Transportation (2013) 40:69–90
DOI 10.1007/s11116-012-9410-0

Quantifying the transport-related impacts of parental school choice in England

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Published online: 2 June 2012

Abstract School travel is becoming increasingly car-based and this is leading to many environmental and health implications for children all over the world. One of several reasons for this is that journey to school distances have increased over time. This is a trend that has been reinforced in some countries by the adoption of so-called 'school choice' policies, whereby parents can apply on behalf of their child(ren) to attend any school, and not only the school they live closest to. This paper examines the traffic and environmental impacts of the school choice policy in England. It achieves this by analysing School Census data from 2009 from the Department for Education. Multinomial logit modelling and mixed multinomial logit modelling are used to illustrate the current travel behaviour of English children in their journey to school and examine how there can be a significant reduction in vehicle miles travelled, CO_2 emissions and fuel consumption if the 'school choice' policy is removed. The model shows that when school choice was replaced by a policy where each child only travelled to their 'nearest school' several changes occurred in English school travel. Vehicle Miles Travelled (VMT) by motorised transport fell by 1 % for car travel and 10 % for bus travel per day. The reduction in vehicle miles travelled could lead to less congestion on the roads during the morning rush hour and less cars driving near school gates. Mode choice changed in the modelled scenario. Car use fell from 32 to 22 %. Bus use fell from 12 to 7 %, whilst NMT saw a rise of 17 %. With more

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children travelling to school by walking or cycling the current epidemic of childhood obesity could also be reduced through active travel.

Keywords Schools · Mode choice · Vehicle miles travelled · Fuel consumption · CO_2 emissions

Introduction

Millions of children all over the world travel to and from school daily, and an increasing proportion of those journeys are made by car. Meanwhile the number of children actively travelling to school is decreasing (Buliung et al. 2009; McMillan 2007). In the UK the 'school run' is the term to describe the traffic generated by parents driving their children to school each morning and collecting them from school in the afternoon. It has been claimed that the school run traffic causes congestion in residential areas, increases carbon emissions and makes the area around schools unsafe for children as a result of increased cars parked on side roads, cars driving fast, and dependency on car use leading to health problems (Pike 2003).

Whilst often providing positive benefits for individual car users, such a trend has also been linked to a whole range of negative impacts that tend to worsen over time for society more broadly. These include: impacts on personal health (e.g. through increased levels of obesity as a result of reliance of car travel); on the environment (due to deteriorating air quality, and increased CO_2 emissions); and rises in traffic and congestion (Valsecchi et al. 2007).

The reasons for these circumstances will be explored in more detail in the subsequent sections. However, the basic premise of this paper is that one factor in the UK context that has led to increased car use on the roads has been the introduction of an education policy which seeks to improve standards by enabling parents to choose the school that their children go to, instead of requiring that children attend the school nearest to their home.

Consequently the aim of this paper is to quantify the transport-related impacts of allowing parental choice of schools on personal travel behaviour, on traffic levels, fuel use, and CO_2 emissions, and to explore the wider implications on public policy. The next section will review the factors affecting travel behaviour of the school run and the following section will provide a brief explanation of the school choice policy in practice. The subsequent two sections will set out the data and method used. This is followed by the presentation of results. Next, interpretations and discussions of the results are provided, while the final section draws conclusions.

Factors affecting travel behaviour of the journey to school

Travel behaviour of parents and their children in terms of trip characteristics (i.e. mode choice, journey length and cost) during the journey to school can be influenced by several contributing factors. These include various area factors (e.g. income deprivation and road density). In addition, personal factors (such as age, gender, ethnicity, income and attitudes) as well as policy choices put in place by the national and local government affect travel behaviour of the journey to school.

Applying discrete choice modelling, Müller et al. (2008, p. 342) investigate area level factors influencing pupil's mode choice and state that "[journey] distance strongly influences the travel-to-school mode choice, because students switch from modes appropriate for short distances like cycling to modes appropriate for longer distances like public transport". Marshall et al. (2010, p. 1540) also employ a multinomial logit model and find that when a child's school is close to home (approximately 1 mile) the likelihood that they will walk increases, but "the odds of walking decline rapidly at longer travel distances: for travel distances greater than 1.6 km". Schwanen and Mokhtarian (2005) report that the type of area a child lives in greatly influences their travel behaviour in which children living in more urban areas were more likely to cycle or use public transport than those from more rural areas. This is primarily due to the availability of public transport services, better cycling infrastructure and shorter distances between a child's home and their school.

Using a discrete choice model, researchers report that household structure and parental factors play a vital role in how children travel to school (e.g. Gliebe and Koppelman 2005; McDonald 2008; Ahlport 2008). For instance, children are less likely to walk to school when parents work (O'Fallon et al. 2004). Gliebe and Koppelman (2005) state that parental employment directly influences how a child travels to school, noting that the younger a child is, the more likely they are to be dependent on their parents to drive them. Research carried out by McDonald (2008) highlights the significant impact a working parent had on a child's travel behaviour. His study reveals that the likelihood of children walking or cycling to school decreased when their mother commuted to work, yet this was not the case for children whose mother did not work outside the home. There was less direct impact on travel when the child's father worked outside the home. Ahlport (2008) adds that time management such as their work schedule or the need to transport siblings to other schools can be some of the barriers to allowing their children to walk or cycle to school as opposed to driving them.

There are several personal factors that contribute to school travel (Fyhri and Hjorthol 2009; Pont et al. 2009). For instance, both age and gender are found to have a strong influence on travel to school as independent mobility increases with age and that boys are often more independently mobile than girls (Fyhri and Hjorthol 2009). Pont et al. (2009) have also noted a significant relationship between a child's ethnicity and household income with their level of active travel. Their study justifies that this is likely to be due to a higher income resulting in car ownership and higher car use in the household.

The DfT (2009c) finds that age for example, can dramatically impact mode choice in school travel. In 2008/09, for a journey of 1–2 miles to school 62 % of children under the age of 11 used the car as their main mode of transport, whereas 62 % of children aged 11 and older walked this distance to school. For journeys over 5 miles, 69 % children aged 10 years and younger made this journey to school by car compared to only 22 % of children aged over 11 years in Great Britain.

Gender is also a key factor in how children travel. In 2008/09 22,000 trips by bicycle were made by males under the age of 17, compared to 9,000 females travelling by bicycle; while 61,000 trips were made on local buses by males under the age of 17 compared to 71,000 by females under the age of 17. These independent variables strongly influence on how children travel to and from school.

