CO_2 Emissions and the Pupil School Commute

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KEYWORDS: CO2, Transport, Routing, Schools

1. Introduction

Internationally, the rates of active transport (e.g. cycling or walking) to school are in decline (Tudor-Locke et al., 2001; Schlossberg et al., 2006; McMillan, 2007; Trang et al., 2012), and the corollary switch to less sustainable modes of travel have been linked with negative effects on the environment in terms of increased emissions (Van Ristell et al., 2012), increasing traffic congestion around schools (Collins and Kearns, 2001)and health impacts related to lower physical activity levels (Faulkner et al., 2009) or pollutant exposure (McConnell et al., 2010). In a UK context, schools account for 15% of total public sector emissions (DCFS, 2010), which in England is estimated to be the equivalent of around 9.4 million tonnes of CO_2 per year (SDC, 2006). 7% (658k tonnes) of this total is associated with the pupil-school commute, and as such, there are significant environmental benefits of pupils adopting more sustainable travel behaviours.

International research on commuting to school reveals that mode choice is impacted by multiple interacting factors including: actual and perceived distance to the school (Ewing et al., 2004; McDonald, 2007; Müller et al., 2008; Lang et al., 2011), road infrastructure (Bostock, 2001; Ewing et al., 2004), urban form (McMillan, 2007; Mitra et al., 2010; Panter et al., 2010; Cui et al., 2011), ethnicity(McDonald, 2007), socio-economic status (Wilson et al., 2010) and lifestyle factors (Babey et al., 2009). It has also been argued that policies enabling school choice can lead to longer commuting distances, which have a corresponding impact on mode choice and emission levels (Marshall et al., 2010; Wilson et al., 2010; Van Ristell et al., 2012).

The mode of transport adopted for the pupil-school commute has obvious implications for CO_2 emissions. With a few recent exceptions (Wilson et al., 2007; Marshall et al., 2010; Van Ristell et al., 2012), there has been limited study to date that estimate the emissions impact of these journeys; with only Van Ristell et al (2012) examining this at a national scale (albiet using a sample). In two of these studies (Marshall et al., 2010; Van Ristell et al., 2012), different types of regression analyses are used to predict the pupil-school commute mode choice given a range of influencing factors (Wilson et al., 2010). From these models, CO_2 emissions are estimated by multiplying the distance and frequency of trips between locations by the average CO_2 attributed to specific modes of transport. Commuting distance is treated differently between these studies, with Van Ristell et al (2012) adopting straight line distance, whereas Marshall et al (2010) and Wilson et al (2007) implemented network based distances derived using as shortest or actual commuting paths. The advantage of straight line distance is that it can be computed quickly, however, this will typically underestimate the true distance travelled, given that actual routes follow street/rail/footpath topology. However, the estimation of shortest or quickest path along a street network is computationally intensive; thus creating an additional challenge for studies concerning very large sample or total population surveys. The second component in the estimation of emissions is consideration of the CO_2 g/km values attributed to the selected mode choice. The use of national averages are prevalent in most existing models, however, may over or underestimate geographical differences in actual emissions characteristics; for example, relating to the typical types of car owned between different types of area.

As such, there is a challenge to create transport linked CO_2 emissions estimates that better account for geography, both in the estimation of the distances travelled, and where possible, through integration of geographically sensitive emissions input parameters. This complex task is computationally intensive, however, as illustrated by this paper, can be enabled through the application of geocomputation to provide estimates of school commute linked CO_2 emissions at an individual scale and for a national cohort of pupils. A geographically sensitive model is specified that integrates network (road / rail) level routing with geographically disaggregate vehicular emissions data.

2. Geographically Sensitive CO2 Emission Estimates

An estimate of CO_2 emissions attributed to a pupil (*p*) school commute (*k*) can be defined as:

$$k_p = 2\left(d_{pijt} e_{ptg} w_{pt}\right) \tag{1}$$

where *d* is the distance travelled between origin *i* (pupil domicile unit postcode) and destination *j* (school unit postcode) utilising transport mode *t* with associated CO_2 g / km value *e*. The distance estimation technique is mode choice dependant; for example, it would not be logical to base a commute by train on road network distances. Furthermore, in the case of transport by car or light rail, vehicle emissions can vary by location *g*. This parameter is used flexibly within the model to indicated a location as either a Lower Super Output Area (LSOA) in the case of car travel, or in the case of light rail, the nearest network to the pupil domicile. A final weighting parameter *w* is required to adjust an estimate where occupancy is not already accounted for in the emission value associated with the transport mode. In this model, this only includes those whose travel mode is by car sharing, where a weighting of 0.5 is presumed (i.e. an occupancy of two).

