were entered into the multivariate fully adjusted model one at a time and only the variable that was most strongly associated

[5] The roads not available for walking and cycling such as motorways were omitted from these analyses.

[6] SLICES (Separated land use & cover information system) is a raster dataset produced by the Finnish National Land Survey. The dataset combines geographical datasets on land use from different organisations, such as the Ministry of Agriculture and Forestry, the Ministry of the Environment, the National Land Survey, the Finnish Forest Research Institute, Finland′s environmental administration and the Population Register Centre. The dataset offers a hierarchical classification of land use, land cover, soil types and special use and restricted areas, and covers Finland with a resolution of 10 m.

[7] The building centroid dataset for each building in the Helsinki region, containing the information on housing units, floor areas and population demographics for the building, was obtained from the city administration.

[8] Digiroad is a national database which contains precise and accurate data on the locations of all roads and streets in Finland, and their most important physical features. The dataset also includes other transport system-related objects, such as public transport stops or traffic lights, stored as dynamically segmented events. The Finnish Transport Agency maintains and updates the dataset.

with the transport mode choice was included in the final model. (see also Mitra, Buliung 2012; Panter et al. 2010).

3. Results

3.1. Partially adjusted models of transport mode choice on school journeys

Table 2 presents the direction and significance of associations from the partially adjusted models for walking and cycling on the school journey. Of the variables concerning traffic and personal safety, most were in significant association with the transport mode choice. Increasing street light densities as well as increasing proportions of intersections with street lights decreased the probability of choosing active transport modes rather than taking the bus or being driven in a car. These associations were in contrast to the hypothesised increased feelings of safety and consequential increase in walking or cycling. Targeting further the issue of traffic safety, the density of major roads on the school journey was significantly associated with walking and cycling: the increasing density decreased the propensity of AST. The variables used to study personal safety were partly in expected association and partly in unexpected association with the transport mode. Increasing building densities in the school journey and home environment decreased the propensity to walk or cycle. The higher the prevalence of public buildings in the home environment, the less likely the respondent was to walk and cycle. The increasing mix in building uses in both the home and school journey environment decreased the probability of choosing one of the active transport modes.

The variables related to connectivity showed significant association with transport mode choice in particular with road and intersection densities along the school journey route. Moreover, the proportion of four-way intersections, as a percentage of all intersections, was in significant inverse association with activity on the school journey. Each of these associations supports the view that a denser environment decreases the probability that an active mode will be chosen. Not surprisingly, the density of public transport options around the home and school journey decreased the probability of walking or cycling.

Comfort and attractiveness were studied with a set of variables concerning land uses in the home and school journey environment and the availability of separate walk or bikeways. The proportion of forests in the environment was not associated with the transport mode choice, but the more recreation areas there were around the home or school journey, the less likely the respondents were to walk or cycle. This finding contrasts with the supposed association. The increasing proportion of land covered by single-family housing increased the likelihood of walking and cycling to school significantly, as was hypothesised. Then again, the availability of separate routes for walking and cycling was not associated with choosing these modes of transport.

Finally, concerning the conceptual domain of maintaining social capital, the urban environmental variables showed significant associations with the choice of cycling to school. Increasing population and housing densities in both the school journey and home environments decreased the likelihood of cycling. The associations with walking were weaker, but still significant at $p < 0.05$ level. Making the school journey in the company of friends was not associated with the mode choice.

In general, all the associations studied, apart from the proportion of single family housing around the home environment, showed a similar tendency: the denser the measured variable, the less likely the respondent was to walk or cycle. This has to do with the respondents choosing between active transport modes and using public transportation rather than being driven in a car.

In addition, the associations between the variables describing the school journey environment had more significant associations with the mode choice than with the same variables describing the home environment. We suggest that this is so because the school journey environment depicts rather closely the environment that might have some effect on the mode choice, whereas the environment surrounding the respondent's home potentially gives too generalised a definition of the environment to matter.

Table 2
Partially adjusted multinomial regression models between neighbourhood and route environments and school journey transport mode.

