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A cost and CO_2 comparison of using trains and higher capacity trucks when UK FMCG companies collaborate

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Abstract

Companies working in a collaboration are able to achieve higher vehicle capacity utilisation and reduced empty running, resulting in lower costs and improved sustainability through reduced emissions and congestion. Collaboration produces higher volumes of goods to be moved than individual companies which means that further efficiencies may be possible by relaxing the freight mode constraints and considering rail and higher capacity vehicles. This paper explains how real world data has been used in a model to quantify the economic and environmental benefits in the FMCG sector delivered through collaboration utilising road and rail freight modes. Data for one month was provided by 10 FMCG companies and included freight transport flows between depots and customers, inter depot movements, and supplier collections. Detailed road and rail costs and operating characteristics were obtained and, with the transport flows, applied to a network design model which was used to validate the company data sets. A strategy examining the potential use of alternative higher capacity vehicles and rail for the flows between nine regional consolidation centres showed cost and CO_2 savings. Just under half the inter-regional flows benefited from double deck trailers, longer heavier vehicles for 30% of the flows and rail with different wagon configurations for the rest. In summary there was a 23% reduction in cost with 58% fewer road kilometres and a 46% reduction in CO_2 emissions. The ability to backhaul the same mode of transport between most of the regional centres was one of the strengths of this strategy.

Key words: freight transport; multimodal; collaboration; FMCG; modelling; higher capacity vehicles

1. Introduction

Road freight transport is unsustainable in its current form. The main factors driving inefficiency in the road transport industry are the high percentage of empty running and low load factors. Empty running is a consequence of geographical trade imbalances and a lack of scale at companies moving the goods. Low load factors are mainly due to order fragmentation at shipper's premises following just in time production and working capital reduction policies. Over a period of 10 years the level of empty running and the capacity utilisation of a road based freight vehicle has hardly changed. EU statistics show a range of between 24% and 28% empty vehicle running, and a capacity utilisation by weight ranging from 54% to 57%, over a 10 year period (Eurostat, 2016). This paper examines the opportunity of using a range of alternative higher capacity road based vehicles or rail freight when companies in the fast moving consumer goods (FMCG) sector collaborate to generate sufficient volume to produce cost competitive and environmentally effective flows.

In the UK, road is the dominant transport mode for freight in the FMCG sector representing over 90% of tonne kilometres moved (DfT, 2015). The EU and national governments are all encouraging the transition from road to rail following the publication of the EU white paper (2011). However, the economics of doing so are complex and companies are reluctant to change modes unless there is a cost effective, timely solution.

Optimizing truck movements through collaboration routinely achieves cost savings and efficiency gains of between 6% and 10% according to Transport Intelligence (Graham, 2011). From the many surveys undertaken (EFT, 2010; Palmer et al, 2012; Gartner, 2012; ECR/McKinsey, 2012; Aberdeen, 2013) it is clear that collaboration is currently playing, or going to have to play, a key role in companies thinking and operations. There is a consensus of opinion from many companies that certain collaborative approaches would increase vehicle asset utilization and therefore achieve cost efficiency, whilst also reducing the environmental impact caused by logistics activities (Hingley et al. 2011). Practical demonstrations and pilot studies of new value chains and business strategies between major companies/shippers produced real world logistic cost reductions of 10-20%, and carbon footprint reductions of 20-30% (CO3, 2014). In the FMCG sector, benefits such as enhanced customer service and better on shelf availability from more frequent deliveries were seen, together with lower inventory at customer distribution centres, and this was achieved with lower transport costs, better truck utilisation and lower carbon footprint (Surtees, 2013)

Using collaborative partners with a compatible mix of products, transport and delivery areas, enables higher capacity utilisation and reduced empty running to be achieved on road freight, with the added benefit of improvements to the sustainability through reduced emissions and congestion (Palmer & McKinnon, 2011). However, the generation of higher volumes from collaborative flows may provide opportunities for the use of alternative higher capacity road based vehicles and rail freight options which also have the ability to reduce costs and emissions (OECD, 2011; Bina et al, 2014; SteadieSeifi et al, 2014).

In the EU, competition law has often inhibited the adoption of collaborative practices since in many instances companies suitable for a collaborative partnership can be competitors. The legal aspects of collaboration were examined in the EU sponsored project Collaborative Concepts for Co-modality (CO3) (Biermasz & Louws, 2014). The outcome was a framework around which companies could legally overcome the limitations of competition law relating to collaboration by ensuring that any efficiency gains are shared with customers, and that the way the potential partners implement the collaborative arrangements should be transparent to avoid the accusation of them being a cartel.

The study addressed in this paper is part of a wider project to assess the potential for transport efficiency improvements by modelling the strategic opportunities for vertical and horizontal collaboration in FMCG supply chains. One particular strategy involving the use of regional consolidation centres has been selected to examine in more detail the opportunities of using higher capacity vehicles or more effectively combining rail and road, the outcomes of which are discussed in this paper. This strategy has been chosen because it produces a higher volume of goods to be moved between regional consolidation centres which means that efficiencies may be possible by relaxing the freight mode constraints. The objective of this paper is to focus on UK transport options and to set a credible independent, objective and impartial basis for an economic and sustainable evaluation that is rational and robust. Information on road based truck costs and operations is readily available from various sources. However, the paucity of information from official and industry UK rail sources has long been a major problem in analysing multimodal sector cost and performance structures (Woodburn, 2012). Despite this, sufficient reliable information has been obtained to identify theoretically possible cost effective and environmentally beneficial modes of transport for various high volume flows so that the participating companies can make informed, sustainable decisions which would be less freight transport intensive.

The paper starts with a background and review of relevant literature to explain why this project is significant. The research methodology section then covers the data collected from the participating companies, the modelling approach and strategies considered. This is followed by a discussion of the results of two strategies, and conclusions explaining the implications of the findings and further research opportunities.

2. Background

There are various forms of collaboration such as backhauling and load consolidation. However, simply sharing transport, or using a logistics service provider (LSP), does not mean collaboration. For example, typically, a LSP would have to consolidate whatever orders had been provided on a particular day within the constraints of the customers using the LSP services. They would not necessarily have the awareness of future orders, nor the flexibility to decide when goods should be delivered. Collaboration involves a level of communication between shippers in a partnership, so that value is added in the form of more efficient transport, through orchestration, management and sequencing of cargo. Collaboration of part loads can be considered as synchronised consolidation. This can only come about when there is mutual trust, openness, shared risk and shared rewards that produce competitive advantage (Lambert et al, 1999). There is no doubt that these requirements can be a barrier for some companies which is why collaborations can take a long time to become established. Nevertheless there are many examples of successful collaborations, particularly in the FMCG sector (Palmer et al, 2012). Collaboration can be considered vertical when suppliers and customers coordinate loads, or horizontal when companies at the same level in a supply chain coordinate loads. There is also multilateral collaboration which is a combination of vertical and horizontal (Ritter el al, 2004; Simatupang and Sridharan, 2002). Cruijssen et al (2010) show, using empirical data, that collaborating companies operate more efficiently than non-collaborating companies.

