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Children's travel to school—the interaction of individual, neighbourhood and school factors

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ABSTRACT

The increase in average distance from home to secondary school over recent decades has been accompanied by a significant growth in the proportion of pupils travelling to school by motorized means as opposed to walking or cycling. More recently this switch in travel mode has received considerable attention as declining levels of physical activity, growing car dependence and the childhood obesity "crisis" have pushed concerns about the health of future generations up the public health agenda, particularly in the U.S., but also in the UK and Europe. This has led to a proliferation of international studies researching a variety of individual, school and spatial characteristics associated with children's *active travel to school* which has been targeted by some governments as a potential silver bullet to reverse the trend. However, to date national pupil census data, which comprises annual data on all English pupils, including a *mode of travel to school* variable, has been under-utilised in the analysis of how pupils commute to school. Furthermore, methodologically, the grouped nature of the data with pupils clustered within both schools and residential neighbourhoods has often been ignored - an omission which can have considerable consequences for the statistical estimation of the model. The research presented here seeks to address both of these points by analysing pupil census data on all 26,709 secondary pupils (aged 11–16) who attended schools in Sheffield, UK during the 2009–10 school year. Individual pupil data is grouped within school, and neighbourhood, within a cross-classified multilevel model of *active* versus *motorised* modes of commuting to school. The results support the findings of other research that distance to school is key, but suggest that sociospatial clustering within neighbourhoods and schools is also critical. A further finding is that distance to school varies significantly by ethnicity, with white British pupils travelling the shortest distance of all ethnic groups. The implications of these findings for education and transport policy are discussed.

1. Introduction

In the mid-1980s the mean distance travelled to school by 11–16 year olds in the UK was just over 2 miles; by 2013 this had almost doubled, increasing to 3.7 miles (Department for Transport, 2013). This lengthening of the high school commute has been influenced by some of the urban-structural processes which have occurred over the past 50 years. Firstly a marked increase in the size of high schools, which began in the post-war decades (Rigby, 1979) has resulted in secondary schools drawing their pupil intakes from wider catchment areas on average. Second, the suburbanisation and decentralisation which has occurred in many cities has dispersed some school-aged children to family housing in low density new-build housing estates on the outskirts (Hoare, 1975), which involves both longer travel distances and an urban form that favours car use (Dieleman et al., 2002, Newman and Kenworthy, 2006). A third factor that has also influenced the length of children's journey to school is legislation promoting parental choice, which has encouraged the selection of out-of-area schools (see for example Parsons et al., 2000, Hoare, 1975). In recent studies it has been estimated that less than half of all school-age children in England now attend their nearest school (Allen, 2007, Ferrari and Green, 2013).

These changes in the spatial configuration of schools and urban space have been accompanied by significant social change such as the rise of the dual-working family and growing private car ownership, a corollary of increased household affluence. These have occurred over a period that has seen the cost of car travel decrease in real terms compared to other forms of transport (especially following deregulation and privatisation of public transport which occurred in the 1980s (Fairhurst and Edwards,

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1996)). The rise in volume of road traffic associated with increased private car use has also led to rising concerns about road safety, which has in turn contributed to decreasing child independence and increased parental surveillance. Parental strategies to cope with this dual challenge often most conveniently involve driving children to school *en route* to work.

All of these factors have combined to produce a highly complex pattern of travel from home to school characterised by, and enabled by, growth in the use of motorised forms of transport. According to 1975/6 National Transport Survey data for Great Britain, 55% of all secondary school pupils walked to school, and 7% travelled by car (Rigby, 1979). By 2012 only 38% of pupils aged 11–16 years walked to school and 26% travelled by car (Department for Transport, 2013). In 1975–6, walking was the selected mode of travel for 93.6% of all "education" trips under 1.6 km (approximately 1 mile), exemplifying the key underlying constraint on modal choice: distance.

Notwithstanding the effect of distance, the choices that children (and their parents) make with regards to school commuting may depend crucially on the interaction of several factors operating at a number of levels. Neighbourhood-level factors, which include characteristics of the urban form and structure, may have a range of direct and indirect effects on travel behaviour. School-level factors, most notably variations in the 'performance' of schools and the socioeconomic composition of their pupil intake, may influence school and residential location choices, thereby potentially circumscribing travel options and average travel distances to school. Individual-level characteristics, such as age, have a relationship to the extent to which children will countenance or be empowered to choose active forms of travel. The relationship between factors at these different levels is likely to be very complex: individual pupils are simultaneously 'members' of their neighbourhood and the school they attend, and models of travel behaviour may be underpinned by both fixed (e.g., age, gender) and random effects (e.g., distance to school).

The aim of this paper is to specifically consider the interaction of these effects in explaining the travel mode of choice for secondary school children in Sheffield, UK. A typical UK city characterised by a high degree of self-containment, significant social variation between schools and neighbourhoods, and a highly heterogeneous set of pupils within the context of a 'loosened', non-hierarchical spatial relationship between home and school locations. The findings are important for policy makers aiming to maximise the use of active forms of transport (e.g. for public health reasons) or to minimise car use (e.g. for environmental or congestion reasons) and suggest that policy efficacy is likely to be highly contingent on contextual factors, not only of individuals but of the schools they attend and the neighbourhoods they live in.

1.1. Structure of the paper

The paper is organized as follows: Section 2 highlights some of the shortcomings of the literature in this area to date. Data and Methods, are described in Section 3, and the Results of the multilevel models are presented and discussed in Section 4. The concluding remarks and policy implications are outlined in Section 5.

