ASSESSING THE CARBON FOOTPRINT OF TRANSPORTING PRIMARY AGGREGATES

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ABSTRACT

Minerals are essential in maintaining our economy and lifestyle, but their extraction, processing and handling are responsible for about 7% of total global energy consumption. Reduction of this significant carbon footprint in the face of accelerating demand for commodities and construction materials is a major challenge facing the mining industry and its regulators over the next 30 years.

Transport of primary minerals is responsible for around 40% of the energy consumed by the industry. Although no figures are available, the proportion of energy consumed transporting bulk construction materials such as aggregates is likely to be even higher. Moves toward more sustainable procurement and transport of aggregate minerals are therefore likely to have a significant effect on the overall carbon footprint of the minerals industry in the UK.

In order to be able to look for savings in carbon emissions it is important to evaluate the output resulting from the current transport of aggregate minerals. This research has sought to obtain a strategic assessment of the carbon footprint resulting from transporting aggregates by rail within England.

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INTRODUCTION

Primary aggregate minerals are vital in underpinning the English economy. The aggregates industry is the single largest extractive industry in terms of annual tonnage of output in the UK and aggregate minerals provide essential raw materials to the construction industry. In England this industry makes a gross value added contribution of £50 billion (about 6% of the total value of the economy) (Brown *et al.*, 2008). Around 217 million tonnes of aggregate were consumed in England in 2005, of which only about 4% were imported from elsewhere in the UK or Europe (BGS, 2007).

Supply and demand for primary aggregate are unevenly distributed in England. High quality hard rock resources are predominantly located in the north and west of the country, whilst demand is centred in London and the south east. As a result, the transport of primary aggregates from producer to consumer represents a major mass flow of material within our economy and represents a significant source of carbon dioxide (CO_2) emissions associated with the industry.

Road movement by lorry has consistently been the main mode of transport of aggregates. Being low value high weight/volume products the average road delivered distance is about 40 kilometres with transport typically accounting for half the delivered costs of most journeys over 25 kilometres. In 1997 movement by road accounted for 94.2% of all primary aggregate sales (BGS, 2000). In 2001 it was 90.5% (BGS, 2003) and in 2005, 89.3% (BGS, 2007). Road transport has been the dominant freight option because of the advantage of flexibility in the unit size of the loads, location of delivery point, time, frequency of delivery and ability to respond to changes in demand.

During the same period, the proportion of aggregates transported by rail has increased from 5.5% in 1997, through 8.6% in 2001, to 9.8 % in 2005. This represents a 64% increase in the volume of aggregates transported by rail from 9.4 Mt in 1997 to 15.4 Mt in 2005. (In addition to road and rail a very small proportion of aggregates movement is taken up by internal shipment by water). Rail transport of aggregates is theoretically more environmentally appropriate but many reasons limit its practicability. Potential is limited unless sufficient volumes are required by specific rail depots. Further, issues surrounding capacity of the rail network to handle more freight and competition from higher value freight goods also contributes to limiting increases in the volume of aggregates transported by rail.

Moves toward more sustainable procurement and transport of aggregates are likely to have a significant effect on the overall carbon footprint of the minerals industry in the UK. Individually the total amount of carbon dioxide (CO_2) and other greenhouse gases emitted over the full life cycle of a product or service can be seen as its carbon footprint. In order to be able to look for savings in the carbon footprint associated with aggregate minerals it is important to evaluate the output resulting from the current transport of aggregates. This research looked at how GIS network modelling can be used to assess the carbon footprint resulting from transporting aggregates by rail and how it can be compared with emissions associated with equivalent transport by road. Such modelling will allow comparisons to be made between the effects of different policy scenarios.

Estimating Carbon Emissions

Several quarries in England and Wales are either directly rail linked (via a railhead on site) or supply aggregates to nearby railheads for transport by train to areas of demand. The principal source areas are the East Midlands and South West regions followed by Yorkshire and the Humber, South Wales and North Wales. Rail linked quarries in these regions transport high volumes of aggregates to numerous rail depots located around England (Figure 1). Due to the economies of scale, aggregates can be moved over larger distances by rail than lorry and therefore, whilst located some distance from the areas of demand such quarries are of strategic importance in the supply aggregates. Of particular importance is the supply of crushed rock aggregates to those areas of the country deficient in hard rock resource (notably south and east England).