Environmental charasteristic	OR (CL 95%)	
	Walk to school	Cycle to school
Traffic or personal safety		
LIGHT_DTY_H	*0.382 (0.177, 0.827)*	**0.183 (0.082, 0.409)**
LIGHT_DTY_SJ	**0.816 (0.716, 0.929)**	**0.735 (0.632, 0.853)**
LIGHT_PROP_H	0.95 (0.897, 1.006)	**0.918 (0.87, 0.968)**
LIGHT_PROP_SJ	**0.942 (0.906, 0.98)**	**0.912 (0.877, 0.949)**
MAJOR_RD_PROP_H	0.999 (0.972, 1.026)	0.99 (0.971, 1.008)
MAJOR_RD_DTY_H	0.936 (0.772, 1.135)	0.868 (0.753, 1.001)
MAJOR_RD_DTY_SJ	**0.226 (0.108, 0.472)**	**0.126 (0.062, 0.254)**
MAJOR_RAIL_INT_SJ	0.361 (0.121, 1.081)	0.524 (0.249, 1.104)
BUILD_DTY_H	**0.018 (0.001, 0.229)**	**0.001 (0.000, 0.028)**
BUILD_DTY_SJ	**0.031 (0.003, 0.293)**	**0.01 (0.001, 0.087)**
PUBLIC_BUILD_PROP_H	**0.852 (0.764, 0.95)**	**0.838 (0.765, 0.918)**
BUILD_USE_MIX_H	*0.271 (0.094, 0.78)*	**0.246 (0.111, 0.546)**
BUILD_USE_MIX_SJ	**0.059 (0.01, 0.355)**	**0.085 (0.026, 0.284)**
Connectivity		
FOURWAY_PROP_H	0.961 (0.919, 1.005)	*0.966 (0.936, 0.997)*
FOURWAY_PROP_SJ	*0.958 (0.927, 0.99)*	**0.962 (0.938, 0.986)**
ROAD_DTY_H	0.895 (0.767, 1.044)	**0.858 (0.768, 0.959)**
ROAD_DTY_SJ	**0.2 (0.089, 0.451)**	**0.171 (0.087, 0.337)**
INTERSECT_DTY_H	0.977 (0.952, 1.001)	**0.971 (0.952, 0.99)**
INTERSECT_DTY_SJ	**0.961 (0.939, 0.983)**	**0.967 (0.951, 0.984)**
PUBL_TRANS_DTY_H	*0.942 (0.893, 0.995)*	**0.924 (0.884, 0.966)**
PUBL_TRANS_DTY_SJ	**0.67 (0.551, 0.815)**	**0.595 (0.499, 0.71)**
Comfort and attractiveness		
RECR_PROP_H	*0.923 (0.853, 1.000)*	*0.934 (0.874, 0.999)*
RECR_PROP_SJ	*0.903 (0.821, 0.993)*	**0.842 (0.766, 0.926)**
FOREST_PROP_H	1.008 (0.975, 1.042)	1.005 (0.986, 1.024)
FOREST_PROP_SJ	1.032 (0.982, 1.085)	1.022 (0.993, 1.052)
SINGLE_FAM_PROP_H	**1.06 (1.014, 1.107)**	**1.059 (1.023, 1.096)**
SEPAR_WALK_SJ	1.389 (0.77, 2.507)	1.019 (0.642, 1.618)
Maintaining social capital		
SJ_WITH_FRIENDS	1.017 (0.352, 2.939)	1.672 (0.782, 3.575)
POP_DTY_H	*0.753 (0.597, 0.951)*	**0.64 (0.516, 0.795)**
POP_DTY_SJ	*0.822 (0.692, 0.977)*	**0.739 (0.632, 0.863)**
HOUSING_DTY_H	*0.956 (0.923, 0.991)*	**0.926 (0.892, 0.961)**
HOUSING_DTY_SJ	*0.969 (0.945, 0.993)*	**0.952 (0.929, 0.975)**
Household		
MOB_LICENCE_COUNT	0.854 (0.631, 1.157)	0.887 (0.697, 1.13)

Note: All associations are adjusted for respondent age group, gender, household car-ownership, and distance between home and school.
Odds ratios in **bold** are significant at $p < 0.01$, odds ratios in *italics* are significant at $p < 0.05$.