Companies have tended to focus on making their internal organization and processes more efficient, and through vertical collaboration with supply chain partners (Mason et al, 2007). However, competitive pressures have made companies more amenable to the concept of horizontal and multi-lateral collaboration. Palmer et al (2012) provides a number of examples of collaborations that have been shown to be successful. Collaboration increases the complexity of a supply chain which can dissuade companies from pursuing this approach. A study by the Global Commerce Initiative and CapGemini (2011) offered a vision of a sustainable future supply chain in 2020. This envisaged enhanced collaboration between supply chains with shared transport, shared warehousing and shared infrastructure the norm. Suppliers would ship goods from production locations to collaborative warehouses from which collaborative multi-modal and ‘green’ transport services would move them to other regional and urban consolidation centres before final delivery to customers. The work undertaken in this study has assumed that all 10 FMCG companies will collaborate with part loads to achieve the most efficient transport. A modelling approach has been applied to this vision to assess the use of rail and higher capacity vehicles that takes into account sustainability by reducing the kilometres travelled thereby reducing cost and traffic congestion.

The majority of long haul FMCG road traffic is undertaken by articulated trucks up to 44 tonnes with 13.6m semi-trailers capable of handling 26 UK sized pallets, 1200mm by 1000mm, single stacked. The FMCG sector tends to be more time constrained than most and the generally low density of freight carried means it is suitable for the use of high volumetric capacity vehicles. The use of these vehicles provides an opportunity to deliver more freight in a single journey, reducing fuel consumption and GHG emissions per tonne-km of freight movement. Evidence shows that over 50% of operators within the voluntary Low Carbon Reduction Scheme (LCRS), run by the Freight Transport Association, have made greater use of double deck/high cube vehicles, and just under 40% have consolidated loads on longer and/or heavier vehicles (Office of Rail and Road, 2015). However, LCRS membership covers only a small fraction of the domestic HGV fleet. Higher volumes generated in collaborative flows could reveal opportunities for improved efficiencies through the use of higher capacity road based vehicles such as double deck vehicles which can hold up to 52 pallets, and 15.65m longer semi-trailers which are being trialled in the UK capable of holding 30 pallets. Although both these vehicles are larger, and therefore heavier, than the standard trailer, they are still limited to 44 tonne maximum gross vehicle weight. Another road based vehicle used in selected European countries is the longer heavier vehicle, sometimes called the mega truck (Leach and Savage, 2012). This vehicle which has a length of 25.25m and a gross vehicle weight of 60 tonnes was evaluated for UK roads in 2007 and was rejected (Butcher, 2009). However, situations change and this type of vehicle may become acceptable in the future. With higher collaborative volumes, rail may become more attractive as a transport mode by being able to provide full train loads, this being the most economical way of moving goods by rail.

Double decked vehicles, where goods are loaded on two levels, are becoming more widespread in the UK, especially for long haul movements, increasing from 2.7% in 2004 to 4.1% of all articulated fleets in 2010 (Greening et al, 2015). They are typically used in the FMCG sector for moving goods between distribution centres. Although there are different types of double deck vehicles, characterised by the way the top deck is loaded and unloaded such as a hydraulic moving deck or tail lift, there can be a need for external lifts for loading and unloading at the various facilities. There have been safety concerns relating to the loading and discharge of cargo using this type of trailer and also to the possibility of overturning in high side wind conditions (Health and Safety Executive, 2012)

Generally, double-deck distribution is possible in the UK as there are fewer vehicle height restrictions than in other European countries. Bridges and tunnels offer sufficient height clearances to accommodate double-deck trailers which are typically between 4.8 and 5 meters tall. These vehicles are often restricted on payload weight as they are heavier than a single-deck, while operating at the same gross weight limit of 44 tonnes. Double-deck trailers are thus mostly used for the distribution of light goods. FMCG goods distribution often falls within the efficient range for double-deck trailers. Because they are taller than standard single-decks, they have a higher drag coefficient but overall there is an environmental benefit from the reduced energy consumption per tonne-km.

A 10 year trial of longer semi-trailers (LST) was introduced in the UK in 2012 with the aim of evaluating the impact on efficiency, emissions and safety. This trial permits a trailer length of up to 15.65m, an increase of 2.05m over current regulations, and operating within the current 44 tonne weight limit. A maximum of 1,800 of these types of vehicles were permitted with 1,764 being used by July 2016 (DfT, 2016). It has been calculated that LST operations are achieving significant savings in the number of vehicle kilometres driven on GB roads, with consequential environmental benefits. Between 8.7 and 10.6 million vehicle km of HGV journeys have been removed from the road during the operation of LSTs since September 2012 which equates to removing 75 – 90,000 journeys by the standard 13.6 metre trailers. 35% of all LST km involve FMCG products, with the majority of movements being between distribution centres and to/from retail sites.

In the UK, applications from two hauliers, each wishing to trial a longer heavier vehicle (LHV), were refused in 2005. However, interest in this type of vehicle has grown within the road freight industry both in the UK and elsewhere in Europe. There was evidence to suggest that when legislation was passed by the UK government to increase the maximum permitted weights of goods vehicles from 41 to 44 tonnes it reduced vehicle kms, freight transport costs and carbon dioxide emissions relative to what they would otherwise have been (McKinnon, 2005). Given that continued freight growth is expected, maintaining current regulations on weights and dimensions would, with all other things being equal, be expected to result in an increase in the number of goods vehicle movements and a relative increase in pollution, accidents and congestion arising from those movements. However, the nature of goods transported has changed and a larger proportion of loads shipped are now constrained by the available volume or deck area rather than the available payload weight. In the UK, LHVs would most likely be used for regular flows of low density products on primary distribution in sectors such as fast-moving consumer goods. Potentially, it was estimated that between 5% and 10% of the tonne-kms carried by articulated vehicles could move to LHVs of 60 tonnes or more (vehicles offering an increase in both available volume and payload). This represents a migration of up to approximately 11.8 billion tonne-kms per year. An analysis of the internal and external costs of freight transport has suggested that the ongoing costs could be substantially reduced (Knight et al, 2008). A study conducted by TRL suggested that carbon intensity could be reduced by up to 13% for one longer and heavier vehicle configuration (Knight et al., 2008)

Higher volumes from collaborating partners also provide opportunities to efficiently exploit rail freight. Consolidation is an essential element to make the best use of multimodal transportation (SteadieSeifi et al, 2014). The EU in its White Paper (EU, 2011) set out aspirations for rail and other less environmentally damaging modes of transport (inland waterways and coastal shipping) to secure 30% of traffic moving over 300km by 2030 and to secure 50% by 2050. In order to achieve this target, the market share of rail would need to double from its current level of 18% (Islam et al, 2016).