2. Active commuting: definition and correlates

The majority of the literature on commuting to school focuses on walking and cycling, which are generally referred to as "active" modes of transport. This term is often used in an oppositional, dichotomous sense which either explicitly states (see for example Lee et al., 2008), or implies that modes of transport such as travelling by car, bus, or train are totally "passive" or "non-active" (see for example Sirard and Slater, 2008, Voss and Sandercock, 2010). However, this is not necessarily the case, particularly with regards to public transport where users walk to and from bus or tram stops or train stations (Rissel et al., 2012). Yet, whilst it is acknowledged that the degree of activity involved in different modes of transport can be conceptualised as a continuum, which itself has significant policy implications, data considerations in the present study mean that we generally classify journeys into those that are predominantly "active" or "motorised".

There is now a burgeoning international literature on active commuting to school, particularly from the US, in the wake of a childhood obesity 'epidemic', which has shone a spotlight on school commuting as a potential ameliorative agent that could provide children with a regular daily dose of physical exercise (Banerjee et al., 2014). Although there are considerable differences between the case of the US and Europe in terms of local geography, school-siting, the level of car dependency and the proportions of children walking and cycling to school, the dramatic decrease in active commuting witnessed across North America in recent decades is one possible future scenario in the UK.

A wide range of factors have been found to be associated with active school commuting. Stewart's (2011) review of 42 studies found 480 correlates including: distance to school, family income (access to private transport), concern about traffic and crime *en route*, parental views on walking, cycle use and family timetables. Urban form has both a direct effect on mode of travel choice and, by influencing parental opinion, an indirect effect. The urban form factors Stewart (2011) identified from other studies include:

- Active transport *infrastructure*-pavements, safe crossings, cycle paths;
- *Barriers* such as *major road or railway crossings* encountered en route;
- Network *connectivity*-local streets, route choice, cul-de-sacs;
- *Land use* mix-residential (populated) versus industrial, parks, derelict land;
- Residential *density* – increased numbers of people, "eyes on the street";
- *"Walkability"*-aesthetic environment (greenery, trees, etc).

The evidence of the impact of urban form is broadly mixed and is likely to be highly context specific. Kemperman and Timmermans (2014) found that Dutch primary school children were more likely to walk (though not necessarily cycle) in more urbanised neighbourhoods, although the relationship between factors is complex and the impact of environmental characteristics may be indirect (in that distance, for example, is a function of density). Schlossberg et al. (2006) found that the density of road junctions and cul-de-sacs in a neighbourhood, as proxies of 'walkability', were significant predictors of walking rates among middle school pupils in Oregon. Urban form explanations can only be partial, however. Stead (2001) found that individual and household-level socioeconomic factors were more important than urban form in explaining travel patterns, although no attempt was made to predict travel mode.

The literature is further complicated by the impact of age on the results. It is widely understood that age is a significant correlate of active commuting (see for example Aarts et al., 2013, Johansson et al., 2012). However, previous studies comprise a wide range of subject age-groups, which preclude systematic comparison. There has tended to be a focus on younger children, who often have less independence (Mammen et al., 2012) and who live closer to school on average. English primary school children aged 5-10 live 1.6 miles from school on average, compared to 3.7 miles for 11–16 year olds (Department for Transport, 2013). In order to minimise the potential effect of parental supervision and variations in the extent children may be allowed autonomy, this study focuses on high school children aged 11–16.

Much of the literature focuses either on individual-level predictors of commuting behaviour or on the effect of physical neighbourhood characteristics (urban form). Given that both strands of research appear to claim at least partial success in explaining mode suggests that there are important interaction or multilevel effects that arise from pupils' multiple membership of non-hierarchical groups (e.g. households, schools and neighbourhoods simultaneously). Although multilevel methods have been employed to investigate children's mode of travel to school in the Netherlands (Aarts et al., 2013; Bere et al., 2008), Australia (Trapp et al., 2012) and Belgium (D'haese et al., 2011), to the best of the authors' knowledge this is the first piece of research to use this technique in the UK. This is important because there is a need for country-specific studies given substantial differences in education policy, urban policy, and levels and forms of urbanisation (Kemperman and Timmermans, 2014, Sirard and Slater, 2008).

Aarts et al. (2013) found that low SES neighbourhoods were negatively correlated with active commuting but that high social cohesion and perceived social safety (among other factors) were positively associated with walking and cycling. D'haese et al., (2011) used multilevel modelling to allow for clustering within schools, but (probably due to small sample size) no school-level factors were entered into the model. Despite the inclusion of neighbourhood environmental factors such as aesthetic quality in the model, no clustering by neighbourhood was undertaken. Trapp et al. (2012) also adjusted for clustering within schools but not for pupils living in different residential neighbourhoods (which vary 'substantially' by socioeconomic status p.173). The issue of cross-classification where pupils from different neighbourhoods attend the same school is not addressed. Although neighbourhood walkability factors such as street connectivity and traffic volume are in the model, they are attached to the school rather than area of residence. Bere et al. (2008) also took clustering between schools but not neighbourhoods into account, despite finding significant differences in school commuting patterns by ethnicity. Therefore although the above studies have used components of multilevel models they have not taken into account patterns of autocorrelation through sociospatial segregation of residential areas into account.