Policy too, can greatly affect school travel. For example, the free bus fare policy in London allows children between the ages of 5 and 18 years to travel on all buses and trains (both underground and over ground) at no cost with a valid 'Oyster' smartcard. According to Transport for London (TfL), since introducing the free travel scheme in 2005, the number of car journeys has fallen by 6.4 % which they claim is the equivalent to 3.3 million annual car journeys or nearly 7.5 million miles (TfL 2010). Less direct perhaps, are the implications of policies in other sectors. One such example is the so-called 'school choice' policy, whereby parents are encouraged to choose what they see to be the most appropriate school for their children to attend.

It can be seen from the above studies that the primary factors affecting school travel behaviour are residential location, socio-demographic characteristics (e.g. age, gender, ethnicity) and household structure (e.g. whether parents are in employment, household income, car ownership). This study will further investigate whether these factors have an effect on mode choice of children travelling to school while analysing school census data from England.

School choice policy and its impact on travel behaviour

In many countries across the world 'school choice' policies have been established which allow parents to choose to send their children to any school instead of being restricted to sending their children to the school closest to their home (O'Shaughnessy 2007; Barrow 2002). The rationale for this approach is that encouraging schools to become more diverse and to compete with one another for students raises the quality of education provided across the sector as a whole (Burgess et al. 2006) and proponents would argue this is what has happened. Burgess and Briggs (2010, p. 83) state that "doing well at school is helped by attending a good school" adding that originally only the children from richer backgrounds had access to better quality schools. In England the school choice policy was implemented from the 1980s and subsequently successive Governments of both major parties have continued along the increased school choice path, such that as of 2009 only 42.5% of pupils attended the school closest to their home (DCSF 2009). Moreover, this trend is set to continue (Burgess et al. 2007).

Interestingly, over the same period GCE 'A'-Level (i.e. the English High School national examination) pass rates have continually improved for 27 years in a row in England (Joint Council for Qualifications 2009) and the numbers of students applying for further education at universities have also continued to rise in England (UCAS 2009). This however may not necessarily be a direct result of school choice as there may be other factors which may have contributed to this such as the development of ICT (particularly the internet in schools) in education, improved facilities, better teacher training or more funding invested in education. Burgess and Briggs (2010) highlight the benefits of the school choice policy in England noting that it allows social mobility through children from poorer families able to access to higher quality schools without being restricted by where they live.

The UK Government published findings in 2005 that state the school choice policy has benefited schools across England between 1997 and 2005 by increasing funding to schools (by £16 billion) increasing the average pass rate of exams (by 11 %) and increasing the number of teachers in England (by 32,700). It also claims "To respond to parental demand, we need to expand choice, create real diversity of provision, and ensure that the benefits of choice are available to all" (DESF 2005, p. 20). However, there are also issues that have arisen. Thus Burgess et al. (2005) note that school choice can also lead to too much demand on certain schools forcing them to have to ration places.

Burgess et al. (2005) add that originally value of homes would increase around schools considered to be 'high quality' but with the introduction of school choice in some cases this has changed. Finally, the school choice policy may lead to lesser quality schools not being monitored or receiving the attention needed when parents can choose for their children not to attend them. Burgess et al. (2005) suggests there needs to be regulations or standards enforced to ensure this does not happen. Burgess and Briggs (2010) state that the policy also opens up to parents trying to 'work' the system to ensure their children attend a certain school and not necessarily following the rules as others. In England there have been some reported incidents in which parents had temporarily rented flats, used a friend's address or moved in with a relative in a particular catchment area to obtain a place at a specific school for their child (Curtis 2009).

As a result, it is likely that the children and their parents take advantage of the school choice policy (and so are usually not eligible for free bus travel) and that this school is outside of practical walking and cycling distances of 1–1.5 miles (Müller et al. 2008; van Sluijs et al. 2009) and therefore are increasing nationwide VMT and CO_2 emissions. Overall, several studies have been conducted that investigate the 'success' of 'school choice', but one area that does not appear to have been widely explored is the impact that the parental choice agenda has on travel patterns and the resulting impacts.

Two exceptions to this have examined these issues in detail, both in St Paul, Minnesota. Marshall et al. (2010) examined the effects of a school choice policy on CO_2 emissions using a multinomial logit model and determine that children travel further to school as a result of the school choice policy. They found that parental school choice significantly increased CO_2 emissions—by between four and seven times—in the area studied and that the number of children walking to school increased by eight times (Marshall et al. 2010). Wilson et al. (2007) also explored this and explain that changes in children's travel behaviour can result in considerable transportation and cost implications including pollution such as emissions. They found that in one example, if the bus was removed from school travel, cost, distance travelled and CO_2 emissions all rose by 4.5 times (Wilson et al. 2007). Therefore, as governments continue to push the school choice agenda, the time would seem right for assessing what the wider transport-related impacts of the policy may be as a consequence.

The school travel context in England

Before detailing the data used in this study, it is helpful to understand the current school and transport situation in the England and UK. In brief, in England in 2009 there were over 26,000 schools teaching more than 9 million school aged children residing in England, of which 7 million are of 'compulsory school age' (aged between 5 and 16 years) and are therefore required to attend school by law (ONS 2010). Of these schools, 21,695 were 'Government maintained' or 'state' schools which are funded through the auspices of a Local Authority (LA)—a part of local government. Specifically, LAs are responsible for local implementation of national policies and the raising of achievement and standards in schools (Fletcher-Campbell and Lee 2003). In total, there are 152 LAs in England which are responsible for spending roughly 13 % (in 2010) of local authority expenditure (Chamberlain 1980) going towards supporting pupils through help with travel to school of 'free school meals' in which children from poorer families are provided lunch every day at school. There are a variety of types of schools which exist in England. Most schools are funded by central Government. These include state or 'grant maintained' schools, academies (publicly funded but outside of Government control) and some publicly funded faith or denominational schools (Department for Education (DfE) 2010). There are also private 'independent' schools (confusingly also called 'public' schools) which are usually funded through parents paying fees. All these different types of schools normally follow the same curriculum as 'maintained' schools but are not funded directly from the local Government they are not included in the School Census and therefore are not covered by the statistics used in this study.

The 1944 Education Act states that the LA has a responsibility of aiding those living within certain distances of their nearest school (2 miles for primary school age and 3 miles for secondary school age) in the form of free transport (Headicar 2009). This is usually in the form of a bus pass, unless the pupil is considered to have special medical needs (SEN). Interestingly though, if pupils do not attend to the school closest to their home, the Education Act transport provision does not apply—an important point to note given that some 57 % of pupils in England no longer attend their nearest school.