In Europe, some companies in the FMCG, and other, sectors have started to use cloud based open collaborative logistics platforms such as MixMoveMatch, to ensure their transport is used as efficiently as possible. One company, Procter & Gamble, increased its use of rail from 10% to 30% between 2009 and 2012, and are part of an EU project called Clusters 2.0 which will develop a pan European platform for intermodal transport called CargoStream to try and achieve up to 50% by rail (Verelst, 2017).

In the UK, rail is heavily dependent on bulk commodity traffic, primarily coal. However, coal experienced a large decrease in freight moved in 2015-16 compared to 2014-15, with a 64.2% reduction to 2.3 billion net tonne kilometres, in response to climate change measures aimed at eliminating coal fired power generation (ORR, 2016). Finding alternative markets poses a major challenge to the rail freight sector. The intermodal sector has been identified as a major prospective market. Tesco, the largest UK FMCG retailer, uses trains for an Anglo-Scottish route which is of a distance in excess of 300km that makes rail economically viable. The company also uses rail to serve Wales and London which is a shorter distance and, although the economics are finely balanced, has more to do with their desire to be a zero carbon business by 2050 (IGD,2017). The trains they use pull between 20 and 32 wagons each carrying one 45' container capable of holding 26 pallets. The containers are loaded and unloaded by cranes at the depots located at the rail freight terminals. It is this type of rolling stock that has been assumed for this study. Although the train volumes represent only a small part of Tesco's supply chain operation, they are keen to develop this aspect of their business. They claim the main benefit of rail is reliability, knowing exactly when the train will arrive (IGD, 2017).

However, there are some significant shortcomings that rail freight companies have to address if they are to successfully exploit the opportunities for growth in intermodal movement to meet the 2023 forecasts predicted in the Network Rail Freight Market Study (AECOM, 2016). Rail is perceived by shippers, forwarders and wider cargo interests as a complex, bureaucratic and less agile option compared with road transport alternatives (EU, 2015; AECOM, 2010). The rail sector is only able to provide a limited offering compared to shipper's needs in relation to matching shipper's expectations on service, product and pricing. Rail has not developed or maintained a coherent and embedded process for product development in relation to supplying the transport vehicle and train capacity, and capability, able to match that offered by road transport.

Rail freight volumes demand competitive commercial rates compared to road transport, whilst at the same time exploiting rail's inherent benefits with regards to energy efficiency and lower environmental impact in terms of noise, emissions and safety. Rail has generic advantages by operating within a controlled and secure environment and, with 5% of rail freight tonne km using electric traction (Office of Rail and Road, 2015), a bonus in terms of being environmentally beneficial. Rail also has the potential to reduce road congestion on heavily used inter-urban routes and reduce road infrastructure attrition (EU, 2011).

Terminal handling costs and the requirement for road transport for pre and end haulage can erode rail's line haul cost advantage (Comtois, 2015). The reliance on long, relatively slow trains together with competition from passenger services for train paths also constrain rail's potential using existing operational, technical and commercial models. Weekend engineering work on the railway infrastructure also precludes the operation of 24/7 services and constrains rails ability to develop services for the FMCG sector.

Frequency of movement and speed of replenishment are generally a feature of FMCG movements and as a result rail freight may need different transport structures, policies and objectives (SteadieSeifi et al, 2014). In order for rail to succeed in the FMCG sector it will need a portfolio of service types and products to regain market volume and revenue. It needs to become much closer to the users and to identify developing and emergent trends and requirements in terms of technology, operations, terminal capacity and capability. It has to aspire to match what the best of road transport does on a routine basis. This could include the use of shorter faster and more responsive train formations able to exploit rail's speed advantage and operate within streams of fast moving passenger traffic. These could be self-propelled or push-pull formations able to be loaded and discharged in terminals very rapidly where containers or swap bodies are the cargo module. Such trains would need to be able to operate widely over as much of the rail network as possible with cargo modules of at least an equivalent volume and weight capability of tri-axle semi-trailers.

There are examples of such trains in Europe. In Switzerland, a concept called RailCare, set up in 2009, provides short distance rail operations for Co-op and other FMCG companies with horizontal loading and unloading of containers. Another Swiss innovation, Innovatrain, is a push-pull intermodal train that stops at many terminals a short distance apart. Light-Combi was a Swedish concept designed to service smaller volumes of traffic. The train formation was limited to 8 freight cars/wagons. The concept was used to service retail store products on a trial demonstration basis but was not a success because of concerns relating to access charges and a changing business environment (PACT, 2000). Similarly, CargoSprinter, which was initially developed in Germany in the 1990's as a self-powered train for carrying containers, was not successful either. During an EU project in 2001 under the 4th framework programme, a CargoSprinter was converted into a container carrying train (Two power cars and intermediate unpowered container flat cars) and it was evaluated as a proof of concept on trials from Southampton to inland terminals. It did work but several limitations were identified these being low power to weight ratio, low acceleration rates at full service loads, poor adhesion on the power cars with repeated slipping and low top service speed of 60mph (IRIS, 2001). From this, the TruckTrain concept was designed to have more installed power, higher operating speeds and cargo weights, new drive train and suspensions. It was developed as a composite concept for a short fast, bi-directional self-propelled formation and was designed in response to the identification of a market requirement set by the shippers, receivers and forwarders. It has been designed to minimise the pre/end haulage component by being able to utilise terminals nearer the origin and destination of goods. It has also been designed to be used more intensively than traditional rail freight, and to travel at a speed comparable to passenger trains. It was thus important to see if an intensively operated short, fast, bi-directional self-propelled train could match the cost base of road transport. The TruckTrain is still a concept but an interesting option to consider in this study for comparison with road and traditional rail freight.

3. Methodology

The discussion in the previous section highlighted both benefits and issues relating to alternative road and rail freight modes. However, this strategic analysis has been designed to highlight cost and sustainable opportunities, which might help encourage innovations to overcome some of the identified limitations. A wider study of collaborative opportunities has applied data from ten FMCG companies to a network design model to evaluate a range of collaboration strategies, one of which involved regional consolidation centres. This particular strategy was then selected for detailed analysis, related to alternative road and rail based options, using a specially developed model, and is the subject of this paper.