3.2. Fully adjusted models for the home and school journey environment

After investigating the initial associations between the variables selected to depict the conceptual domains of Mitra's model, we ran fully adjusted models separately for the home and school journey environments. These are presented in Table 3.

In the final model concerning the home environment, significant associations persisted for the domains of proximity and personal safety. The longer the distance between home and school, the less likely children and young people were to walk or cycle to

Table 3
Fully adjusted multinomial regression models between neighbourhood and route environments and school journey transport mode

Model	OR (CL 95%)	
	Walk to school	Cycle to school
Neighbourhood environment		
DIST_CROW	**0.993 (0.990, 0.995)**	**0.997 (0.996, 0.998)**
GENDER	1.681 (0.564, 5.007)	**2.889 (1.289, 6.475)**
AGE_GROUP	2.603 (0.539, 12.574)	**6.512 (2.019, 21.006)**
BUILD_DTY_H	**0.019 (0.002, 0.226)**	**0.001 (0.000, 0.017)**
School journey environment		
DIST_CROW	**0.993 (0.991, 0.995)**	**0.998 (0.996, 0.999)**
GENDER	1.380 (0.413, 4.607)	*3.281 (1.282, 8.396)*
AGE_GROUP	3.932 (0.622, 24.865)	**12.370 (2.792, 54.806)**
OWN_CAR	1.085 (0.372, 3.168)	**3.910 (1.715, 8.914)**
MAJOR_RD_DTY_SJ	0.500 (0.188, 1.334)	**0.192 (0.070, 0.528)**
INTERSECT_DTY_SJ	0.990 (0.956, 1.024)	1.027 (1.000, 1.056)
PUBL_TRANS_DTY_SJ	*0.774 (0.607, 0.986)*	**0.659 (0.528, 0.824)**

Note: Odds ratios in **bold** are significant at $p < 0.01$, odds ratios in *italics* are significant at $p < 0.05$.
Referent groups for age and gender are 8th graders and girls.

school. Interestingly only the density of the built environment was significant in the final model in spite of the large number of potential variables related to the urban environment. Increasing building density around the home decreased the likelihood of walking and cycling. In addition, the specific qualities of each child, namely, its gender and age, were closely associated with cycling in particular.

The final model for the school journey environment showed more significant associations, for proximity, traffic safety, and connectivity-related variables. Longer distances between home and school decreased the likelihood of choosing active transport modes. The effect of growing distance does not seem very significant based on the odds ratios, but it must be noted that only the respondents with distances from one to three kilometres were included, and thus an increase of one unit (km) cannot produce very large odds ratios.

As expected, the greater the incidence of major roads near the route, the less likely the respondents were to cycle to school. The association with walking to school here was not however significant. Intersection density was significant for the model in general, but could not differentiate between the active transport modes. The odds ratio for the variable concerning the density of public transportation stops along the school journey was 0.659 in relation to cycling, which implies that for each unit increase in the number of bus stops per kilometre of the route, the odds that cycling was the mode chosen decreased by 34%.

Gender and age group were associated with cycling. The younger age group was 12 times more likely to cycle to school compared to the older one, and boys more likely to cycle than girls. Also car-ownership in respect of the household was significantly associated with the transport mode. Interestingly, the more cars there were in the family, the more likely the respondents were to cycle or walk to school.

The fully adjusted model for the school journey environment predicted the transport mode choice correctly in 72% of cases. It succeeded particularly well in predicting cycling and non-active travel behaviour, whereas walking was less likely to be predicted correctly. The fully adjusted model for the home environment was less successful in making the correct predictions (62%), but notwithstanding this, the model's prediction rate was better than the proportional by chance accuracy rate of 35%, specified for the data at hand.

In Fig. 2, the environmental variables significant in the fully adjusted models are depicted on a series of maps. The first map shows the transport modes and the actual school journeys drawn by the respondents as well as the building densities in their home environments. The three remaining maps depict the urban characteristics of the school journey environment that were associated with walking and cycling. The lowest rates of walking and cycling to school can be seen in Helsinki city centre and the surrounding urban core areas (the south-eastern part of the region) as well as in the area where the main north-bound motorway and the ring road meet (central north area on the map). These areas and the pattern between transportation modes and the environmental variables is clearly visible on the map depicting the major road densities around school journeys, but also the other maps illustrate similar patterning.