The average number of trips made by walking has fallen from 292 in 1995/97 to 221 in 2008 (DfT 2009a). Car ownership has also risen from 17 % of households owning two or more cars in 1985/86 and rising to 32 % of households owning two or more cars in 2008 (DfT 2009b). It is only to be expected that school travel has followed similar trends of car use levels increasing whilst walking levels have fallen steadily. The Department for Transport (DfT 2009c) examines the changes in school travel in the last decade and the percentage change in children travelling to school and report that the number of children walking to school reduced by 6 % between 1997 and 2009, while the number of car trips rose by 2 % over this time. The percentage of pupils travelling to school by car notably rose between 1998 and 2002, however the percentage of pupils travelling to school by car has remained fairly steady in the UK between 2002 and 2009 (DfT 2009a).

Current traffic patterns suggest that traffic congestion increases during school term (i.e. during term time). Traffic volume in England on a normal weekday peaks between 8 a.m. and 9 a.m. in the morning and again between 4 p.m. and 6 p.m. in the afternoon (DfT 2009d). Most dramatically, at 8.45 a.m. some 18 % of the traffic on the roads is due to travel to school. At these times traffic is nearly double the average level due to commuting and trips to school (DfT 2009d). In 2008, there were 262 million vehicle miles travelled (VMT) by car in the UK (only around 3.4 m miles were travelled by bus), emitting over 59 tonnes of CO_2.

Of all this travel, trips to school by children (5–18 years) in England made up 11 % of daily personal trips. Of these, 41 % are by walking, 11 % by bus, and 45 % are made by car (DfT 2008). The average time spent per trip to school related journeys has risen from 11 min in 1995/99 to 13 min in 2008. The average trip length also increased in 2008 to 3.3 miles from 2.9 miles in 1995/97. As these journey lengths increase, so does the impact on transport related impacts such as traffic levels, fuel use, energy use and the environment.

Data used

The Department for Education (known as the Department for Children, Schools and Families until 2010) carries out the School Census (DCSF 2009) which is a survey of schools within the local authorities of England, and this data has been analysed for the purpose of this study. In 2009, the survey had a total of 7,484,001 students from 22,170 Government maintained schools in England. The details of each individual child are recorded including variables such as their main mode of travel to school, how far they travel whether they are entitled to free school meals, the distance to their closest school and basic personal and individual details such as age and gender. Interestingly the question asking their main mode of travel was only introduced in 2007, and the details of distance travelled to school was first used in 2009 to aid the Government in its school travel plan initiative. The distance to school is generated from the postcode of the child's to the postcode of the child's school (i.e. they are measured along the shortest available route along which a child, accompanied by an adult if necessary, may walk in reasonable safety). Only non-Government maintained schools are excluded from the survey.

Table 1 Modal share for the full dataset and five random samples

	Sample categories	Full dataset	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5 (used in this paper)
		Percentage share of mode					
Car	Car	26.1	26.3	26.9	26.1	26.7	26.7
Car share		2.9	3.1	2.8	2.8	2.8	3.1
Dedicated school bus	Bus	7.8	7.6	7.4	8	7.9	7.8
Public service bus		6.7	7.3	6.7	6.9	6.6	6.7
Bus (type not known		1.6	1.6	1.7	1.7	1.8	0
Walk	Non-motorised transport	50.5	49.8	50.2	50.5	51.3	51.3
Cycle		1.9	1.9	1.9	1.7	1.9	1.9
Train	Other public transport	0.5	0.5	0.5	0.5	0	0.5
Taxi		0.9	0.9	1	0.7	0	1
London underground		0.1	0.2	0.1	0.2	0.1	0.1
Metro tram		0.1	0.1	0.1	0.1	0.05	0.1
Other		0.7	0.7	0.7	0.8	0.9	0.8
Boarder		0.1	0.1	0.1	0.1	0.04	0

An analysis of the School Census 2009 reveals that only 42.5 % of children attend the school closest to their home. This suggests that a significant proportion of vehicle miles travelled (VMT) is generated as a result of children not travelling to their closest school, but instead travelling (usually by car) to a school further away from their home.

For the purpose of this study, a sample of 69,910 pupils was randomly selected from the Census population of 7,484,001 pupils. Due to the size of the dataset, an analysis for the whole sample population was not possible due to computing power and time constraints[1]; yet the random sample represents an accurate picture of the dataset as seen in the percentage share comparison of the pupil's main mode of travel in Table 1.

A random sample was taken using a simple random sampling process which means the selection probability of each unit is the same. This was tested five times (see Table 1) to ensure the distribution remained similar. Sample 5 was chosen for the final model. The Census dataset presented 11 different categories of transport (see Table 1) as the pupil's main mode of travel. Modal shares for some of these modes are very low and given the complexity of a choice model increases with the increase in choice alternatives (Train 2003), the 11 modes of travel have been combined into 4 mutually exclusive categories consisting of:

- Car (including travel by car and car sharing)
- Bus (including travel by dedicated school bus and public school bus)

[1] We have employed the statistical package—STATA and it took between 7 and 10 days to estimate a mixed logit model in a PC with 8 GB RAM and 3.2 GHz speed.

Table 2 Summary statistics of the variables used

Variable	Obs	Mean	Std. Dev.	Min	Max
Transport mode	69345	Car = 29.9 %; Bus = 14.7 %; NMT = 53.7 % and other PT = 1.7 %			
Trip characteristics					
Distance to current school (mile)	69910	1.296	2.091	0	161.2
Distance to nearest school (mile)	62783	0.5876	0.7728	0	24.12
Monetary cost of the trip (£)					
Cost of car (£)	69910	1.296	2.091	0	161.20
Cost of bus (£)	68472	1.179	0.121	0	1.2
Cost of NMT (£)	69910	0	0	0	0
Cost of other public transport (£)	69910	1.995	0.306	0	40.77
Personal characteristics					
Age (year)	69910	10.91	3.923	3	21
Gender (female = 1, male = 0)	69910	0.49	0.500	0	1
Free school meal (yes = 1, no = 0)	69910	0.15	0.355	0	1
IDACI score (range 0–1)	69910	0.23	0.186	0.006	0.996
Ethnicity					
Asia (excluding Chinese)	69910	0.083	0.276	0	1
Black	69910	0.043	0.203	0	1
Chinese	69910	0.003	0.056	0	1
Mixed	69910	0.035	0.185	0	1
White	69910	0.791	0.407	0	1
Other	69910	0.044	0.206	0	1
Roadway density (km/sq km)	69910	12.877	8.084	0	60

- Non-motorised transport (NMT) (including travel by walking and cycling)
- Other public transport (OPT) (including train, taxi, metro tram, London underground and other transport).