The ten FMCG companies, consisted of two retailers, one wholesaler and seven manufacturers, and they provided comprehensive data on freight movements in either May or June 2013. These months were chosen as they represented typically average demand for the FMCG sector. A previous identical study undertaken with Efficient Consumer Response (ECR) UK, had obtained the same data for the same months in 2010 for nine of the ten companies (Palmer & McKinnon, 2011). A comparative analysis was undertaken which showed slight differences in locations serviced, an increase of 8% in pallets moved and an increase of 5% in delivery movements (Dadhich et al., 2015). Obtaining this flow data has been possible because these ten companies expressed interest in collaboration, and non-disclosure agreements were signed, but it takes a lot of encouragement and cajoling to make the companies provide the data because it takes time, and they are more focussed on their day to day operations.

The data provided by the companies included all freight transport flows between depots and customers, interdepot movements, returns from customers and supplier collections under the company's direct control (i.e. paid for by the company). The data specifications minimised the risk of movements between manufacturers and retailers being double counted. Also excluded were any collections by customers from company depots. For all the eligible flows, data was provided on the origin and destination postcode locations, the type of vehicle used, the quantities moved and frequency of delivery. The volumes were generally provided in pallet quantities but some retailers indicated the number of roll cages, which were converted into pallet equivalents at the ratio of 2.14 roll cages per pallet. An indication of which movements were backhauled was also provided. The data provided was analysed and validated to ensure that it was consistent and appropriate for the task.

The data collected for depots included national distribution centres, regional distribution centres, local warehouses, cross-docks and other facility depots. The data provided by companies for road based vehicles included vehicle type, carrying capacity (tonnes and pallets), trailer length, type of trailer, and ambient or temperature controlled commodities and operating parameters such as loading and unloading times, shifts and vehicle utilisation.

In the UK there are various sources from which road based costs and operating characteristics can be sourced for a range of different vehicles such as the Freight Transport Association (FTA), Road Haulage Association (RHA) and freight transport journals such as Motor Transport. In order to establish a sound basis for cost comparison, RHA cost tables were used to apply fixed and variable costs to the various road based vehicle types used by the companies (RHA, 2013). Obtaining rail freight costs and operating characteristics have been challenging. Whereas there are thousands of vehicles and operators for road based transport there are only a few rail freight operators who naturally regard their costs as commercially sensitive in a highly competitive area. In addition, the cost structure of rail is significantly more complex in comparison to road freight transport. However, costs and operating characteristics were derived from two key papers (MDS Transmodal, 2012; ARUP, 2014), and a spreadsheet used by the DfT for assessing rail freight grants was an important source of information. Discussions were also held with various rail freight experts and one specific rail freight operator, to verify the figures and assumptions.

In order to analyse this data a logistics network design model was used to allocate the flows between customers, suppliers and depots. This heuristic and linear programming based model involves creating a series of logistic networks that are run against various minimising algorithms across the different constituent elements of the supply chain, for example outbound load consolidation or optimisation of inter-depot movements. For each supply chain network, subject to any constraints or parameters, the model minimises the network resource costs and emissions. It uses a matrix of costs for each of the vehicles and depots, to help it decide on the best allocation. These cost functions are created using route planning algorithms and are the basis for the allocation minimising algorithms.

In the first instance, the logistics network design model was used to produce a base case for each of the individual participating companies. Discussions then took place with each of these companies to ensure the outcomes were satisfactory for the next phase of the project.

The aim of the entire project was to look at collaboration opportunities in general so the individual company data was combined and a number of road based strategies were initially examined. These included backhauling, co-loading of part loads between nearby located depots, consolidation of part loads using regional consolidation centres and urban consolidation centres. A part load, or LTL (less than truck load shipment), was assumed to be any single movement that represents less than 60% of the capacity of the vehicle used for that movement and would be part of a multi drop journey. Out of a total of 10.9 million pallets moved by the 10 companies in one month, 17% of these (1.8 million pallets) were part load deliveries.

The results of these road based strategies show potential cost savings of between 2% and 5%, with savings in vehicle-kms of 5% from improved backloading and a range between 2% and 7% from consolidating part loads. Using urban consolidation centres combined with night time deliveries had the potential to reduce vehicle-kms and CO_2 by nearly 30%, for urban movements.

One of the strategies involving nine regional consolidation centres was considered suitable for examining the potential use of alternative higher capacity vehicles and rail. A total of 100 depots were used by the 10 companies. Clustering and centre of gravity analyses were used to identify nine regions of the UK with a radius of 35km as the optimum that encompassed 66 of these depots, as shown in the map in Figure 1. The map also shows the pallet throughput for all depots indicated by the map key. Similar clustering of food manufacturers' and retailers distribution depots were seen in the original Starfish study and was also observed by McKinnon (1989) in a survey conducted in the late 1970s. The assessment of consolidation opportunities focused on these 66 facilities. The other depots located outside of these nine regions continued to operate as currently. Each regional centre was therefore optimally positioned within the vicinity of clusters of depots and capable of receiving part loads destined for other regional centres.

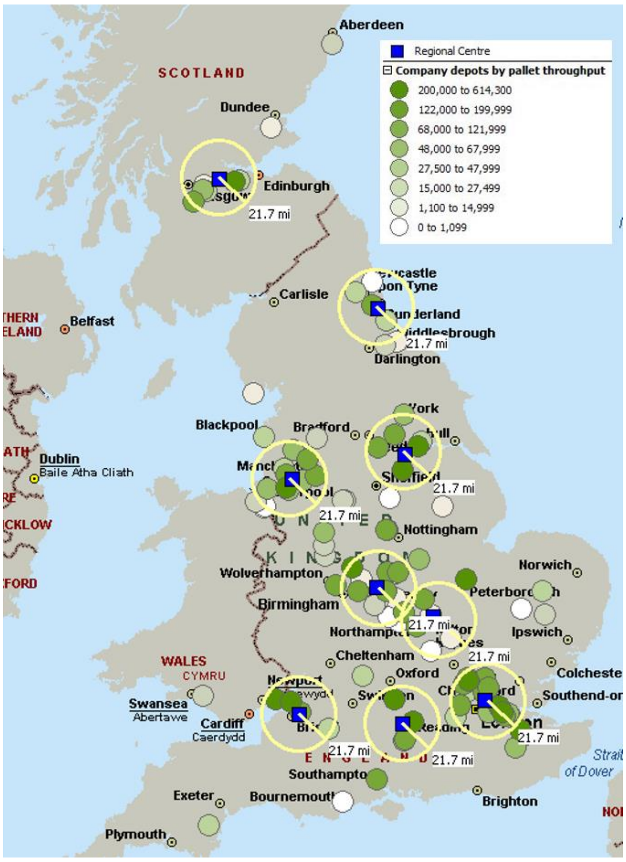

Figure 1: Location of regional consolidation centres

Combined loads would be trunked between these regional consolidation centres, with local collection and delivery of the part-loads within each region. The consolidation centres would not be used for any intra-regional flows of part-loads. All movements of over 60% of a vehicle load would also be excluded from this regional consolidation system. This option allows for vehicles to be backloaded between regions as well as maximizing the use of vehicle capacity by consolidating the loads within regions. The model assumes a minimum of 20 movements per month between the regional consolidation centres.