3. Data and methods

The research design conceptualises pupils as having (multiple) membership of both schools and neighbourhoods thus they are grouped within both. The relationship between schools and neighbourhoods however, is complex, with pupils from one neighbourhood attending many schools, and pupils within a single school potentially hailing from many different neighbourhoods. Pupils also possess personal socioeconomic characteristics (age, gender, and ethnicity). A cross-classified multilevel model is constructed to estimate the factors that best explain the variance in pupils' 'active' and 'motorised' commuting to school using a binary logistic function.

Analysis was performed on all pupils aged 11–16 attending a state-funded secondary school (including academies) in 2009-10 in Sheffield, England, a relatively self-contained city dominated by state school provision[1]. In our dataset, the neighbourhood-level proportion of pupils who attend their nearest school[2] was on average 48.8% (median=48.3%), but varied considerably (min=0.0%, max=95.2%, σ=27.3%). It is clear that children attending schools that are not their nearest is very widespread, validating the selection of a cross-classified model in which pupils are members simultaneously of schools and neighbourhoods.

A linked database comprising tables on pupil, schools and neighbourhoods was created. Anonymised data on pupils was supplied by Sheffield City Council within a strict data-sharing agreement. Pupil variables included: school attended at the time of the relevant pupil census[3], age, gender, ethnicity, eligibility for free school meals (FSM), a special educational need (SEN) flag for SEN-statemented or "School Action Plus" (as these two categories may affect the choice of school), together with the geographical coordinates of pupils' residential location and attended school. Importantly, the data included a variable recorded at a single timepoint on pupils' mode of travel to school. This variable was mandated in pupil census data by the Department for Education from 2008–9 to 2010–11. The principle advantage of the variable is its sub-population coverage which comprises the vast majority of pupils. Its disadvantages lie in having been recorded at a single point in time with little by way of contextual information. Most significantly, the variable does not represent the variability of home-school travel by direction of travel, potential variation through the week, or seasonal change. Although one US study of pupils aged 9–15 found that, for those children who lived less than a mile from school, the majority of pupils who commuted to school by active means one day a week did so for all five days (Martin et al., 2007), this cannot be verified in the present case. The data were reality-checked by local authority officers who expressed concern that cycling is probably under-represented because the survey is undertaken in winter when daylight is minimal and weather conditions can be severe. Consequently, we do not disaggregate walking and cycling in our results. It should also be noted that data collected in a classroom situation may be affected by peer-group dynamics or 'social desirability' bias (Millward et al., 2013). Several research designs, such as those incorporating the use of GPS tracking or travel diaries (DfT, 2013) can overcome these limitations, but at the cost of sacrificing the scale of data collection. The use of survey data, such as the British Household Panel Study/Understanding Society allows more socioeconomic context but the sample size would not be large enough to analyse local neighbourhoods and the role of school-specific or urban form factors. Consequently, it was concluded that despite several significant shortcomings the value offered by capturing usual mode of travel at the individual level offered significant analytical advantages.

The pupil table comprised 26,709 pupils linked to 100 different 'neighbourhoods' and attending one of 27 different state secondary schools in Sheffield. Following the exclusion of missing and unclassifiable data, 25,798 cases remained (representing a loss of 3.4% of the data). Even taking into account this data loss, the high level of study population coverage avoids problems such as sample bias endemic in many national sample surveys (see for example Mcdonald, 2008). Furthermore the size of the study population and inclusion of all pupils resident within an entire local authority district enabled a multilevel analysis of all neighbourhoods and in this case, secondary schools across the city.

Data on the 27 schools came from the city council and the Department for Education's *EduBase2* web portal. Variables included: the proportion of pupils in the school eligible for free school meals (the FSM rate); the proportion of pupils recorded as

[1] In 2009–10, 3.8% of children in Sheffield attended an independent school, compared to an England average of 7.2% (Department for Education, 2010). Schools, Pupils and their Characteristics. London., table 10a; 6.3% of schools in Sheffield were independent, compared to an England average of 9.7% (*ibid*., table 10b).

[2] As measured by walking network distance, not crow-fly distance.

[3] Late January 2010.

having any special educational need (SEN rate); the proportion of pupils from black and minority ethnic backgrounds (BME rate); the proportion of pupils for whom English was an additional language (EAL rate); mean school Key Stage 4 results (proportion of eligible pupils achieving five GCSEs at grades A*-C, including English and Maths); and the faith status of the school (Christian/secular).

Neighbourhood characteristics were drawn from the 2011 Census and other small area data. In order to avoid small cell sizes within the multilevel model (see below), census output areas (OAs)[4] were aggregated into 100 neighbourhoods previously delineated by Sheffield City Council for policy analysis (Thomas et al., 2009). A bespoke weighted house-price index was also created using Land Registry's data on property sales (sales were pooled for the period 2007–2011 and seasonally adjusted to overcome small cell counts).

For each pupil, their route to school for both active and motorised modes was modelled using ArcGIS Network Analyst 10.1. Route distances from home to school were calculated using the Ordnance Survey Integrated Transport Network (ITN) for Sheffield, including the new Urban Paths layer on the basis of shortest route. These layers were downloaded from Digimap (Edina, 2014). Assumptions were made about overall walking speeds (2.5mph) and driving speeds on different types of roads at peak commuting times to determine the route. The calculation of walk-specific distances (using urban paths as well as roads) is an important innovation that overcomes significant limitations of previous research by allowing model variables to more closely replicate actual walking behaviour among pupils.

Several urban form variables which previous research had identified as being related to commuting mode of choice (Schlossberg et al., 2006) were also created for Sheffield local authority district. These included: residential density (calculated from Office for National Statistics postcode directory data), building density (from Ordnance Survey MasterMap), cul-de-sac density, road junction density and network junction density (including junctions with urban paths)-all of which were calculated from Ordnance Survey Integrated Transport Network layers using techniques described in (Reference Suppressed for Review).