The School Census data is a survey of how children travel to school. For this reason, all references to journeys and travel only refer to the journey made by the individual child. Any travel made by their parents after the journey to school is complete is not considered in this study because the journey patterns or purpose of the parents is not available. As the aim of this paper is to quantify the transport-related impacts of allowing parental choice of schools on personal travel behaviour, traffic levels, fuel use, and CO_2 emissions; the modes of travel of walking and cycling have been combined into the category of 'non-motorised transport' as neither of these modes have a cost, produce CO_2 emissions or contribute towards vehicle miles travelled. Moreover, cycle trips only constitute 1.8 % of the total school trips.

Table 2 outlines the variables used in this study and how they will be employed in the modelling. The average distance to current school is 1.3 miles and this reduces to 0.6 miles for the case of the average distance to nearest school.

The data does not contain the exact income of each child's household, however, if pupils are eligible for free school meals (represented as FSM in the data) then their household meets a Governmental criterion for being a 'low-income household' and so the model will indicate a low income household from free school meal eligibility. Due to the nature of the data, we do not know the income of the household the children live in. For this reason the Income Deprivation Affecting Children Indices Score (IDACI) for the area a child resides in is used as a proxy for income. The score is between 0 (0 %) and 1 (100 %). The higher the IDACI score, the more deprived an area is. However, it is important to note that not everyone living in that area is necessarily deprived, but the circumstances of the majority of people living in that area contribute towards the score.

The cost of car travel was estimated through average cost of fuel per mile figures from the AA website (AA 2011). The cost for bus travel was obtained from the annual operating revenue per passenger journey (2009/10) on local bus services at £1.20 per vehicle mile (an average cost for London, English metropolitan and English non-metropolitan local bus services) which was sourced from Department for Transport Public Service Vehicle Survey (DfT 2009d) and was used in this case as a proxy for value. The mean figure is a result of modelling two types of bus users. Pupils who travel by dedicated school bus (DSB) are generally assumed to not pay for their bus travel (as a result of the home-to-school transport policy) and therefore their journey would cost the users nothing, whilst other pupils who travel via public service buses (PSB) pay either full or subsidised fares and have been modelled as paying £1.20. Combined these pupils give an average cost of bus of £1.179.

Road network data was obtained from the UK Ordnance Survey (2010), and road density was calculated based on this road network data (to calculate total road length in an area) and the size of the area used (i.e. Lower Layer Super Output Area, LLSOA). Road density equals total length of roads (miles) per area (squared miles). This has been added as proxy for land-use. Roadway density (km of road lengths per sq km of area where a pupil resides) has been included in the paper as a proxy for the level of public transport activities (as in areas of high road density public transport is generally assumed to be more available and accessible). This also serves as a proxy for geographical location (i.e. urban or rural) of the area where a pupil resides.

For the purpose of comparisons and recommendations in the discussion, Table 3 explains the assumptions made for the purpose of this paper used to derive the impacts from the scenario modelled from various academic and Government sources. The table is divided into the following sections of personal mobility, vehicle miles travelled (VMT) in England, fuel used in England and CO_2 used in England.

The DfT publishes the Road Transport Statistics of Great Britain detailing the average travel made by people each year. The details from this have been used to determine the personal mobility of people in England during 2009. By comparing the average personal miles travelled with the population of England in 2009 we can determine the miles travelled per person per year by car and bus. The DfT also publishes the annual National Travel Survey of household travel in the UK every year by mode of transport and journey purpose.

Using this data, the details of how people of England travel can be compared to average car and bus occupancy with the journey to school allowing VMT in England to be determined. A combination of publications from the Department of Environment, Food and Families (DEFRA 2008) and the Confederation of Passenger Transport (CPT 2005) give details of the average miles per gallon (mpg) of petrol and diesel used in cars and buses allowing for average fuel used in England to be obtained. The Department of Energy and Climate Change (DECC 2008) and the National Atmospheric Emissions Inventory (NAEI 2009) hold databases recording the average CO_2 emissions resulting from road transport and through comparison with the data above, allows for analysis of the CO_2 used and emitted in

Table 3 Assumptions made

Personal mobility (in England)		Source of data
Person miles (individual by car) road transport per year	5,849 miles	DfT (2009b)
Person miles (total car) road transport per year	298 billion miles	
Person miles (individual by bus) road transport per year	277 miles	
Person miles (total bus) road transport per year	17 billion miles	
VMT (England)		
Average occupancy (car trips to school)	2.0 persons per vehicle	DfT (2009a, 2008c)
Average occupancy (bus, all trips)	11.0 persons per bus	
Number of school days (UK)	190 a year	INCA (2009)
Fuel used (England)		
Average mpg petrol (car)	37 mpg	DEFRA (2008), Garner (2010) Personal communication, School of Mechanical and Manufacturing Engineering, Loughborough University (20.11.2010)
Average mpg diesel (car)	44 mpg	
Assumed car fleet characteristics	50 % petrol, 50 % diesel	
Average mpg diesel (bus)	7 mpg	
Tonnes fuel car (petrol) from road transport	12,547 Kilo tonnes	DECC (2008)
Tonnes fuel car (diesel) from road transport	5,785 Kilo tonnes	
Tonnes fuel bus (diesel) from road transport	1,268 Kilo tonnes	
Tonnes fuel all road transport	34,661 Kilo tonnes	
CO_2 Used (England)		
Tonnes CO_2 from road transport	121.8 million tonnes	
Tonnes CO_2 from all sectors	480.9 million tonnes	
CO_2 from petrol car per mile	129.7 g	NAEI (2007)
CO_2 from diesel car per mile	125.4 g	
CO_2 from diesel bus per mile	506.0 g	

England per school day. As limited information in this area is currently available, for the purposes of this study, it is assumed that all cars emit the same levels of CO_2. However, it is acknowledged that this is a generalisation for the purpose of this research, and that different makes of car in reality emit different levels of CO_2 as a result of different levels of fuel consumption, different engine sizes and travelling at different speeds.

Methodology

Figure 1 presents the methodology employed to quantify the transport related impacts of school choice in England. Data from the three different sources (i.e. the School Census 2009, the 2001 Census, and Road Network Data) were integrated using GIS.