4. Discussion and conclusions

In this article, we studied the ways in which the surrounding environment could impact or promote different types of physical activity on school journeys, using the conceptual model proposed by Mitra (2013). Of the domains proposed in the model, proximity, connectivity and traffic safety seemed to be the most relevant in the Finnish context. The associations were more significant when the environment of the school journey was studied than in the case of the home environment. Interestingly, many of the associations present in the partially adjusted models were in contrast to what had been suggested in the context of previous research.

As such, the question thus arises, can the results presented in this article be compared to those generated previously, particularly when we have dropped those subjects living closest to school and those using predominantly active modes from our analysis. While not presented in this article, we also ran the partially adjusted multinomial regressions for all the respondents living within 3 km of their school. These analyses showed no change in the directions of the associations but substantially fewer significant associations. This is understandable, for within 1 km of the school, nearly all the subjects walked or cycled, and hence we would not expect to find an association between the different environmental factors based on those few who had opted for inactive modes.

In their review, Ding et al. (2011) found residential density and land-use mix to be consistently associated with transport physical activity among both children and young people. Our findings however contrasted somewhat with this general conclusion: where increasing residential density and building use mix decreased the likelihood of engaging in AST. Subsequent to the carrying out of our own research, others have found a greater land use mix to be negatively associated with children's walking to school. Su et al., (2013) suggest this might be due to the diverse landscape resulting in more people on the streets and a more disorganised built environment. It is, moreover, possible that the uses selected for the analysis are simply not relevant in respect of children's mobility; and that rather than looking at residential, commercial, office and institutional land uses, an even mix of which has been shown to promote activity in the adult population, we should instead examine other types of land use. This is further emphasised through the notion that dense built environments, often associated with commercial, institutional and office land uses, decreased the likelihood of walking and cycling in this study.

All the partially adjusted models with significant associations to the transport mode showed associations in the same direction, the increase in the variables decreasing the likelihood of walking or cycling being chosen. The only exception was the proportion of single family housing. We reason that actually all of the physical environmental variables used measure at some level the same