After the model input data were assembled into a PostgreSQL database and routing solutions created for both rail and road based journeys, these were coupled using the statistical programming language R (http://www.r-project.org). A pseudo-code implementation of the model is detailed below:

1. Check the pupil mode choice
2. Implement a rail or road based distance calculation according to mode choice
3. Check that the distances returned are plausible
4. Store the distance travelled
5. Get an appropriate geographically sensitive or average CO_2/km emissions estimate depending on location and mode choice
6. Calculate CO2g/km for allocated trip
7. If necessary, weight CO2g/km to account for car share arrangements
8. Store emissions estimate

3. The Geography of School Commuting Mode Choice and CO_2 Emissions

Although the overarching purpose of this paper is to explore the results of the CO_2 emissions estimates, it is pertinent to examine how mode choice is impacted by distance between school and pupil domicile, as the interaction between these paired factors is critical to the emissions total. The commuting distance of the national cohort of pupils was divided into 500 meter bins and plotted as a line graph to explore the proportional change in the four main transport mode choices at distances away from the pupil domicile (see Figure 1). Non motorised transport (NON) has a negative exponential like decay, with car (CAR) based transport overtaking in prevalence after 2.5km. Bus (BUS) becomes more prevalent than car after 4.5-5km; and rail (TRA) based journeys are general low in prevalence, but rise gradually as distance increases. These data illustrate that 1.5-2km from the pupil domicile is a critical threshold at which mode choice switches its dominance from active to motorised forms of transport. This finding fits with a broad literature on neighbourhood schools, and argues that the environmental sustainability of school choice policy might be enhanced if it encouraged or enforced more local choices of school (Van Ristell et al., 2012).

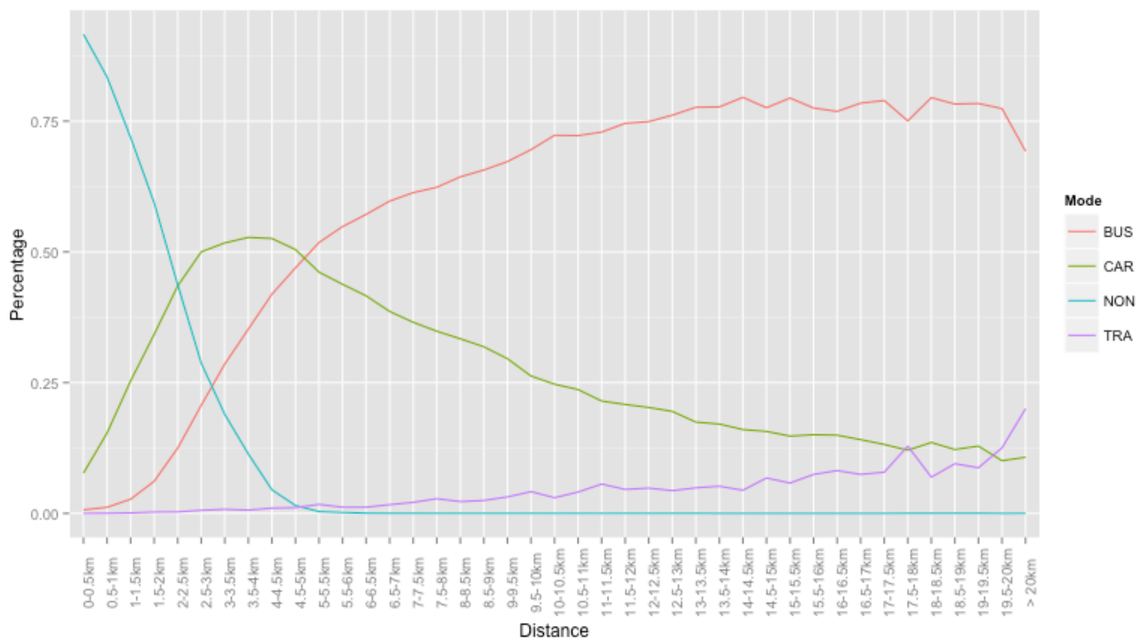
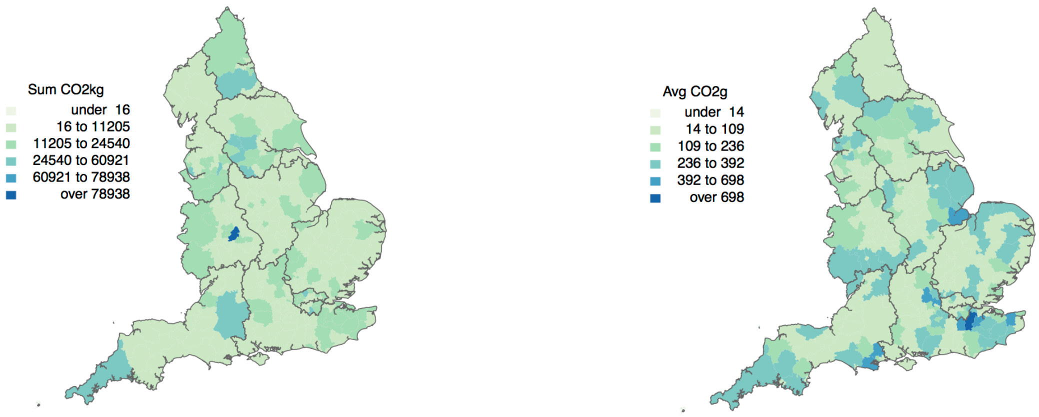