A discrete choice model (either a multinomial logit model or a mixed multinomial logit model as discussed below) needs to be developed to show the relationship between mode choice and distance travelled by children travelling to their current school while controlling

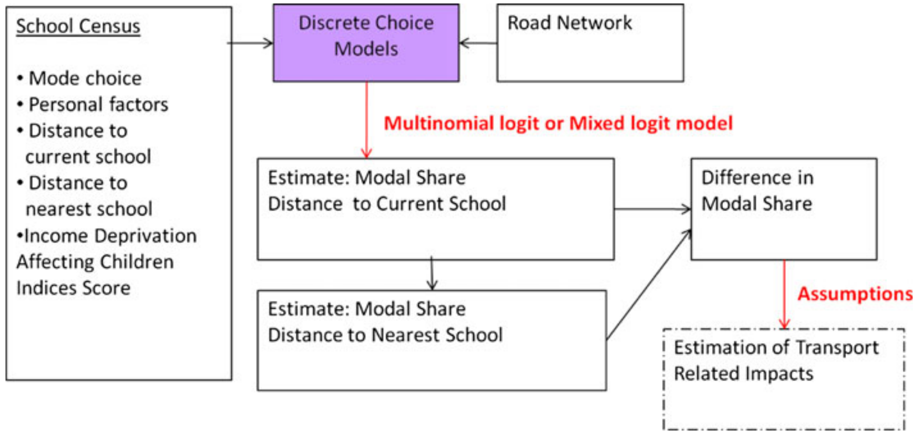

Fig. 1 Research methodology to quantify the transport related impacts of school choice

other factors such as: cost of travel, age, gender, ethnicity, proxy for household income (i.e. eligibility for free school meals and IDACI of multiple deprivation score for the pupil's neighbourhood) and road density. Roadway density (km of road lengths per sq km of area where a pupil resides) has been included in the paper as a proxy for the level of public transport activities (as in areas of high road density public transport is generally assumed to be more available and accessible). This also serves as a proxy for geographical location (such as urban, rural) of the area where a pupil resides.

The developed discrete choice model can then be used to estimate the modal share of the sample of the census data for children travelling to their current school. The same model can also be used to estimate the modal share of the same sample if all those children travelled to their nearest school. This can simply be achieved by replacing 'the distance to the current school' in the calibrated discrete choice model with 'the distance to the nearest school'. Table 4 can then be utilised to produce the differences that can be made if all children are to travel to the nearest school as opposed to their current school. As a result, one could quantify the transport-related impacts of allowing parental choice of schools on personal travel behaviour, on traffic levels, fuel use and CO_2 emissions. However, this does not take into account any 'unobserved factors'. Even if travelling to their nearest school some children may not change their mode choice. For example, if the child's nearest school was en route to a parent's workplace; it may still be seen to be more convenient to drive a child to school even though it is within a feasible walking distance, or the drive to school could be on the way to other destinations the parent is travelling to that day.

This paper adopts the multinomial logit (MNL) model and mixed multinomial logit (MMNL) model for analysing school children's mode choice, both of which have been widely used in modelling nominal response data. The MNL model can be written as (Long and Freese 2006):

$$\Pr(y_i = j) = \frac{\exp\left(\boldsymbol{\beta}_j \mathbf{X}_i + \gamma \mathbf{z}_{ij}\right)}{\sum_{m=1}^{M} \exp(\boldsymbol{\beta}_m \mathbf{X}_i + \gamma \mathbf{z}_{im})}, \quad \mathrm{j} = 1, 2, 3\ldots\mathrm{M} \tag{1}$$

$\mathbf{z}_{ij}$ is a vector of alternative specific variables for mode j and pupil i (cost in the case of this paper); γ is a vector of the effects of the alternative specific variables; $\mathbf{X}_i$ is a vector of pupil specific variables for individual i (such as distance to school, age and gender); $\boldsymbol{\beta}_j$ is a vector of pupil specific coefficients for the effects on mode j relative to the base mode. In this paper, the "car" is used as a base mode choice.

The standard MNL model has the assumption of independence of irrelevant alternatives (IIA). IIA effectively assumes that the choices (e.g. car, bus, NMT and OPT) for a child are independent to each other. If this assumption is violated the model estimation results may be biased (e.g. Long and Freese 2006). Moreover, the MNL model does not recognise taste heterogeneity in parameters. Therefore, a mixed logit model which can accommodate complex patterns of correlation among alternatives transport modes and unobserved taste heterogeneity among pupils (Train 2003), is employed in this research. It is able to simultaneously address a range of issues (Hensher and Button 2008). The mixed logit model can be expressed as follows:

$$\Pr(y_i = j) = \int \frac{\exp\left(\boldsymbol{\beta}_j \mathbf{X}_i + \gamma \mathbf{z}_{ij}\right)}{\sum_{m=1}^{M} \exp(\boldsymbol{\beta}_m \mathbf{X}_i + \gamma \mathbf{z}_{im})} f(\boldsymbol{\beta}) d\boldsymbol{\beta}, \quad j = 1, 2, 3 \ldots M \tag{2}$$

where $f(\boldsymbol{\beta})$ is a density function.

Some parameters of the vector $\boldsymbol{\beta}$ may be fixed or randomly distributed. The standard MNL model is a special case of the mixed logit model when $\boldsymbol{\beta}$ are fixed parameters. For random parameters, the coefficients $\boldsymbol{\beta}$ are allowed to vary over different pupils and assumed randomly distributed. In this paper the random coefficients are specified to be normally distributed, e.g. $\beta_1 \sim N(b, W)$ where b is the mean and W is the variance. Similarly, γ may also be specified as random parameters. A parameter is determined as random if the estimated standard deviation (SD) is statistically significant. Similarly some parameters of γ could also be considered as random.

Based on the estimated model, predictions for each pupil using different transport mode can be obtained. Market share for each of the four transport modes can be calculated using the following equation:

$$\hat{S}(j) = \frac{1}{N} \sum_{i=1}^{N} P_{ij}$$

where $\hat{S}(j)$ is the predicted share of transport mode j; N represents the number of pupils modelled; and P_{ij} is the predicted probability of pupil i choosing mode j.