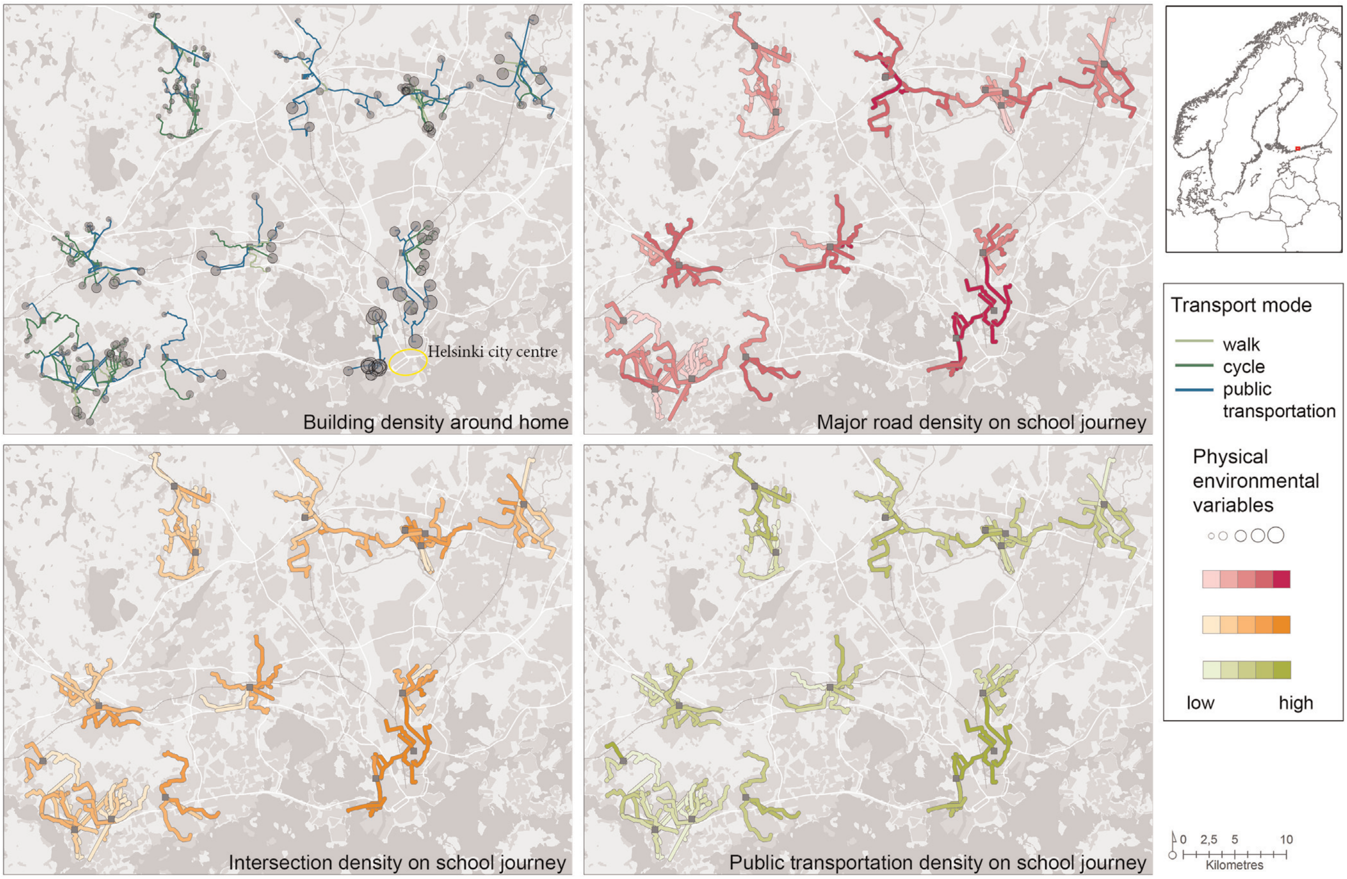

Fig. 2. The higher overall densities of the physical environmental variables significant in the fully adjusted models are reflected in less AST near Helsinki city centre.

thing, urbanity, which in the Helsinki region comes with a well-functioning public transportation network. While the proportion of single housing is associated with smaller blocks and thus possibly a more agreeable walking and cycling environment, the public transport options available are also fewer in number. In addition, the share of longer distance school journeys was slightly larger in the more remote areas of the study regions, but notwithstanding this engagement in active transport is more common. Thus it seems that public transportation options are the key to understanding the mode choices of the students. To further this reasoning, our finding about more cars in the household promoting a greater number of school journeys by cycling contrasts significantly with the conclusions of previous research and what it says in general about the mobility options of the household and the actual mobility. This again may simply be a reflection of the reduced number of public transport options available in the more remote areas of the region which is, in turn, reflected in greater car density.

Finnish children and young people are, in terms of international comparisons, very independent in their mobility (Kyttä et al., 2014), and indeed the use of non-active transport did not necessarily mean being driven in a car, but included also independent use of the public transportation system. When considering the physical activity that can be generated on school journeys, high modal shares for public transportation might seem to be an issue, though some physical activity occurs when walking to the transportation stops. Thinking of the mobility issues in more general terms, learning to use public transportation from an early age could see this become a habit thus reducing the need for private car usage. Indeed, it would be interesting to conduct further research on whether those children and young people who have used public transportation rather than walked or cycled have a smaller propensity to become drivers as they grow up into adulthood. In addition, the amount of physical activity undertaken by those students using public transport also constitutes a potentially interesting area for future research.

Referring back to Mitra's conceptual framework, the strongest support there was for the domain of proximity i.e. the distance to school. Longer distances between home and school decreased the likelihood that active transport modes would be chosen. On distances shorter than one kilometre nearly everyone engaged in AST. In this light, much could be done to increase the perceptions of traffic and personal safety or comfort in respect of walking and cycling by means of planning, but maintaining the neighbourhood school network, despite the economic pressures to centralise educational provision, might be the most effective urban planning strategy to support AST (see also Su et al., 2013) in urban contexts that are already relatively supportive of AST.