Figure 1: Distance and Percentage Mode Choice Adopted #

- BUS (Public and School bus); CAR (Car, Taxi and Car Share); NON (Walking and Cycling); TRA (Train, Light Rail, Tube)

The CO_2 emissions model created values for each valid pupil-school commute which are aggregated into administrative areas (District/Borough/Unitary Authority), for both the median and total daily values in Figure 2.



a) Total Co2 kg

b) Median CO2g

Figure 2: Aggregated Daily Emissions Associated with the School Commute

The administrative areas with the highest absolute emissions are Birmingham (~79 tonnes(t) CO_2/ day), followed by Wiltshire (~43t), Leeds (~42t) and Liverpool (~36t). However, a different geography emerges when examining the median values attributed to school commutes, with journeys in Sevenoaks on average emitting 698g of CO_2; South Buckinghamshire 563g; East Dorset 502g and Purbeck 487g. The geography of absolute cumulative values is important for those policy applications looking to reduce overall CO_2 emissions, however, median values are useful when exploring more localised travel behaviours with their associated impacts. For example, a local authority may have higher emissions values because it has implemented an admissions policy which impacts how far pupils travel to school. Because the model is created at an individual level, the results can also be used to examine more local emission patterns. This might be useful in targeted policy initiatives aiming to encourage non motorised forms of transport. For example, the choropleth map shown in Figure 3 illustrates total daily CO_2 emissions estimates aggregated at Lower Super Output Area, and additionally, the median values for each secondary school.

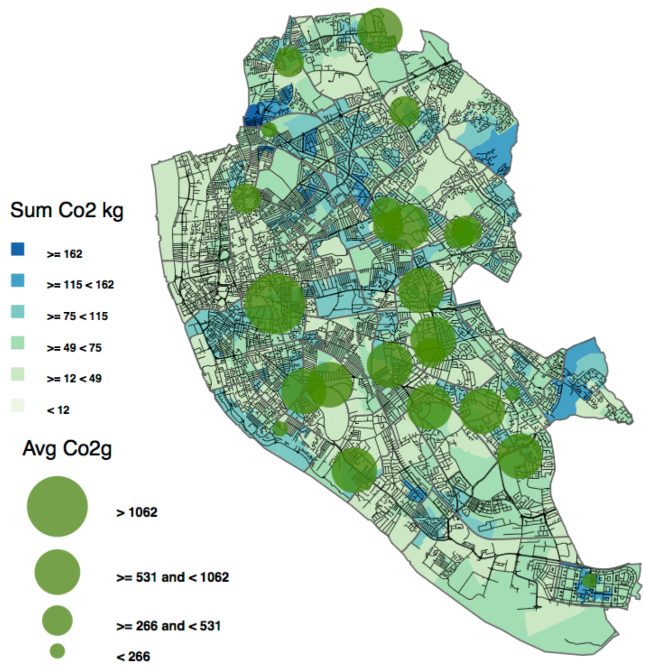


Figure 3: CO2 Emissions within Liverpool

6. Acknowledgements

Thanks to Dr Daryl Lloyd at the Department for Transport for supplying the CO_2 estimate data and answering numerous queries about their calculation! This work was part funded by a 2012 Royal Geographical Society Small Grant.

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Biography

Alex Singleton has been a lecture in Geographic Information Science at the University of Liverpool for the past 2.5 years, previously completing a PhD and working as a research fellow at University College London from 2003. In a general sense I am concerned with how the social and spatial complexities of individual behaviours can be represented and understood within a framework of quantitative social science and computer modelling.