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Reducing carbon emissions related to the transportation of aggregates: Is road or rail the solution?

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ABSTRACT

The transportation of aggregates from quarry to production site raises significant concerns over carbon emissions. A considerable body of literature argues that if more freight could be carried on the rail network, substantial reductions in carbon footprints could be made. This paper describes a modelling framework for estimating the spatial transfer or movement of aggregates between quarries in England and Wales and local authority districts (demand zones). A key part of this framework is the estimation of the carbon emissions associated with both road and rail travel. Once built and calibrated, the model is used for a variety of what-if scenarios relating to the increased use of rail (which includes the necessary construction of new uplifting facilities as well as the number of rail-linked quarries) against future road haulage undertaken through a modernised vehicle fleet. The latter is shown to provide a more realistic and economic solution to reducing carbon emissions associated with the transportation of aggregates.

1. Introduction

All sectors of the UK economy have a responsibility to reduce their carbon footprint given the overall commitment of different UK governments to various international protocols and domestic policies (Department for Environment, Food and Rural Affairs, 2005; Department for Energy and Climate Change, 2009). The UK aggregates market produces around 1.7 million tonnes of CO_2 per year and recent research shows that the transportation of aggregates is responsible for around 40% of the carbon footprint associated with this industry (Mineral Products Association, 2010; Department for Energy and Climate Change, 2009; Zuo et al., 2013). A series of research studies have suggested that modal shift from road to rail could be a positive initiative to improve the environmental footprint of transporting aggregates, as the overall environmental impact per mile for rail is significantly lower than for road transport (Chapman, 2007; Department for Transport, 2008). However, research conducted by Boston Consulting Group (2009) argued that despite the financial and environmental benefits of rail transport, most UK aggregates are transported by road because the greater density of the road network offers far greater flexibility and access to customers. The BCG report does point out that investment in rail could be attractive for large quarries with extensive production volumes. That said, the report also suggested that improvements in the environmental performance of the road vehicle fleet might be a feasible and efficient way to reduce the carbon emission and other environmental impacts of the transport of aggregates. A ‘Synthesis Report’ published in 2012 by ‘Sustainable Aggregates’ (a research programme funded by the Aggregates Levy Sustainable Fund) set both to ‘maintain and increase the

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proportion of land-won aggregates by rail' and to make 'improvements in vehicle to reduce the impacts of road haulage' as two (out of ten) key issues for policymakers and decision-takers (Hicks, 2012).

To date, there are few examples of model-based systems being developed to provide detailed evidence regarding the environmental impacts of alternative policies regarding different modes of travel for freight transportation. In this paper, we will first describe a model to replicate the flows of aggregates from source (quarry) to destination (major UK regions). The model has been developed in partnership between the British Geological Survey (BGS) and the University of Leeds to address challenges in scenario-based planning of minerals transfer in the UK aggregates industry (see Zuo et al., 2013 for more background on the collaborative project). The approach uses a spatial interaction model to match the supply and demand of aggregates, and subsequently estimates the carbon emissions (based on the mode and distance travelled) associated with the movement of those aggregates. It also incorporates a microsimulation model designed to forecast the ageing of the fleet of trucks over time and the gradual upgrading of this fleet to higher standards of European specification in relation to carbon emissions. Thus, we can then test the impacts on carbon emissions of more aggregates being transferred to rail, versus more aggregates being carried on more modern trucks.

The combination of disparate data sources used in conjunction with model-based spatial analytics for scenario planning characterises this exercise as a *spatial decision support system* (SDSS) for minerals planning. This approach permits the spatial disaggregation of the supply chain for aggregates in order to facilitate evaluation of the environmental impacts. This adapts methods which has been widely implemented for retail and service planning (Birkin et al., 2017), but the deployment of a SDSS for scenario analysis for the UK minerals sector is entirely novel, and could be applied more widely to commodities and other industrial sectors. It can be used to simulate and quantify the impacts of a variety of potential policy scenarios to help reduce the carbon emissions associated with the movement of aggregates. We will argue that the conclusions are clear but to some extent perhaps counter-intuitive. The adoption of a spatial perspective, and associated analytical methods, is therefore essential in understanding the impacts of policy alternatives.

The rest of the paper is structured as follows. In Section 2 we describe the structure of the UK aggregates market and discuss elements related to its carbon footprint. Section 3 then introduces the model and discusses its calibration. An extension to the spatial interaction modelling framework is the addition of a microsimulation model of the road fleet used to transport aggregates is described in Section 4. In Section 5 we run a series of scenarios for first increasing rail capacity and hence moving more aggregates across England and Wales by rail. In Section 6 we then look at whether we could make more significant emission reductions by improving the efficiency of the road fleet used for the haulage of aggregates. This involves implementing the microsimulation model of the fleet market and examining the impact of gradually renewing and upgrading the fleet of trucks over time. The final section of the paper provides a discussion of the significance of the substantive results from the analysis. It will also consider the importance of possible limitations in the structure of the models and their implementation and the possibilities for further model enhancement as well as further work using the current models or their successors.

2. Aggregates industry in the UK and its carbon footprint

Aggregates are widely used in the UK construction industry, especially for road repair and construction (32%) and new house build (28%) (Strategic Rail Authority, 2005). The BGS define aggregates as being 'hard, granular materials which are suitable for use either on their own or with the addition of cement, lime or a bituminous binder in construction' (Highley et al., 2007). Although England and Wales are largely self-sufficient for primary aggregates, there are significant regional imbalances in both the location of supply points (the UK quarries) and demand points (major areas of construction, namely towns and cities) which means that large inter-regional movements or transfers of aggregates are required. For example, in the south east of England and London, demand is generally three times that of the supply available within the two regions. In contrast, some regions have greater supply than demand, notably in more rural regions such as the North and East Midlands and the south-west England and Wales. Fig. 1 shows the geography of supply and demand in more detail.

More than 90% of aggregates are currently transported by road (British Geological Survey, 2006). Each year, only 13 million tonnes (less than 10%) are moved by rail (Quarry Products Association, 2006; British Geological Survey, 2006; Mineral Products Association, 2009, 2011, 2013, 2015) with 2 million tonnes additionally moved by coastal or inland waterway (British Geological Survey, 2006). These non-road transport modes are associated with longer average transport distances. According to the Mineral Products Association (2009) the average transport distance in England had reached 144 km for rail and 35 km for road by 2007. It is widely accepted that rail provides lower CO_2 emissions (per tonne kilometre) than road transportation, but whether substantial CO_2 savings can be made by increasing the rail network (thus taking more freight off the road) or by improving/reducing the CO_2 emissions from the road fleet is a question which has so far been harder to answer in the literature. This paper helps to answer this question using the transportation of aggregates as an example.

3. A model for transporting aggregates

3.1. Framework

A central objective of this paper is to produce estimates of the carbon emissions associated with the transfer of aggregates in the UK under alternative scenarios concerning mode of travel. In order to evaluate such scenarios the transportation process needs to be simulated in detail.

Traditionally, models developed for strategic freight transport forecasting follow a four-step modelling structure which combines