Table 1 shows the frequency of the usual mode of travel variable for Sheffield pupils aged 11–16. This variable was recoded into a dichotomous variable representing "active" (walking or cycling) versus "motorised" (bus, car, taxi, tram, train) modes of commuting to school for the purposes of analysis. Local advice from council officers working with schools indicated that the method of administration for this question had varied across schools and time, resulting in inconsistencies in the quality of data recorded over the 3 year period it was collected. It was suggested that the optimal year for data quality and robustness was 2009–10[5]. Therefore this was the year selected for cross-sectional analysis.

Several groups of cases were removed from the analysis. 643 cases in the 'other' category, which might refer to active or motorised modes, were removed from the analysis. These cases primarily related to pupils from three schools, suggesting that there were localised problems in the administration of this question. To avoid potential bias these cases were excluded. A further 265 cases in the 'walk' category were found to involve estimated distances greater than 3 miles, and therefore potentially indicative of an inaccurate home address. These cases were also removed from the analysis. The three mile cut-off was used as it would take approximately one hour at a sustained walking pace in an urban environment, and is also the point at which children of secondary school age are allowed to claim a free bus pass from the local authority. An hour's walk has also been used as a reasonable cut-off point for walking to school by other researchers (Mcdonald, 2008).

Table 1
Categories for the "usual mode of travel" variable 2009–10.

'Usual' mode of travel	***N***	**%**	**Notes**
'Active' modes	13,352	50.0	
Walk	13,310	49.8	Excludes 265 cases (see below) whose distance from home to school was > 3 miles
Cycle	42	0.2	
'Motorised' modes	12,446	46.6	
Bus–Public service	5392	20.2	
Bus–School service	2386	8.9	
Bus–Unknown type	1030	3.9	Likely to be a mixture of public, school bus and minibus for pupils with SEN.
Car	2644	9.9	
Carshare	441	1.7	
Taxi	93	0.3	
Tram	454	1.7	
Train	6	< 0.1	
Excluded from analysis	911	3.4	
Other-not known	643	2.4	Potentially mixed active/motorised modes but primarily from 3 schools—unclassifiable.
Missing data	3	< 0.1	
Walking unlikely	265	1.0	Pupils whose journeys were 3+ miles from home—inaccurate home address?
Total	26,709	100.0	

Sheffield has a number of ethnic communities, many of which comprise small numbers of people who are very unevenly spatially distributed. Therefore for the purposes of analysis within the multilevel model it was necessary to aggregate the detailed ethnic categories provided in the pupil census data into four very broad categories: white British, white other (e.g. EU, Irish), non-white and "not known" in order to avoid the problem of common support (see below).

3.1. Correlation among school-level variables

A significant degree of inter-correlation was found among the school-level variables, especially BME and EAL rates (0.97), FSM and SEN rates (0.79), as well as the SEN and EAL rates (0.59) - all of which were significant at $p=0.01$. Conversely, the school performance results at Key Stage 4 (GCSE-level) were found to be inversely correlated with both SEN (−0.74), FSM (−0.79) and, to a lesser degree with EAL rates (−0.17). A variable was therefore created to represent "cumulative" disadvantage at the school level by summing the FSM, SEN, and EAL rates (as BME and EAL so highly correlated). However this was not found to be significant and was dropped from the model at an early stage.

Faith schools were found to have lower rates of pupils eligible for free school meals (FSM), a proxy for deprivation ($t=4$, d.f.$=4$, $p=0.05$). This may in part be due to the higher degree of control some faith schools have over their pupil selection criteria (Allen, 2007).

3.2. Correlation among neighbourhood-level variables

Significant correlations were also found across a range census data at the "neighbourhood" level. In particular, the proportion of

[4] Of which there were 1817 in Sheffield in 2011.

[5] Personal communication with council officers working directly with schools collecting the data.

people in an output area with *no access to a car or van* was found to be highly correlated with other local indicators of socioeconomic disadvantage such as: unemployment (0.91), the rate of people in basic (low skilled) occupations (0.89), household occupancy (overcrowding) (0.80), and the proportion with no qualifications (0.73). Given these correlations and previous research findings that lack of access to a car '… is the best single indicator of relative deprivation' (Voas and Williamson, 2001, p. 73), this indicator was selected as a key variable measuring socioeconomic disadvantage for entry into the model.

3.3. Urban form variables

The importance of urban form variables is underscored by the distinctive geography of Sheffield. Although England's fourth largest city, it is relatively self-contained with an over-bounded administrative geography. The city comprises a diversity of urban archetypes ranging from dense inner-city terraces to very spacious suburban neighbourhoods and semi-rural villages. The city's topography is hilly, which is likely to have an impact on travel mode choice. For these reasons, it was considered important to include a range of urban form variables in the model. The degree of correlation found among the urban form variables (residential density, population density and building density) was also found to be significant. Cul-de-sac density, and network junction density were also correlated. Small but significant correlations were also found between distance to school and the majority of the urban form variables, which were tested through the addition of interaction terms in the model.