In the road based strategy above, movements between the regional consolidation centres were performed by conventional 44 tonne curtain sided articulated vehicles. However, there may be cost and environmental efficiencies, based on the volumes moved, by using alternative larger vehicles or a combination of rail and road.

3.1 The model

The flow volumes between the regional consolidation centres were produced by the logistics network design model. A new Excel based heuristic model was then developed specifically to examine the cost and CO_2 impact of different road based and multi modal flows between these regional consolidation centres. This model considered all the flow volumes and journeys by applying the road and rail transport parameters shown in table 1.

General Parameters	Time-Related Per Annum
Vehicle Price (representative)	No of employees
No of wagons	Cost/employee
Net weight per wagon (tonnes)	Other employee costs
Cargo weight per wagon (tonnes)	Driver Employment Costs
Total weight (tonnes)	Leasing cost/unit
Average depreciation period (years)	Depreciation/Annual leasing cost
Average kms per annum	Licences
Average days worked per annum	Vehicle Insurance
Hours/day	Goods in Transit Insurance
Price per litre of fuel	Interest on Capital
Litres/100km	Return on assets
Average tyre life (kms)	Overhead per vehicle
Rail lift charges per container	
Pallets per container	Mileage-Related pence/mile
Total pallets per vehicle mode	Fuel
Vehicle capacity utilisation	Tyres
No of journeys per year	Repairs and Maintenance
Average kms per journey	Capacity charge
Number of pallets moved per year	Rail track access charge 2014/15 (£/thousand tonne kilometres)
Cost/pallet moved	
Fixed Drop Time (mins)	
Variable Drop (mins/unit)	
Depot Time (mins)	
Average speed (kph)	
Kgs CO2 per litre of diesel	

Table 1: List of operating and cost parameters for road and rail transport

These parameters, derived from the sources already mentioned, relate to time and distance based operating characteristics and cost. The time based cost elements were converted to a cost per hour taking into account all the time characteristics of the transport modes being considered. Similarly, the distance based costs were converted into a cost per mile taking into account all the distance characteristics. The model calculates road distances between all the various facilities in the model such as regional consolidation centres and rail freight terminals. Rail experts provided the rail distances between the rail freight terminals. Road and rail based speeds were applied to obtain times for the various journeys allowing for loading and unloading, working time directives and shift time.

The following transport options were considered in the model:

- Semi-trailers with two decks (Double decks)
- Longer semi-trailers (up to 15.65m)
- Longer heavier vehicles (Megatrucks - 25 metre, 60 tonne)
- Train with 26 wagons each carrying one 45’ container
- Train with 20 wagons each carrying one 45’ container
- Train with 12 wagons each carrying one 45’ container
- TruckTrain with 5 wagons each carrying one 45’ container

Based on the various transport options, the model calculated the number of journeys, together with times, distances, cost and CO_2 emissions. The flow volumes had to be such that there were at least 20 journeys per month for a transport option to be considered.

For the rail options the model only considered dedicated trains since this was cheaper than purchasing individual wagon loads. This option may be usefully explored at a later stage beyond the confines of this paper. The pallet volumes moved between the nine regional consolidation centres were used to estimate the number of full train loads and road feeder vehicle trips, as well as vehicle trips for the larger vehicle sizes. The volumes in both directions between any pair of consolidation centres were compared for backhaul opportunity. Only where it was feasible to match the number of full train loads between pairs of consolidation centres was rail considered an option. Any imbalances between consolidation centres, after the matched train loads, was undertaken by a conventional road based 44 tonne curtains sided artic and costed appropriately.

The resulting cost and CO_2 emissions for the various transport options were compared with the standard base line 44 tonne curtain sided vehicle used in the logistics network design model.

3.2 The transport options considered

Double deck vehicles are a tall semi trailer, with two internal deck levels. The semi trailer generally has smaller wheels than the tractor unit to accommodate the extra height. They can almost double the amount of goods transported compared to a single deck vehicle. As they are still restricted to a 44 tonne gross weight, the additional deck plus body weight reduces the overall weight carrying capacity, so these vehicles are generally limited to low density product. The model developed to examine this option assumed a maximum weight carrying capacity of 27.5 tonnes. The height of a pallet is also restricted to less than 2 metres. There are many types of double deck trailer designs but a fixed deck trailer has been assumed for this model. This has the highest carrying capacity but means that external lifts have to be available at locations visited. The costs of running a double deck trailer have been derived from Holter et al (2010) in conjunction with the RHA cost tables (2013).

At the moment, the longest semi-trailer allowed on UK roads is 13.6 metres but there is a trial being undertaken over a 10 year period for semi-trailers up to a maximum length to 15.65m. This allows an extra 4 base pallets, or 13% extra capacity. The weight restriction of 44 tonnes remains. The costs of running LST's has been derived from a report produced by WSP as part of an evaluation study commissioned by the DfT (WSP, 2011), in conjunction with the RHA cost tables. It has been assumed that the additional vehicle body mass and weight of the steering equipment would reduce the carrying capacity to a maximum of 28 tonnes.

The analysis also assessed the benefits of using LHV's. Although currently not permitted on UK roads, this type of vehicle is legal on roads in Finland, Sweden, Denmark and the Netherlands. From the 1st of January 2017, Germany decided to allow extra-long vehicle combinations on a dedicated road network including cross border transport, based on bilateral agreements. On their own territory EU Member States are allowed to deviate from the EU guideline for maximum weights and dimensions. The Department for Transport (DfT) carried out an investigation of these vehicles in 2008 (Knight et al, 2008) and, despite showing cost and environmental benefits, was rejected because of necessary changes to infrastructure, developing dedicated routes, and changing certain speed limits. Also, there was concern about goods being transferred from rail to road. Nevertheless, there is pressure to introduce trials of these vehicles which is why they have been included in this analysis. The costs and operating characteristics of these vehicles have been taken from the study undertaken for the DfT and updated to 2013 figures.

For the rail based analysis, the nearest rail freight terminal to each of the nine regional consolidation centres was identified. Rail distances were calculated between all these rail freight terminals as well as road feeder distances between the rail freight terminals and the connected regional consolidation centres. For intermodal rail freight services to be competitive with road haulage, road feeder movements must be short relative to the rail trunk haul. However, the relationship between feeder and trunk haul lengths is highly dependent on market conditions which makes it difficult to estimate the break-even distance (Kim and Van Wee, 2011). Currently, Scotland is the dominant destination for FMCG rail movements, typically starting from the Daventry International Rail Freight Terminal (DIRFT) at Daventry, because of the distance involved. Generally speaking, the further away a depot is from a rail terminal, the longer the trunk haul rail distance needs to be to remain competitive with road. Table 2 shows the locations of the regional consolidation centres and the nearest rail freight terminal plus the road feeder distance.