Results and discussion

As discussed in the methodology, transport related impacts of school choice can be quantified by developing a discrete choice model for the prediction of modal share of pupils travelling to their current and nearest schools. Pupils are assumed to have the choice of four transport modes for travelling from home to school. MNL and MMNL models have been employed to develop a mode choice model. The dependent variable is mode choice of pupils travelling to school (car, bus, NMT and other public transport). Results from the MNL and MMNL models are presented in Table 4. Cost was calculated as 'alternative specific' but employed in the model as 'generic' as economists normally treat money as fungible: a pound (£1) is a pound irrespective to transport modes, no matter where it comes from. Cost could also be employed as 'mode-specific' to capture underlying preferences. However, alternative specific constants (ASCs) may capture such preferences in the case for the 'generic' cost model. Moreover, mode-specific cost variables may increase the level

Table 4 Model estimation results for MNL and MMNL model

	Multinomial logit (MNL) model			Mixed multinomial logit (MMNL) model		
	Coefficient			Coefficient		
	BUS	NMT	Other PT	BUS	NMT	Other PT
Alternative specific constants	−2.424**	0.2037**	−1.188**	−2.837**	0.5846**	−1.7878**
Cost (generic)	−2.566**			−2.4996**		
Pupil specific variables						
Distance	−2.478**	−4.1431**	−2.3383**	−2.2743**	−5.852**	−2.0669**
Age	0.3077**	0.1358**	0.1912**	0.3146**	0.1949**	0.1892**
Gender (female = 1, male = 0)	−0.0773**	−0.0898**	−0.1837**	−0.0892**	−0.0962**	−0.2048**
Free school meal (yes = 1, no = 0)	0.5679**	0.4051**	1.0031**	0.596**	0.4076**	1.09**
IDACI Score	1.6391**	0.8803**	0.6001**	1.6308**	0.9815**	0.6176**
Ethnicity						
Asia	−0.4383**	−0.4155**	−0.4482**	−0.4711**	−0.5602**	−0.5217**
Black	0.9386**	0.071	0.771**	1.0091**	−0.0392	0.8024**
Chinese	−0.5289**	−0.4129**	0.0911	−0.6298**	−0.4992**	−0.1122
Mixed	0.2876**	−0.0875*	0.4329**	0.3192**	−0.1405**	0.4413**
Other	0.6194**	0.2381**	0.8273**	0.6384**	0.281**	0.8181**
White (reference)						
Roadway density (km/sq km)	0.0047**	0.0098**	0.0078	0.0052**	0.0122**	0.0129**
Random parameters (S.D.)						
Cost (generic)				0.2619**		
Distance					1.7129**	
Statistics						
Pseudo R square	0.447			0.4734		
Log-likelihood at convergence	−51379			−48920		
Observations	67014			67014		

** Statistically significant at the 95% confidence level of complexity in estimating the model. Distance which is related to travel time was used as mode-specific. If the marginal cost of using a car to drive a child to school is (nearly) zero, then the cost of car travel should be recorded as zero, instead of something we calculated based on distance. However since we do not know whether this is the case (e.g. if the child's school is just on the way to parent's work place) nor any information on this, cost of car travel is calculated based on distance.

All models are estimated such that the car mode is the reference case and therefore coefficients are interpreted relative to choosing to travel by a car. While the MNL and MMNL models provide similar results in terms of the signs of the coefficients although the values are somewhat different. As expected, cost was found to be a disincentive. The MMNL model outperforms the MNL model significantly in terms of model goodness-of-fit. The pseudo *R* square of the MMNL model (0.47) is larger than the pseudo *R*-square of the MNL model (0.45). A likelihood ratio (LR) test has also been performed to compare the MNL and the MMNL models, and the result indicates that the inclusion of the random parameters (i.e. 'generic' cost and distance related to NMT) in the MMNL model significantly improves the model fit. Among the variables included in the model, both distance (associated with NMT) and cost can be considered as factors reflecting the individual perception and heterogeneity. For instance, some pupils are willing to travel longer distances by foot as their parents are more aware of benefits associated with health with walking. The perception of costs among pupils also greatly varies and the MMNL is able to pick up the fact that the impact of costs on mode choice is 'random' rather than 'fixed'.

Literature suggests that the mode choices made by pupils may change significantly as the children grow older, and in particular when they change from primary school to secondary school (Hillman 1993; Fyhri and Hjorthol 2009). In order to see whether this is the case in England, the whole sample (69,910 pupils) was divided into two parts: (1) all school children aged 10 or under (i.e. primary school) resulting in a sample size of 32,907 and (2) all pupils aged over 10 (i.e. secondary and Post 16) resulting in 37,003. The same mixed multinomial logit (MMNL) model has been re-estimated for these two separate age groups. Results are presented in Table 5. For completeness, the results of the original MMNL model (Table 4) are also reproduced in Table 5.

As we can see, MMNL results for two age groups differ to each other in terms of their parameter estimates and t-statistics. Generally results for pupils aged over 10 seem to be more consistent with MMNL model for whole population, compared to pupils aged 10 and under. For instance, distance is all negative and significant in Table 4, but this is not the case for pupils aged 10 or under (distance associated with OPT was positive but insignificant). This result appears to suggest that pupils in different age groups act differently in terms of transport mode choice.

As with the MNL model, the MMNL model is also a non-linear model, therefore to better understand the impact of distance on pupils' mode choice, the predicted probabilities of different transport modes are plotted against distance in Figure 2 (for a pupil aged 8, white male, without free school meal, IDACI score = 0.5, roadway density = 15). It is interesting to note that there is a notable inverted U-shaped relationship between distance travelled and the probability of travelling to school by car. As the figure shows, the probability of travelling by car increases if the distance is within 3.5 km, but decreases when distance is above 3.5 km.

As for age, as model 1 in Table 5 shows, the coefficients are all significant and positive for bus, NMT and OPT, suggesting that with age increasing, pupils are less likely to travel by car. This may be because as pupils' age increase, parents are more confident that their children can travel by public transport, walk or cycle safely.