3.4. A multilevel model of travel mode

A multilevel model was constructed in which the dependent variable was mode of commuting to school, dichotomised into *active* versus *motorised* means of transport. A multilevel model was appropriate because of the grouped nature of the data (Duncan et al., 1996). The data violates the underlying principle of standard ordinary least-squares regression models of independent, uncorrelated observations. In this case pupils are socially and spatially grouped within both neighbourhoods and schools. If grouping is ignored, this can result in an underestimation of the standard errors of regression coefficients, which means that statistical significance could be over-estimated (Centre for Multilevel Modelling, 2007). In the cross-classified multilevel model employed here pupils from the *same neighbourhood* can attend *different schools*, while pupils in the *same school* can come from *many different neighbourhoods* (Fig. 1).

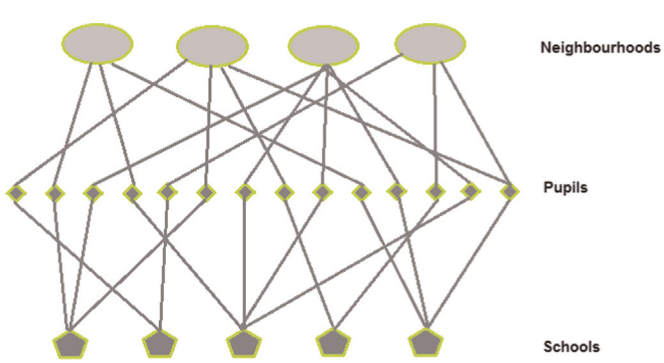

Fig. 1. Schematic diagram of a cross-classified multilevel model showing non-hierarchical membership of neighbourhoods and schools.

3.5. Model estimation and model fit

Models were estimated using the Markov Chain Monte Carlo (MCMC) Bayesian technique (Leckie and Bell, 2013), with initial estimates calculated using iterative generalised least squares (IGLS) as starting points for the MCMC estimation. The Deviance Information Criterion (DIC) diagnostic was used to assess parameter significance and the "goodness of fit" of the model (Browne, 2005). This diagnostic criterion balances overall model fit with parsimony by penalising for model complexity (Reference Suppressed for Review). A general rule of thumb is that a reduction in the DIC of more than 5 implies a variable is significant to the overall model (CMM, 2007). All models were estimated using MLwiN (Centre for Multilevel Modelling, 2014). The significance of the regression coefficients for fixed effects were compared and formally tested using the Wald test in MLwiN, which produces a χ^2 statistic. Random parts of the model, however, such as the between-neighbourhood and between-school variances were tested by observing the reduction in the DIC (Leckie and Bell, 2013). A "null" model was estimated with individual pupils grouped within the two higher level classifications-neighbourhoods and schools, but with no explanatory variables (after Leckie and Bell (2013)). Both of the higher-level variance components – (within school) *between-neighbourhood* variance and (within neighbourhood) *between-school* variance—were found to be highly significant (reducing the DIC by -5989 and -7831 respectively, thereby confirming the appropriateness of a cross-classified multilevel model.

3.6. Small cell sizes

One issue with complex multilevel analysis is that the number of individuals (pupils in this case) is broken down into numerous categories such as school, neighbourhood, age, gender, ethnic group, SEN status and so on which quickly results in small cell sizes. Consequently variables such as detailed ethnic categories and very small areas were aggregated up into larger groups and neighbourhoods in order to ensure there were enough pupils in each category to undertake statistical estimation. However, the small number of pupils in some categories still restricted further exploration of certain variables—such as the interaction between pupils with an SEN flag and gender, detailed ethnic background and gender.

4. Results and discussion

4.1. Some descriptive statistics

The network distances between home and school ranged from less than 100 m to 21.7 km (13.5 miles), although the data are very skewed (see Fig. 2 below). The mean distance for all pupils was 2.7 km but the *median* home-school distance was just over 2 km. The median home-school distance for pupils who walked to school was 1.33 km (mean 1.38 km) and for those who used motorised modes the median was 3.1 km (mean 3.9 km). For pupils living less than one mile from school, 82% walked, although this represents a very substantial decline over the last three decades when compared to over 94% of high school pupils aged 11–17 in 1975/6 (Rigby, 1979). Despite this decline, walking rates in Sheffield are slightly higher than the national average, with just under 50% of high school pupils recorded as walking to school (Table 1), compared to 38% across Great Britain (Department for Transport, 2010).

The results of the final model are presented in Table 2. The most significant explanatory components in the model are between-school variation, between-neighbourhood variation and

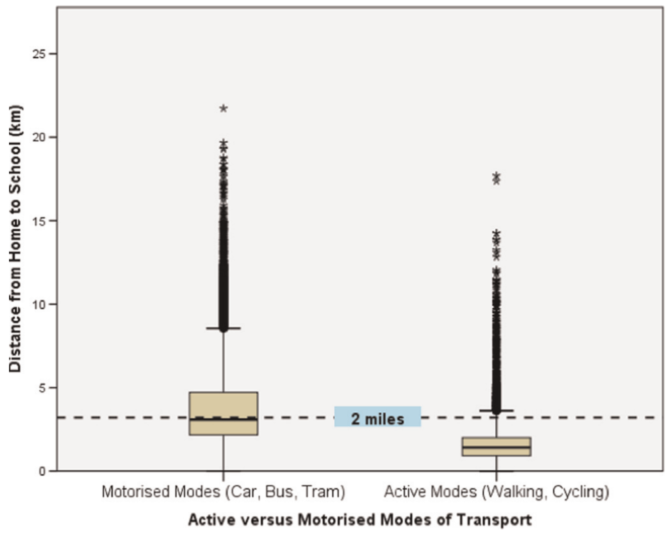

Fig. 2. Boxplot of active versus motorised modes of travel to school. Note–Fig. 2. includes pupils who lived more than 3 miles away from school who were recorded as "walking", most of whom were excluded from the data (see Table 1).