We operationalised the suggested domain of personal safety with building volumes, based on the assumption that big buildings related to large retail centres or employment districts may discourage AST. Indeed, the bigger the building densities around the home, the less likely the respondents were to take part in AST. We suggest that rather than relating to a reduced sense of personal safety due to big building volumes, the negative relationship between building density and AST relates to better public transportation availability in these densely built areas.

Building density was, interestingly, the only physical environmental variable, apart from distance, persisting in the fully adjusted model for the home environment. In general, the home environment showed significantly less associations with transport mode choice than the environment *en route* to school.

Generalising the environment affecting people's mobility and transportation choices into buffers surrounding the home may not however be a suitable way to grasp the elements of the environment meaningful for an individual. Indeed, most children were found to use only 25% of the area buffered along the road network within 800 and 1600 m of their home (Villanueva et al., 2012), or only a narrow section of the circular buffer around their home (Yin et al., 2013). Rather than using assumed neighbourhoods then, future research should instead concentrate on the actual environments the respondents use, and explore the associations of these environments with mobility behaviours.

The domain of maintaining social capital was somewhat awkwardly operationalised as the population density near the home and *en route* to school, due to the limited nature of the data available on the social attributes of the environment. It should however be questioned whether population density is a good representation of the ability to maintain social capital, as the relationships involved here could be diverse and not linear. Nevertheless, previous research in Finland has shown that population density around children's meaningful places increases both the odds for active transport to be used while also stating a positive emotional assessment of the place (Broberg et al., 2013), perhaps supporting the use of population density. Concentrating more on the actual environments where this mobility is enacted, be it on school journeys or to other meaningful places, might also help to tackle this problematic domain. Panter et al., (2008) have also discussed how possible motivational elements on the school journey, such as a friend's house or shops to visit *en route* or parks to play in, might influence the travel mode. Indeed, empirical evidence from a small study using mobile phones and GPS devices to understand children's perceptions of their school journey (Pooley et al., 2010) supports this view of the importance of the child's own motivation to move in the environment, as it was found that pupils who travelled independently were most likely to engage with their immediate environment.

Methodologically we tried to tackle head on the challenges posed by AST research outlined by Wong et al. (2011). Such issues here include the need for accuracy when geocoding the subject's home location and estimating the school journey route based on road network data. We have tried to overcome these problems by letting the subjects pinpoint their home and draw the route taken. The accuracy of the geographical data produced by children and young people can of course be questioned, but generally there have been no real problems in geographical accuracy in our datasets concerning children, possibly due to orienteering being part of the school curriculum. The mapping application also helped children to orientate on the map by automatically panning the map to the school selected from a drop-down list. In addition, Wong et al. (2011) raise the issue of inconsistency in applying the measures of the built environment, which we have tried to minimise by using the measures developed in previous research. Similarly, we also identified the problem of overlapping buffers creating high correlation in the built environment data between subjects. By only including the subjects with school journeys in a certain range, the data became significantly more dispersed. Finally, again as suggested by them, we have used as spatially disaggregated data as possible, which in the Finnish setting is quite easy, as there are spatial datasets concerning for example each building instead of statistical unit aggregates.

It might be argued that the two age groups included should have been studied separately, as it is hypothesised that the travel behaviours of children and young people are different (Mitra, 2013). However, as Finnish children are notably independent in mobility terms from their early years, we found it reasonable to analyse the age groups jointly. Nevertheless, in future research including wider groups of children, the potential impact of age differences should be taken into account.

Acknowledgements

We wish to thank the schools that participated, the headmasters, teachers and pupils there, as well as research assistant Tiina Laatikainen, who organised the data collection at the schools. Dr. Frans Sijtsma from the University of Groningen provided the initial idea of restricting the analysis to respondents within a certain distance of the school. Two anonymous reviewers provided valuable insights which influenced the final version of the article. The overall project was led by Professor Ari Hynynen from Tampere University of Technology and Professor Marketta Kyttä from Aalto University. The project was funded by the Finnish Ministry of Education and Culture.

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