Table 5 Model estimation results for different age groups

	Model 1: whole sample			Model 2: pupils aged 10 and under			Model 3: pupils aged over 10		
	Coefficient			Coefficient			Coefficient		
Mode of travel car reference	BUS	NMT	OPT	BUS	NMT	OPT	BUS	NMT	OPT
Alternative specific constants	−2.837**	0.5846**	−1.7878**	−3.8116**	2.6164**	−3.655**	−0.2877	−1.0861**	−0.5277
Cost (generic)	−2.4996**			0.3442**			−4.069**		
Pupil specific variables									
Distance[a]	−2.2743**	−5.852**	−2.0669**	−0.2660**	−4.7452**	0.0963	−3.7325**	−7.1578**	−3.4978**
Age	0.3146**	0.1949**	0.1892**	0.0689**	−0.0463**	−0.0814**	0.2639**	0.3297**	0.2804**
Gender (female = 1, male = 0)	−0.0892**	−0.0962**	−0.2048**	0.0098	0.004	−0.4514**	−0.1409**	−0.2645**	−0.1098
Free school meal (yes = 1, no = 0)	0.5960**	0.4076**	1.0900**	0.7575**	0.6054**	2.1925**	0.4992**	0.3912**	0.2981**
IDACI score	1.6308**	0.9815**	0.6176**	2.1559**	1.2644**	1.2878**	1.395**	0.4116**	0.3153
Asia	−0.4711**	−0.5602**	−0.5217**	−0.2094	−0.4087**	−0.0629	−0.5882**	−0.9274**	−0.6856**
Black	1.0091**	−0.0392	0.8024**	1.185**	0.0435	−0.0973	1.0204**	−0.1496	1.1652
Chinese	−0.6298**	−0.4992**	−0.1122	0.2239	−0.4119	0.6591	−0.8395**	−0.7621**	−0.2277
Mixed	0.3192**	−0.1405**	0.4413**	0.3531*	−0.0566	0.0599	0.3448**	−0.2437**	0.6554**
Other	0.6384**	0.2810**	0.8181**	0.5815**	0.0307	−0.332	0.5056**	−0.2987**	1.0915**
White (reference)									
Roadway density (km/sq km)	0.0052**	0.0122**	0.0129**	−0.0096*	0.0093**	−0.0311**	0.0121**	0.0118**	0.0366**
SD of cost (generic)	0.2619**			0.2393**			0.468**		
SD of distance		1.7129**			2.5669**			1.478**	

[a] Distance associated with NMT mode is a random variable

** Statistically Significant at the 95% confidence interval

* Statistically Significant at the 90% confidence interval

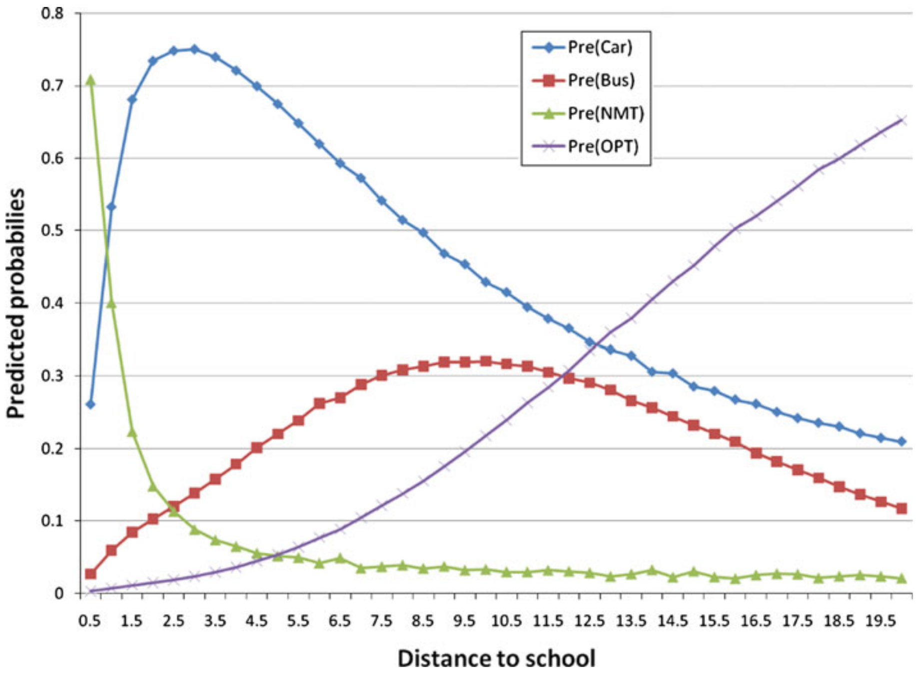

Fig. 2 Predicted probabilities versus distance to school

The coefficients of gender are statistically significant and negative in the bus, NMT and OPT functions. This means that female pupils however, are less likely to travel by public transport or NMT compared to male pupils.

Free school meal eligibility, which is thought of as a good proxy for low income families, also plays an important role in pupils' mode choice. As can be seen, those who receive free school meals are more likely to use public transport or NMT relative to car. Similar effects have been found for IDACI Score. Increases in IDACI score increase the probability of choosing public transport or NMT for travelling to schools.

As for ethnicity groups, the coefficients of Asian and Chinese pupils are all statistically significant and negative, apart from the coefficient of Chinese for OPT which is insignificant. This implies that, compared to white pupils, Asian and Chinese pupils are more likely to travel by car relative to public transport and NMT. Black, Mixed and other ethnicity groups generally tend to use more public transport and NMT compared to white pupils. An exception is that the mixed ethnic group appear less likely to travel by NMT relative to car.

The coefficient of roadway density was found to be statistically significant and positive for bus, NMT and OPT, meaning that pupils are more inclined to travel by public transport or NMT compared to car at places where road density is high. Higher roadway density may indicate better public transport and facilities (e.g. bicycle lanes), which may encourage pupils to use bus and NMT.

Based on the model estimation results shown in Table 5 and the assumptions presented in Table 3, it is possible to calculate the expected market share of different transport modes. The predicted market share of different transport modes for two scenarios are therefore calculated: (1) pupils going to the current school; (2) pupils going to the nearest school.

Calculations were performed to determine the effect of school choice, and how travelling to a school other than the school closest to home, could lead to changes in VMT, CO_2 and fuel consumption.

The models calculated the average distance travelled by pupils by mode and also the modal share of each of the four mode choices. A spreadsheet model was constructed which was used to calculate the results of Table 6 by working out the impacts of travel based on the model share and average distance travelled to school for nearest and current school. The results suggest that if children travelled to their nearest school, instead of the school of their choice the transport-related benefits would be dramatic. Impacts were calculated by considering all pupils in England (7.48 million pupils), pupils aged 10 or under (4.19 million pupils) and pupils over 10 (3.29 million pupils).

Tables 6 shows the differences in modal share, VMT, fuel use and CO_2 emissions of children travelled to their current school compared to the modelled scenario of what these figures would be if all children travelled to their nearest school. As can be seen, there would be a marked difference in daily travel in England if all school children travelled to their nearest school as opposed to their current school. Mode choice changes in the modelled scenario to children travelling less by car and more by sustainable modes. The model shows that car use would fall from 32 % modal share to 22 %. The modal share for bus would also fall from around 12 to 7 %. However, NMT through walking and cycling would rise from around 54 to 71 %. The model suggests that if all children travelled to the school nearest to their home, the total car miles travelled would fall by 1.1 % and the total bus miles travelled would reduce by 10.8 %.