Table 2
Results of the final cross-classified multilevel model.

Variable	Regression coefficient	Standard error	DIC	Difference in model fit (DIC)
Baseline DIC*(individual pupil)*			**35,733**	
Random Components				
(Within school) Between neighbourhood variance			29,744	−5989
(Within neighbourhood) Between school variance			24,912	−4832
Fixed variables				
Constant (intercept)	+2.09***	0.39	24,913	
Distance home–school (km)	−2.32***	0.163	20,729	−4184
Gender:				
Female (ref. cat)	+0.168***	0.035	20,712	−17
Male				
Age (11-16)	−0.189***	0.026	20,696	−16
Ethnic Group:		(altogether)	20,548	−148
Not known	−0.29	0.243		
White British (ref cat.)	−0.286	0.15		
White EU/Irish	−0.727***	0.056		
Non-white (all)				
Individual SEN Status [Statement or *School Action*+]	−0.671***	0.147	20,530	−18
IA: Age × Distance to School	0.066***	0.014	20,503	−28
IA: Distance × Cul-de-sac density	0.301***	0.078	20,474	−29

*** significant at $p=0.001$

distance from home to school. The improvement in model fit which resulted from the inclusion of these variables far outweighs that of the other significant variables. This finding highlights the high levels of autocorrelation that exist across residential space as well as within educational institutions, and the consequent importance of taking the *sociospatial clustering* of individual pupils into account in any examination of school travel patterns. Studies such as those using survey sample data that do not group pupils into neighbourhoods and schools may miss these higher-level effects and may have led to the over-estimation of the proportion of variance explained by individual and urban form variables.

4.2. Route distance from home to school

After taking sociospatial clustering within schools and neighbourhoods into account, distance from home to school was found to be by far the strongest predictor of motorised travel, reducing the DIC by 4184.[6] This confirms findings from international studies on travel to school in the U.S. and Sweden (Johansson et al., 2012, Mcdonald, 2008) and earlier studies in Britain (Rigby, 1979). As implied by the boxplot in Fig. 2 above, the mean distances for active (1.5 km) and motorised (3.9 km) travel were significantly different ($t=-98$, df= 25796, $p=0.000$, variances tested equal). The mean distance from home to faith schools was significantly greater (3.45 km compared to 2 km for secular schools at $p=0.000$), which is unsurprising given that the two Catholic High Schools in Sheffield don't have nominated *de jure* catchment areas and therefore take pupils from across most of the city.

4.3. Gender

More boys walked or cycled to school than girls (the reference group). This finding accords with those studies reviewed by Stewart (2011) where gender effects were identified. Although girls travelled slightly further to school (2.72 km) than boys (2.67 km) on average, this difference was not found to be statistically significant. However, further exploratory analysis showed a significant difference between the proportion of girls and boys who attended a faith school[7] ($\chi^2=$ 11.9 at 1 degree of freedom, $p=0.001$).

Excluding the two faith schools from the analysis, significantly fewer girls walked and significantly more girls travelled to school by car (including car-sharing). Previous research has highlighted gender differences in the level of independence granted to children by parents (Hillman and Adams, 1992) which may involve more restriction in public spaces and a higher level of supervision (Stewart, 2011). Giving a child a lift rather than allowing them to walk affords them less freedom to roam and provides increased opportunity for parental surveillance. Johansson et al. (2012) also found that Swedish boys were significantly more likely to cycle than girls. Among the tiny number ($N=42$, 0.2%) of pupils who cycled to school in the study population[8] the ratio of boys to girls was over 4:1.

4.4. Age

Age was found to be positively correlated with distance travelled to school. Significant differences were found between the mean for 11 year olds (2.5 km) and older children-14 year olds (2.74 km, $p=0.01$) and 15-16 year olds (2.83 km, $p=0.001$). So

[6] Alternative models were also specified, including one in which distance to school was allowed to vary. However, this and several other specifications could not be computed because the existence of a negative definite V matrix, most probably caused by the inclusion of continuous explanatory variables. These variables and interactions between them were considered important hypothetically and were therefore retained; future work could consider experimentation with different categorical and non-linear explanatory variables.

[7] Possibly due to the use of academic and other selection criteria among these schools.

[8] Which may have been at its lowest in late January when the data was recorded due to short daylight hours and cold or inclement weather.

pupils aged 14–16, on average, travelled further to school in 2009–10. This is due to a cohort effect as the school choices available in Sheffield when the children aged 14–16 in 2009–10 *started* high school (i.e. 2004–2006) were different from those available to pupils aged 11 in 2009–10 due to a planned school closure.

An interaction term *age* × *distance to school* was created in order to take account of this interaction. Once this interaction term was added into the model an *inverse* relationship between age and walking to school was observed. This means that older high school pupils were less likely, on average, to walk to school compared to 11–12 year olds *once distance to school was taken into account*. This may be partly due to the well-documented increased changes in sleep pattern associated with puberty (Carskadon, 2011, Foster and Kreitzman, 2014) putting pressure on time in the mornings for teenagers.

4.5. Ethnic group

The mean distance between home and school was tested for different broad ethnic categories using analysis of variance (ANOVA) with a post-hoc Scheffe test (Table 3). All other ethnic groups for which data were available were found to have travelled significantly further to school than white British pupils in Sheffield in 2009–10.