Place Name of Regional Consolidation Centre	Location of RCC	Location of Nearest Rail Freight Terminal	Road feeder dist (km)
Downend	Bristol Area	Avonmouth	16
Waltham Forest	London	Barking	14
Thorne	Leeds/Bradford	Doncaster	19
Grangemouth	Scotland	Grangemouth	2
Weddington	Midlands	Birch Coppice	16
Herrington	Tyne/Teeside	Teesport	43
Bold Heath	Lancashire	Warrington	8
Andover	Reading/Newbury	Andover	1
Wellingborough	Milton Keynes	Wellingborough	2

Table 2: Location of regional consolidation centres and rail freight terminals used

The last mode to be considered was a concept called a TruckTrain®. This is a high speed, low cost, self-propelled rail freight concept that collects and delivers products by rail in close proximity to the origin and destination locations. It doesn't rely on large complex rail freight terminals, related intermodal handling and long road haulage legs although it could use existing inter-modal sites as required. For the purposes of this study, a budget capital cost has been used which compares favourably with conventional trains but is expected to have a higher work capacity and low per unit costs through high speeds, quick turnarounds, 24/7 working and intensive scheduling.

As well as examining the cost and CO_2 implications of the nine regional consolidation centres, a further strategy was considered positioning the regional consolidation centres at the rail freight terminals thus eliminating the need for road feeder movements at either end of the rail journey.

4. Results

Of the 1.8 million part load pallets delivered, 1.35 million pallets remained within a region and 450,000 pallets were consolidated for movement between the nine regional consolidation centres. In total there were 51 flows between the regional consolidation centres, of which 11 were one way flows. Although in practice hauliers would always try to find return loads for vehicles with an outbound leg only, a worst case scenario assumption has been made in the model that any vehicle with a one way flow would be costed as having an empty return leg. The volume of pallets moved varied from 31 pallets to over 31,000 pallets per month as shown in figure 2.

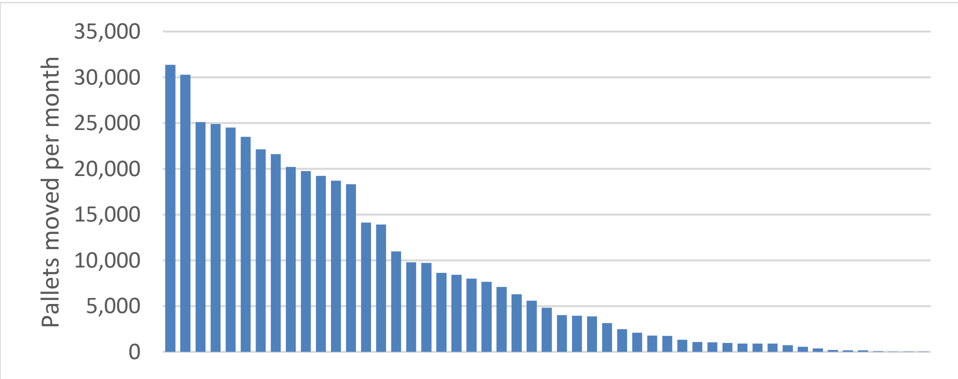

Figure 2: Pallet flows between pairs of regional consolidation centres

The model produces a cost, time, distance and CO_2 for each of the 7 road and rail options, for all flows between the regions. A high capacity vehicle or rail option would be rejected if any flow volumes are insufficient for the transport option. There has to be a minimum of 20 movements per month between the centres at full transport mode capacity. Where there are two way volumes to be moved backhaul is assumed for the lower of the two volumes with empty legs assumed for the balance. Based on the lowest cost, the model then selects which of the 7 modes of transport should be used between each pair of consolidation centres.

Two options have been modelled and analysed. The first is to place the regional consolidation centres at the centre of gravity location which means that the depots, customers and suppliers in a region have the lowest overall distance to travel to and from the regional consolidation centre, as shown in figure 1. The second option is to place the regional consolidation centre at the nearest rail freight terminal which eliminates the road feeder distances between the rail freight terminals and the regional consolidation centres, which should encourage the rail options to be selected for the inter regional movement, but may have a negative impact on distances between the depots, customers and suppliers moving goods to and from the regional consolidation centres.

4.1 Option 1

A schematic of this option is shown in figure 3. This shows the movements of part loads between depots (D), customers (C) and suppliers (S) to and from the regional consolidation centres. Road flows are shown direct between the regional consolidation centres (in red) and rail movements (in blue) are shown as a broken line.

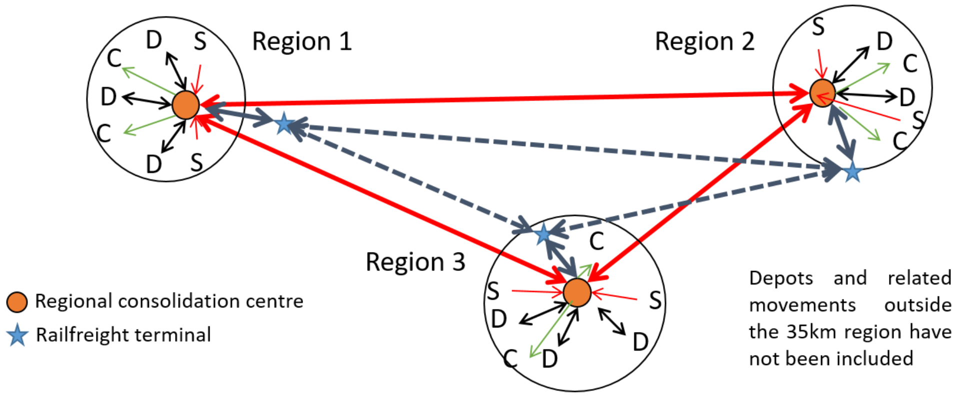

Figure 3: Schematic showing the freight flows between three regional consolidation centres

The results, summarised in table 3, show the costs, kilometres travelled and CO_2 emitted if each mode of transport is the only one used for all possible inter regional flows. The final row shows the values if the optimum mode is chosen for each flow. There are cost savings of nearly 23% to be made by using alternative higher capacity vehicles and rail for the appropriate inter regional movement, with an almost 58% reduction in road kilometres and a commensurate reduction of 46% in CO_2 emitted.