It can be seen from Table 6 that the model has simulated the travel changes for both age groups in comparison to the full dataset sample. The changes in model share for car for younger pupils is double that for older pupils. It is also evident in the summary statistics that younger children travel by car more than older pupils. As a result, miles travelled by bus and other public transport and changes in modal share are much higher for older pupils than for the younger pupils.

There are subtle differences between pupils of primary school age and secondary school age. For instance, younger pupils are much more car reliant than older pupils, but those aged over 10 have higher levels of bus usage than younger pupils. However, in both cases, when the school choice policy is removed in both age groups motorised transport falls and travel to school by non-motorised travel significantly rises.

Clearly there are strong reasons for allowing parents to choose the schools to which they send their children. As Burgess et al. (2007) have noted the school choice policy has greatly benefitted the English education system and created more accessibility to better education regardless of IDACI. Nevertheless, there are serious (presumably unintended) consequences on other areas of public policy, such as the impacts increased amounts of travel and longer journey distances have on the environment (as already noted). In addition, there are also wider implications such as longer distances impacting on mode choice. Wilson et al. (2010, p. 2181) state that "school choice substantially influences school commuting travel behaviour, mainly by increasing travel distance" suggesting that the school choice policy is largely responsible for children travelling further to school. This could threaten the health of children due to the reduction in so-called 'active travel'. In addition, poorer parents are less able to exploit the available opportunities because they are less likely to own a car and/or have less money to send their children longer distances by public transport. There needs to be more research done to examine potential ways of keeping good quality schools accessible to all children, but also not promoting a policy which encourages children to have to travel further each day and usually in an unsustainable way.

Table 6 Quantification of the transport-related impacts for different age groups

Mode	Total pupil population	Pupils aged 10 years and under	Pupils aged over 10 years
Percentage change in mode share (%)			
Car	−0.1	−0.14	−0.07
Bus	−0.05	−0.01	−0.09
Walk/cycle	0.17	0.16	0.18
Other public transport	−0.02	−0.01	−0.03
Total pupil mileage per day (two way; millions)			
Car	−5.489	−5.66	−2.31
Bus	−4.152	0.65	−3.3
Walk/cycle	−0.515	−0.79	−0.1
Other public transport	−1.674	−0.55	−1.32
Total vehicle miles travelled on a school day (%)			
Car	−1.08%	−0.62	−0.46
Bus	−10.8%	−0.73	−8.58
Walk/cycle	–	–	–
Other public transport	−1.6%	−0.14	−0.62
Energy and emissions			
Petrol used—education based journeys per school day (tonnes)	−290.66	−152.83	−138.11
Diesel used—education based journeys per school day (tonnes)	−501.66	−154.45	−302.66
CO_2 emitted by education based journeys per school day (tonnes)	−2586.46	−1102.63	−993.87
CO2 emitted by education based journeys as a proportion of total CO2 emitted by road transport (%)	−0.78	−0.33	−0.38
CO2 emitted by education based journeys as a proportion of total CO2 emitted by all sectors (%)	−0.2	−0.08	−0.09

Secondly, there are implications for other sectors too—the location for health care facilities being one. Thus, trends in the UK towards offering patients the choice of where they can be treated within a health 'marketplace' may deliver more comprehensive and cost effective medical treatments but once again impact on the ability of (often the most vulnerable) patients and visitors to access them. Similar issues may also apply to other facilities where user choices are broadened (either as a result of policy or market decisions) such as supermarkets, airports, universities, and employment centres generally.

Implications for the model include sample size. Further research would require larger datasets being modelled to identify more trends and changes in travel. In addition if similar data was available for other countries which allow school choice such as the US, international studies would allow for further comparisons to take place to see how much VMT and CO_2 could be reduced around the world. Additional factors to enhance the current model would include school performance indicators as these may play a vital role in why parents choose certain schools over others. Ideally, knowing each pupil's postcode would allow mapping of travel and what public bus alternatives are available, however currently this data is sensitive and access is limited.

Conclusion

The aim of this paper was to quantify the transport-related impacts of allowing parental choice of schools on personal travel behaviour, on traffic levels, fuel use and carbon dioxide emissions and to explore the wider implications on public policy.

The model shows that when school choice was replaced by a policy where each child only travelled to their 'nearest school' several changes occurred in English school travel. The results suggest that VMT by car would fall by 1 % and VMT by bus would fall by 10 % per day. The reduction in VMT could lead to less congestion on the roads during the morning rush hour and less cars driving near school gates. Mode choice changed in the modelled scenario. Modal share for car use fell from 32 to 22 %. Bus use fell from 12 to 7 %, whilst NMT saw a rise of 17 %. With more children travelling to school by walking or cycling the current epidemic of childhood obesity could also be reduced through active travel. As well as being a healthier option for children, the reduction in car use could also mean CO_2 emissions would fall by 0.78 % or the equivalent of 2,500 tonnes per day in England alone. This could result in an annual saving of over a million tonnes of fuel used in England as a result of school travel. This supports the US findings of Marshall et al. (2010) and Wilson et al. (2010) that a change in the school choice policy can have significant benefits from a transport and environment view, as walking increases whilst travel by car and bus decrease on a small scale. The findings of this paper build on this to show the results at a national scale with larger population.

This paper illustrates some of the impacts the school choice policy has in England. It needs to be noted that not all behaviour would change if the policy was changed and all children travelled to their nearest school. The main limitation of this research is the inability to fully predict travel behaviour by taking into account personal preference as well as personal factors which influence choice. Some children would still choose to travel by car, yet the impacts are still very significant. If this research were to be applied at either a UK wide or even global basis, the impacts of changes in daily travel as a result of the school choice policy could lead to Governments revising whether the educational benefits outweigh the environmental impacts. With regards to the dataset, as the Census only focuses on the child's travel behaviour other travel factors, particularly regarding parental travel behaviour, cannot be included in the analysis (i.e. trip chaining, employment status, car ownership). Even though this limitation restricts the potential analysis, the data still gives a useful insight into how children travel to school each day and the personal factors which may influence their travel mode choice.

The wider implications for policy are that whilst diversity is encouraged through school choice, it brings many negative side effects through transport, health and the environment. If parents continue to allow their children to travel to school by car, these figures are only likely to rise as the population grows. The school choice policy is not the only factor affecting children's travel, but as this study shows it does have a strong influence.

Acknowledgments Thanks are due to the UK Department for Education for supplying the dataset for this research. Thanks are also due to the Engineering and Physical Sciences Research Council (EPSRC) and JMP Transport Consultants Ltd for their contributions to this study and for funding this research.

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