Exploring variation in mean distances to school using the more detailed ethnic categories uncovered significant heterogeneity among pupils from Sheffield's different ethnic communities (Table 4). Of particular note is the fact that pupils from Black ethnic groups travelled the furthest to school, at 4 km and over, compared to an average of 2.5 km for white British pupils. Further analysis found that this was driven by a higher propensity for pupils from the Afro-Caribbean and 'African–Other' groups to attend a Christian faith school, which has also been noted by other researchers (Weekes-bernard. 2007). Somali pupils, however, did not attend Christian schools, probably due to Islam being their main religion of their community - yet on average these pupils travelled the furthest of all. This may be partly due to the clustering of the Somali population in particularly deprived neighbourhoods in inner-city locations[9] with access fewer schools nearby.

4.6. Interaction between gender and ethnicity

A chi-squared test of mode of travel by gender by ethnic group indicated that fewer girls from certain ethnic groups were recorded as actively commuting to school. Among pupils of Asian descent, significantly more girls travelled by car compared to boys ($\chi^2=23$, d.f.$=11$, $p=0.05$), although no significant difference was found in distance from home to school for Asian boys and girls. In some cultures girls may be perceived as more vulnerable or as requiring greater 'protection' than boys. For example, Weekes-bernard (2007) presents the concerns of several ethnic minority parents specifically with regards to escorting their daughters to school.

4.7. Special educational need status

Until now, special educational need does not seem to have been included or described as a relevant explanatory factor in studies of travel to school. However, the flag for SEN-statement or "school-action plus" status, which applied to 457 pupils in this dataset, was found to be significantly *inversely* associated with walking or cycling to school. A *t*-test on mean distance to school showed that these SEN pupils travelled significantly further than non-SEN pupils (means of 3.9 km and 2.7 km respectively). As mentioned above, children with these types of SEN may be required to travel further in order to access schools which are equipped to support their particular needs. Although male pupils with this SEN flag outnumbered girls by 3:1, it was not possible to add an interaction term between individual SEN status and distance to school or gender into the multilevel model due to small pupil numbers.

[9] Following the arrival of many of their parents in Sheffield as refugees in need of social housing.

Table 3
Mean distance to school by broad ethnic category.

Ethnic category	*N*	Mean distance from home to school (km)
White British (Reference group)	20,890	2.5
"Not known"	142	2.75*
Non-white	5224	3.38***
White Irish/EU	453	3.45***

* Significant at the 0.05 level;
*** Significant at 0.001 level

Table 4
Distance to school by detailed ethnic group.

Ethnic group–detailed categories	*N*	Distance to school (km)
White British	20,890	2.50
Not known	142	2.75
Other e.g. Yemeni	568	2.84
Mixed-White and Black	709	3.00
Asian Pakistani	1459	3.05
Mixed-White and Asian	526	3.10
Romany	27	3.24
White Irish/EU etc	453	3.45
Asian-other	717	3.64
Black-Afro-caribbean	243	**3.97**
Black-African: Other	435	**4.27**
Black-African: Somali	440	**4.35**

4.8. Urban form variables

Although there has been a significant focus on the impact of urban form factors on commuting behaviour in recent years, the model presented here suggests that urban form only explains a very limited amount of the variation between pupils who commute by active and motorised means. The only urban form variable which was found to be significant was the density of cul-de-sacs (no-through roads). Analysis showed that taking account of distance to school, pupils who lived closer to school in areas of high cul-de-sac density, were more likely to engage in active commuting. This finding is *in opposition* to findings from some studies in the US (see for example Schlossberg et al., 2006) and likely reflects the differences in the detailed layout of suburban archetypes. In the US dead-end roads are typically not through routes for pedestrians. However, post-war suburban expansion in Sheffield, in common with many English cities, was based on variants of the "Radburn" principle (Womersley, 1954), where road cul-de-sacs exist alongside a traversable network of walking routes.

4.9. Variables not in the model

The proportion of households without access to a car or van was found to be of borderline significance (it reduced the DIC by only 4) with an inverse relationship to walking or cycling to school. This implies that pupils living in areas with less access to private transport were in fact *more* likely to use motorised travel.

However, as outlined above, area levels of no/low car access have been found to be correlated with core indicators of deprivation (Voas and Williamson, 2001), and further exploration using analysis of variance (ANOVA) exposed an interaction between ethnicity and levels of car ownership/access. Black Somali children were found to live in the most "deprived" neighbourhoods as indicated by the lowest levels of car access[10]. As noted above, Black Somali pupils travelled the furthest to school on average. Pupils from the lowest car access neighbourhoods were significantly less likely to cycle or walk, take a dedicated school-bus (many of which serve faith schools), to car-share or take a tram, and *more* likely to more likely to travel by car, use a public bus or bus of "unknown type", or travel by "other" means.

Pupil eligibility for free school meals (FSM status) was not found to be significant and school faith status and mean school GCSE performance (Key Stage 4 statistics) were not found to be significant over and above the *between school* variation in the model at the higher level.

5. Discussion and policy implications

The findings in this paper suggest that the predictors of active school commuting are complex and conditioned by neighbourhood- and school-level factors as well as individual or household characteristics. Initiatives promoting active commuting through, for example, transport and urban design improvements will have only limited effect if societal and sociospatial structures oblige some groups of pupils to commute long distances-yet this is the corollary of policies promoting school choice. The mismatch between education and transport policies has been discussed with reference to the air quality impacts of school choice by Marshall et al. (2010); this study provides further evidence of the mismatch that can arise from school choice programmes.