Transport mode	Total cost	% Cost saving	Kilometres travelled	% km saving	Total CO2	% CO2 saving
Road 44tn vehicle	£8,607,005		5,919,437		5,602	
Road Double Deck vehicle	£7,506,105	-12.8%	3,214,795	-45.7%	3,688	-34.2%
Road Longer Semi Trailer	£7,913,570	-8.1%	5,132,632	-13.3%	5,181	-7.5%
Road Longer Heavier Vehicle	£7,468,389	-13.2%	3,854,074	-34.9%	5,444	-2.8%
Rail 26 wagon train	£8,046,576	-6.5%	2,658,969	-55.1%	3,126	-44.2%
Rail 20 wagon train	£7,543,682	-12.4%	2,545,654	-57.0%	3,446	-38.5%
Rail 12 wagon train	£8,052,231	-6.4%	2,588,514	-56.3%	4,249	-24.2%
Rail 5 wagon TruckTrain	£8,006,938	-7.0%	2,770,057	-53.2%	3,659	-34.7%
Optimum Tpt mode	**£6,645,274**	**-22.8%**	**2,506,491**	**-57.7%**	**3,009**	**-46.3%**

Table 3: Summary of results for multimodal/alternative high capacity vehicle option for all possible inter regional flows.

Table 4 shows the optimum mode for each inter regional flow. The results indicate significant transport cost and CO_2 savings from using double deck trailers. However, the cost of external lifts has not been included. If permitted, the use of a longer heavier vehicle would also yield a cost and CO_2 benefit between Wellingborough and Weddington for instance. The results clearly show that these larger vehicles are beneficial but there are operational issues to be addressed such as the ability of a facility to receive such a vehicle and the need to maintain high utilization of the asset to justify the capital outlay. On the basis of 26 pallets per wagon and between 26 and 12 wagons per train, the analysis identified some major opportunities for modal shift. Between eleven pairs of consolidation centres the model indicates a 20 wagon train is cost effective. Ten of the inter consolidation flows are only in a single direction which means that a two way flow has been costed using road based vehicles only, without any backhaul opportunity.

From Regional CC	To Regional CC	Main Transport Mode/Vehicle
Weddington	Wellingborough	Road LHV
Wellingborough	Weddington	
Andover	Downend	Rail 20w train
Downend	Andover	
Wellingborough	Waltham Forest	Road DD
Waltham Forest	Wellingborough	
Waltham Forest	Andover	Road DD
Andover	Waltham Forest	
Bold Heath	Thorne	Road DD
Thorne	Bold Heath	
Thorne	Weddington	Rail 20w train
Weddington	Thorne	
Bold Heath	Weddington	Road DD
Weddington	Bold Heath	
Wellingborough	Andover	Road DD
Downend	Weddington	Rail 20w train
Weddington	Downend	
Herrington	Thorne	Rail 20w train
Thorne	Herrington	
Weddington	Waltham Forest	Road DD
Waltham Forest	Weddington	
Thorne	Wellingborough	Rail 20w train
Wellingborough	Thorne	
Weddington	Andover	Road DD
Wellingborough	Downend	Road DD

From Regional CC	To Regional CC	Main Transport Mode/Vehicle
Downend	Waltham Forest	Rail 20w train
Waltham Forest	Downend	
Wellingborough	Bold Heath	Rail 20w train
Bold Heath	Wellingborough	
Herrington	Bold Heath	Rail 20w train
Bold Heath	Herrington	
Grangemouth	Herrington	Rail 20w train
Herrington	Grangemouth	
Downend	Bold Heath	Rail 20w train
Bold Heath	Downend	
Waltham Forest	Thorne	Road DD
Bold Heath	Andover	Road DD
Downend	Thorne	Road DD
Herrington	Weddington	Road DD
Weddington	Herrington	
Waltham Forest	Bold Heath	Road DD
Bold Heath	Waltham Forest	
Grangemouth	Bold Heath	Rail 20w train
Bold Heath	Grangemouth	
Grangemouth	Thorne	Road DD
Waltham Forest	Herrington	Road DD
Herrington	Downend	Road 44tn
Weddington	Grangemouth	Road DD
Wellingborough	Grangemouth	Road DD
Grangemouth	Wellingborough	
Waltham Forest	Grangemouth	Road DD

Table 4: Transport suggested for flows between regions when locating the regional consolidation centres at the centre of gravity

4.2 Option 2

One of the disadvantages for rail is the cost of the road feeder legs to get the goods to and from a rail freight terminal. Consequently, an additional strategy considered placing the regional consolidation centres away from the centre of gravity and locating them at the nearest rail freight terminal, as shown in figure 4 which represents a schematic of this option.

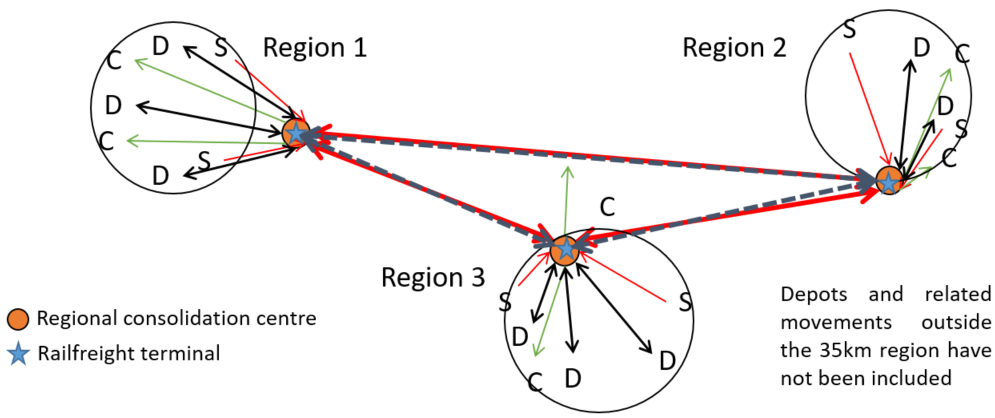

Figure 4: Schematic showing the freight flows between three regional consolidation centres when positioned at the nearest rail freight terminal

Clearly, because the rail freight terminals are not located at the centre of gravity, and may even be positioned outside a 35km region, there will be a higher cost of moving goods between the depots, customers and suppliers and the regional consolidation centres.

However, in this instance, the cost, kilometres and CO_2 for the inter-regional flows are lower than option 1, as shown in Table 5, with a cost reduction of nearly 28% over the 44 tonne vehicle option when the optimum transport mode is selected for moving goods between each of the pairs of regional consolidation centres. There is also a higher overall reduction than option 1 in road kilometres and CO_2 of nearly 64% and 49% respectively.