In order to obtain indications of the carbon dioxide emissions associated with the transport of aggregates by rail to destinations within England a spatial database has been produced to allow for the creation and management of both a rail and road transportation network within a Geographical Information System (GIS). The database defines the locations of active aggregate quarries, railheads and existing rail depots. It also stores data on railway lines and roads. The database allows for characterising the spatial distribution of primary aggregate demand and the definition of the required transportation network linking suppliers (active quarries) to consumers (rail depots). Network analysis procedures can then be used to calculate the route and distance travelled between each quarry and the rail depots it supplies. Network analysis procedures allow a user to solve common network problems, such as finding the least cost route across a city or finding the closest emergency vehicle to an accident. In this research, rail freight haulage information was used to inform the network analysis in order to model the routes taken by the trains. The model was developed by evaluating the links and turns needed to traverse the rail network. Once calculated the network allows the user to display the routes to or from any quarry or rail depot combination, which in turn permits the calculation of the distance for each route. It is these travel routes from the quarries to the rail depots that are of interest in this analysis as they form the basis for the derivation of the CO_2 emission figures.

The distances between each quarry and rail depot when multiplied with the volume of material transported across the network enables calculation of the total tonne-km of aggregates transported between a quarry and the rail depots it supplies. A tonne-km is the distance travelled multiplied by the weight of aggregates transported to each destination. Approximately 15 million tonnes of aggregates were transported by rail in 2005 between the quarries and the rail depots. Within the network created this equates to 2,095 million tonne-km. The average distance aggregates are transported by train to delivery point within England is calculated by the model as 138 kilometres.

The total energy consumed and associated carbon dioxide emission is expressed in terms of MJ and $kgCO_2$ (often converted to tonnes CO_2). Total CO_2 emissions associated with transport of aggregates by rail is obtained by multiplying the amount of tonne-km associated with transporting aggregates between each source and destination by the Defra conversion factor for diesel trains of 0.021 kg CO_2 per tonne-km (Defra, 2008). Total CO_2 emission for transporting aggregates to rail depots in England in 2005 using this model was 43,998 tonnes. Figure 2 shows the carbon footprint associated with the transport of aggregate to each consuming region.

Comparing the impact of different transport scenarios using the Shadow Price of Carbon

In order to place a value on the expected increase or decrease in greenhouse gas emissions resulting from a proposed policy the Department for Environment Food and Rural Affairs (Defra) utilise the Shadow Price of Carbon (SPC). The SPC reflects the damage costs of climate change caused by each additional tonne of greenhouse gas emitted - converted to carbon dioxide equivalent for ease of comparison (Defra, 2007). In the context of the current research it was utilised to calculate an indicative value on the damage costs of greenhouse gas emission associated with transporting aggregates by rail. Using the 2005 SPC of £23.30 per tonne of CO_2 (as this reflects the year for which the volume of aggregates flow data was available) and based on CO_2 emissions of 43,998 tonnes, the indicative damage costs of climate change from transporting aggregates by rail is £1.0 million.

The SPC can be used to compare the damage costs of transporting aggregates by rail with alternative transport scenarios. For example, whilst transporting an equivalent volume of aggregates by road over the distances currently served by rail would be economically prohibitive, an assessment was undertaken to estimate the carbon emissions that would result should all 15 million tonnes of aggregates have been transported to their destinations by lorry instead of by rail.

In order to calculate the road equivalent distances from source quarries to destination rail depots an integrated road network has been created to allow for the calculation of distances between the source quarries and destination rail depots. A hierarchy was applied to the different road types when creating the road network. This means that when calculating the distances between sources and destination the model will favour Motorways and a-roads over b-roads and, likewise, b-roads over more minor roads. This reflects the assumption that aggregates hauliers would favour the majority of their journey being undertaken on major roads. Whilst this may not reflect the exact routes that may ultimately be driven in such a scenario, the routes calculated did, nonetheless, provide a good approximation.