It is also important to acknowledge that the home-school commute is at the juncture of a number of different policy areas. Joint working across education, housing and health policy domains as well as transport will be essential to make any real impact in terms of modal shift to active commuting, transport sustainability and associated future budgets for transport subsidies. For example, in terms of *distance to school*, optimal school-siting within appropriate population centres, school size, residential planning and development and policies on parental choice are all key factors. Policies on selective schools such as grammar and denominational schools are also implicated, as these often draw students from much wider catchment areas (Rigby, 1979, Taylor, 2002, Parsons et al., 2000).

Currently many educational policies are working in opposition to sustainable transport goals of local travel and low carbon cities by driving system-wide patterns of 'excess commuting' (Horner, 2002) to more distant schools. Such policies may also run counter to public health objectives to increase physical exercise among children and reduce exposure to environmental pollution. Policies aimed at promoting active travel that do not recognise the intermediate benefits of modal switch to public transport (e.g. buses and trains) may be unrealistic in a context of further school decentralisation, consolidation, and parental choice. A key priority, therefore, is to ensure that transport planners who aim to encourage modal shift from private to public transport do not miss the opportunity to work *in tandem* with public health officials to focus on the benefits of public transport as a 'mixed-mode' form of commuting which comprises both active and motorised components.

The core findings of this study are that mode of travel (active versus motorised commuting) is socially patterned within both schools and neighbourhoods. Rates of active commuting vary primarily by school, neighbourhood, and with the length of the home-school commute. Furthermore distance to school has been found to vary by pupil age and ethnic background. Motorised/active transport has been shown to vary by age, gender, ethnicity and parental views on child independence and the need for escort (which may be related to perceptions of neighbourhood safety).

In order to be successful, it is likely that transport policy goals need to be grounded in the everyday reality of pupils' travel to school which includes taking account of route distance to school, family schedules, parental concerns about road safety, neighbourhood safety and child safety. And importantly, given that transport choices vary by neighbourhood, pupil gender, age and ethnicity, blanket policies across entire schools or cities may not be appropriate. In their stead more flexible and responsive measures need to be developed that aim to meet the expressed need of individual communities. For example, the possibility of organising appropriately chaperoned walking school buses specifically for girls might be explored jointly with some ethnic communities, where education escort is gender-biased. At the very least, it suggests that detailed transport planning associated with schools needs to recognise these factors. Whilst education planning in England does require an element of cooperation with transport planners at the individual school level (e.g. through the production of statutory school travel plans), it is likely that better links between education, health, transport and land use policies (for housing planning) are needed at the 'macro' (e.g., city-wide) level. While the government's Travelling to School Initiative had some success, its evaluation found that improvements to child health were far from transformative—one barrier, according to local stakeholders, being that travel distances implied by increased school choice (DfE and DfT, 2010). Notably, revised statutory guidance for school travel planning in England has resulted in a less prescriptive framework aimed at better reflecting 'the requirements of today's dynamic and increasingly autonomous schools system' (DfE, 2014, para 2.1).

In the context of the considerable distances that some children travel to school, walking all the way to school is unlikely to be realistic aim (Mcdonald, 2008). Mixed-mode objectives may be more appropriate in such circumstances: for example, campaigns that encourage bus commuters to "walk an extra stop", possibly in combination with behavioural change incentives linked to bus fare structures. On the other hand, educational travel subsidies may provide perverse incentives, such as families deliberately opting for more distant schools in order to qualify for a subsidised bus pass. More in-depth, qualitative research into the reasons that children travel long distances to school would be helpful to shed light here.

Given the importance of socioeconomic factors associated with distance travelled to school and modal choice, it is likely that transport policies will impact differently on the educational outcomes of diverse sub-populations. Transport is not simply reacting to 'demand' but rather an integral to societal frameworks of opportunity and constraint within which education choices are articulated. Increased pressure on public funding has already led to the withdrawal of discretionary transport funding such as free bus passes for children attending faith schools in some areas (Sheffield City Council, 2014). Since such schools may provide a viable alternative route to higher-performing schools for low-income families (Ferrari and Green, 2013), it seems likely that such decisions would disproportionately affect those families and contribute to worsening educational inequalities.

[10] Probably due to the historical placement Somali refugees into social housing in central areas of the city.

6. Conclusion

This paper has demonstrated that a range of individual pupil, school-level and neighbourhood level factors are associated with walking or being driven to school. Consistent with other studies, the distance between home and school is found to be the most significant *individual-level* factor by far, although there are important correlates of distance that suggest systematic socio-economic variation in the geography of school commuting. At a time when less than half of all English pupils attend their nearest school, rates of active commuting are likely to decline further. Given the public health benefits of increased active commuting among children and reduced "excess" commuting by motorised means, serious consideration is needed of the implications and contradictions between education policies that promote parental choice, public health policies seeking to reduce childhood obesity/ increase levels of physical activity, and environmental policies aimed at reducing pollution and promoting sustainable transport.

6.1. Limitations and future research

The key limitation to studies of the type reported in this paper is the lack of hard, measured data on the *actual* journeys to school made by pupils. As noted at the outset, the model of travel variable employed in this study has several limitations, although at present it remains the most appropriate means by which travel mode can be analysed within individual level models. It is important to note that the question was removed from the School Census after 2011, limiting the potential for future work in this area. Any future studies aiming to consider the determinants of school travel behaviour aimed at evaluating the impact of competing national policies would benefit from the systematic inclusion of a small set of pupil-level school travel indicators within the pupil census data. There remains scope to further develop the specification of multi-level models to ensure that they are robust.

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