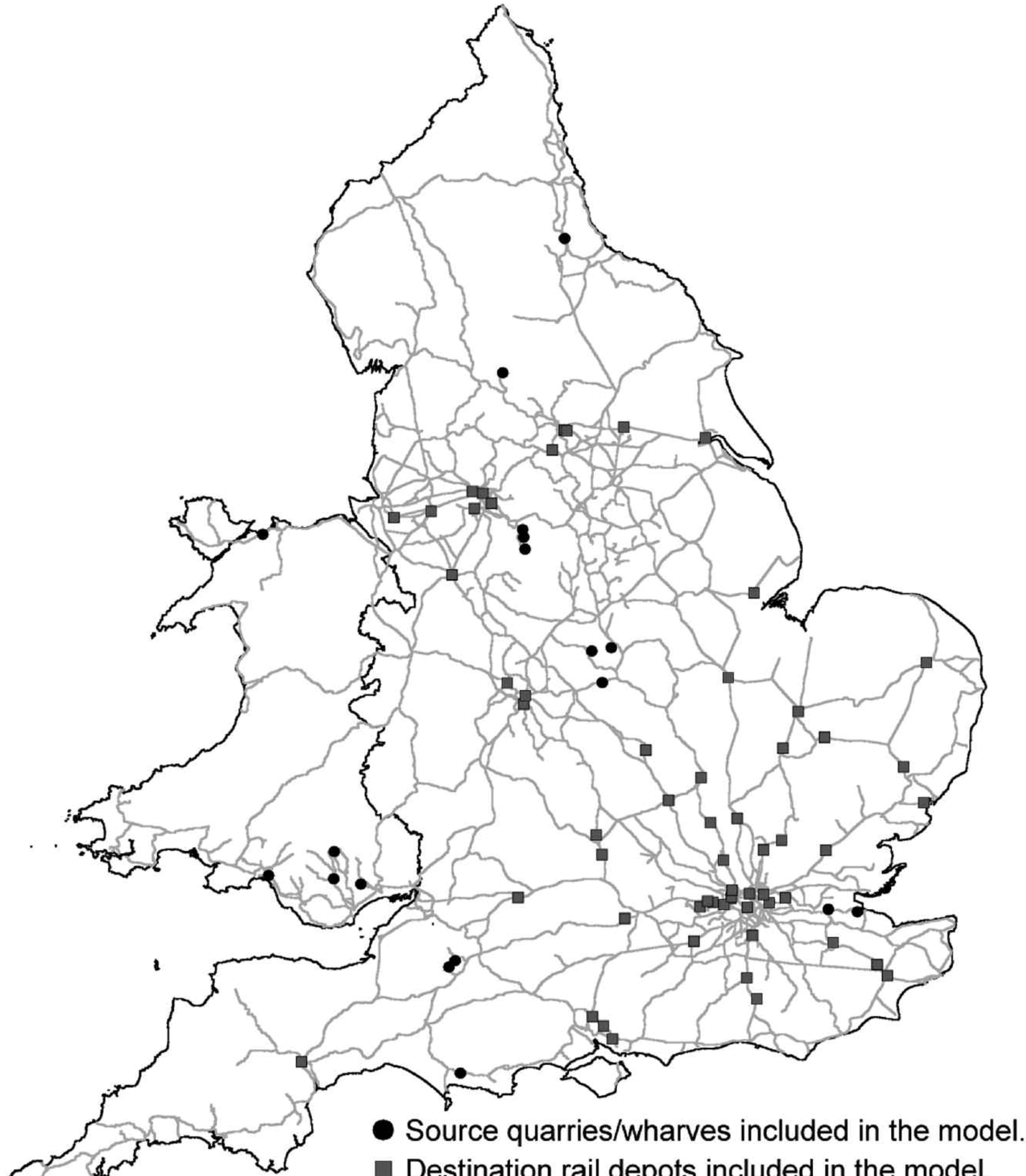

Figure 1. *Aggregates sources and destinations included in the rail network model.*

Using the model to distribute 15 million tonnes of aggregates by road from the quarries to the rail depots they serve resulted in 1,885 million tonne-km. Using the Defra conversion factor of 0.163 kg CO_2 per tonne-km (based on a 30 tonne articulated lorry) the carbon emissions for transporting the aggregate by road are 307 335 tonnes CO_2. Using the SPC this equates to £7.2 million in damage costs of climate change. Therefore, the benefits of utilising rail over road for transporting these aggregates to their destinations are minimum indicative savings of 263,337 tonnes CO_2 or £6.1 million in damage costs.

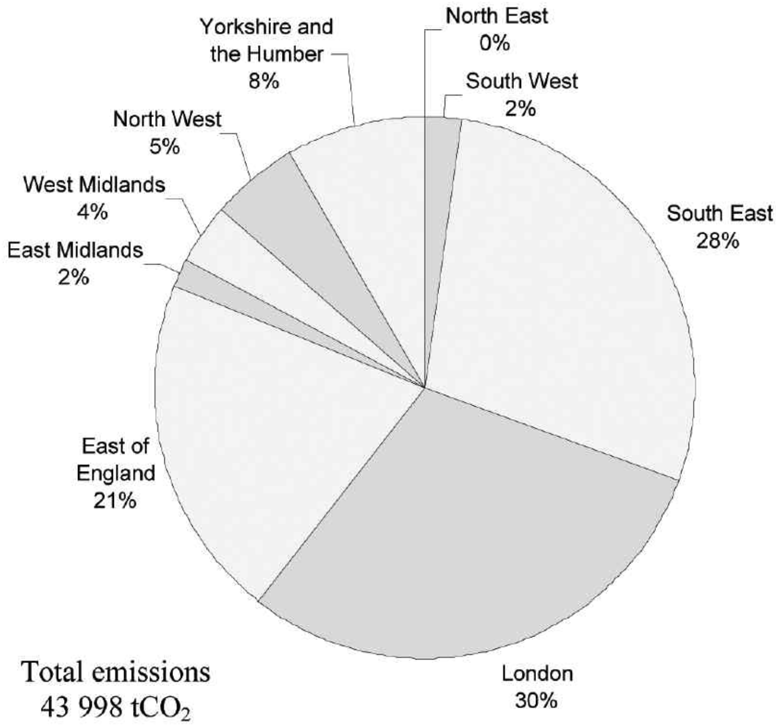

Figure 2. *Carbon dioxide emissions associated with the transport of aggregates by rail to each consuming region as calculated by the model.*

CAVEATS

Whilst care was taken to ensure the research was as accurate as possible, some data had to be reasonably estimated due to issues of confidentiality. Individual outputs from each quarry are confidential and not available. Therefore, the total tonnages moved from each Mineral Planning Authority were allocated pro-rata between the individual source quarries/railheads and the destination rail depots based on the number of train movements and average tonnages carried by the trains. Further, whilst regular / scheduled deliveries are able to be modelled some specific rail flows typically result from market dynamics which result in delivery on an as required basis. Whilst such deliveries can be estimated it is not possible to model them accurately without the pre-requisite data. Finally the amount of carbon dioxide produced during the movement of aggregates will vary depending on many factors such as the amount of load transported at a time, speed of the transportation, etc. Within this research it has been assumed that every train and lorry carries a full load. However the principal aim of the research was to assess the feasibility of undertaking such an analysis to produce estimates of carbon emissions associated with transporting aggregates by rail and the refinements required to enable future model development.

Whilst the model incorporated the transport of aggregates from quarries in Wales to England it did not include those transported from quarries in England to Wales. This is because the research was attempting to estimate only the carbon emission associated with the transport of aggregates which were being consumed in England. The model will be expanded in the future to include transport of aggregates from England to Wales.

CONCLUSIONS

Future large infrastructure projects and developments that will be required to help mitigate the effects of climate change will generate significant additional demand for aggregates. The planning process will be critical in ensuring that the aggregates required to meet this demand are sourced and transported in ways that minimise emissions of greenhouse gases. In respect to this data on the volume of aggregates being moved along with transport information based on producing and consuming areas is being used to develop carbon implication models. Modelling the flow of aggregates through rail and road networks as presented here represents the first steps in the development of such models. Given more precise data on actual tonnages hauled to each destination rail depot and the fuel economy of trains over their respective journeys, such modelling could be refined further to help provide a better baseline figure for calculating carbon emissions associated with moving aggregates by rail. Further research is now being undertaken to build and refine the models including the incorporation of information on network capacity, and the identification/location of 'pinch points' (thus helping to provide an understanding of limiting factors on route choice and path availability).

Such models will help lay the foundations for future policy/construction scenario analyses. Given time, other data models are being built that integrate transport networks along with generalised cost functions. Such models will be able to explore the impact of policy choices on weightings of trip cost functions (such as the effect of moving from minimum financial cost system to minimum environmental cost system). One objective is to model likely carbon emissions resulting from different policy scenarios. These could include modelling the CO_2 effects resulting from:

- Decline in production from National Parks
- The application of a quota system on marine-dredged material
- Greater access to imported material through increased port capacity
- Greater reliance on a small number of very large quarries.
- Supply of aggregates to future large infrastructure projects (airports, flood defence, power stations etc).

Further consultation is required in order to define better and formulate likely policy scenarios with the ultimate aim being to allow industry and policy makers to simulate the carbon footprint and other economic, environmental and social impacts for different aggregate mineral supply and transport policies.

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