Transport mode	Total cost	% Cost saving	Kilometres travelled	% km saving	Total CO2	% CO2 saving
Road 44tn vehicle	£8,849,858		6,110,213		5,782	
Road Double Deck vehicle	£7,695,447	-13.0%	3,317,935	-45.7%	3,806	-34.2%
Road Longer Semi Trailer	£8,136,058	-8.1%	5,297,914	-13.3%	5,348	-7.5%
Road Longer Heavier Vehicle	£7,677,903	-13.2%	3,977,928	-34.9%	5,618	-2.8%
Rail 26 wagon train	£7,870,091	-11.1%	2,460,568	-59.7%	2,938	-49.2%
Rail 20 wagon train	£7,301,328	-17.5%	2,312,371	-62.2%	3,225	-44.2%
Rail 12 wagon train	£7,802,002	-11.8%	2,337,323	-61.7%	4,011	-30.6%
Rail 5 wagon TruckTrain	£7,734,664	-12.6%	2,507,993	-59.0%	3,411	-41.0%
Optimum Tpt mode	**£6,379,822**	**-27.9%**	**2,205,516**	**-63.9%**	**2,938**	**-49.2%**

Table 5: Summary of results for multimodal/alternative high capacity vehicle option with regional consolidation centres located at rail freight terminals for all possible inter regional flows.

Table 6 shows the selected mode of transport between the regional consolidation centres, and even though they are co-located at the rail freight terminals, the model results still show a preference for road in many instances, although the modes have changed for many of the inter regional flows. These results reflects the revised distances involved, the time taken to move the goods and the cost, compared to option 1.

From Regional CC	To Regional CC	Main Transport Mode/Vehicle
Birch Coppice Wellingborough	Wellingborough Birch Coppice	Road LHV
Andover Avonmouth	Avonmouth Andover	Road LHV
Wellingborough Barking	Barking Wellingborough	Rail 20w train
Barking Andover	Andover Barking	Rail 26w train
Warrington Doncaster	Doncaster Warrington	Rail 26w train
Doncaster Birch Coppice	Birch Coppice Doncaster	Road LHV
Warrington Birch Coppice	Birch Coppice Warrington	Rail 26w train
Wellingborough	Andover	Road LHV
Avonmouth Birch Coppice	Birch Coppice Avonmouth	Road LHV
Teesport Doncaster	Doncaster Teesport	Road LHV
Birch Coppice Barking	Barking Birch Coppice	Rail 26w train
Doncaster Wellingborough	Wellingborough Doncaster	Road LHV
Birch Coppice	Andover	Road LHV
Wellingborough	Avonmouth	Road LHV

From Regional CC	To Regional CC	Main Transport Mode/Vehicle
Avonmouth Barking	Barking Avonmouth	Road DD
Wellingborough Warrington	Warrington Wellingborough	Road DD
Teesport Warrington	Warrington Teesport	Road DD
Grangemouth Teesport	Teesport Grangemouth	Road DD
Avonmouth Warrington	Warrington Avonmouth	Rail 5w TruckTrain
Barking	Doncaster	Road DD
Warrington	Andover	Road DD
Avonmouth	Doncaster	Road DD
Teesport Birch Coppice	Birch Coppice Teesport	Road DD
Barking Warrington	Warrington Barking	Rail 20w train
Grangemouth Warrington	Warrington Grangemouth	Road DD
Grangemouth	Doncaster	Road DD
Barking	Teesport	Road DD
Teesport	Avonmouth	Road 44tn
Birch Coppice	Grangemouth	Road DD
Wellingborough Grangemouth	Grangemouth Wellingborough	Road DD
Barking	Grangemouth	Road DD

Table 6: Transport suggested for flows between regions when locating the regional consolidation centres at rail freight terminals

Although the cost, kilometres and CO_2 savings are greater in this second option, if the costs are then added to the other road based costs for the entire network such as all the full load movements from depots which is 60% of all pallets in the sample, plus part load movements within region and movements from those depots outside the 35km regional boundary, then a smaller overall percentage cost and CO_2 savings are achieved, compared to the two options. Table 7 shows the entire collaborative network savings as a percentage of the totals for the 10 individual company operations, for all three options. The first (base case) is based on a standard 44 tonne articulated truck for moving pallets between the regional consolidation centres and show almost a 4.8% reduction in kilometres and a similar fall in CO_2 emissions compared to the way the individual companies currently operate. However the smaller cost reduction reflects a relatively smaller saving in hours. One of the disadvantages of considering regional consolidation centres is the additional cross-docking required. Part loads undergo additional handling at consolidation centres in both the origin and destination regions. This inflates unloading and loading times and potentially increases the risk of product damage. Option 1 shows an extra 0.9% cost saving by using the appropriate alternative higher capacity vehicle or rail with a commensurate reduction of 1.8% in kilometres and 1.4% in CO_2. However, if regional consolidation centres are located at the nearest rail freight terminals (option 2) instead of their centre of gravity location, then the cost, kilometres and CO_2 savings are much lower. The cost saving for option 2 is less than half that of option 1. This is due to a higher cost of moving all part load goods between the depots, customers and suppliers and the co-located regional consolidation centres and rail freight terminals. These results are for transport operations only and do not include the costs of any consolidation centre.

Collaboration Option (% saving over the entire fleet operation)		Total Cost	Total Kilometres	Tonnes of CO2
Totals for 10 individual company operations for one month in 2013		**£77,360,485**	**62,037,850**	**58,737**
Base case	**Regional consolidation centres located at their centre of gravity - 44 tonne vehicle only**	2.0%	4.8%	4.4%
Option 1	**Use of alternative modes in conjuction with regional consolidation centres located at the centre of gravity**	2.9%	6.6%	5.8%
Option 2	**Use of alternative modes in conjuction with regional consolidation centres at rail freight terminals**	1.1%	3.8%	3.6%

Table 7: Savings from regional consolidation centre model compared to individual company operations

5. Conclusions

The main deliverables from this study were quantified estimates of the potential reductions in truck-km, energy and emissions, for the multimodal options and alternative higher capacity road based vehicles. This study has provided a greater insight into the strategic planning of companies' physical logistics networks by improving awareness of the economic and environmental benefits of alternative transport modes. It supplements current efforts by industry to improve road freight sustainability through the use of road and rail at operational and technological levels with a review of the higher-level, strategic options, for making logistics networks and supply chains less freight transport-intensive.

This paper reports the results of a strategic assessment of the potential for saving cost and CO_2 emissions in the FMCG sector by applying a range of collaborative transport initiatives. Opportunities for multi-modal collaboration were investigated across a sample of 10 large FMCG businesses. The analyses have shown that there are opportunities to improve operational efficiency and cut carbon emissions. However, for time-sensitive grocery deliveries some of the multi modal options involving multiple handlings may not be acceptable. When the results of this and a wider study were presented at various FMCG workshops and meetings a number of companies expressed an interest in operationalising the results so they could realise the savings. Future research should look at this area, plus it would be useful to modify the cost and operational factors in the model to test various scenarios that could encourage greater use of rail, as desired by the EU and UK government. It may be possible to bring about any beneficial modifications through policy measures. Future work should also involve looking at costs of operating regional consolidation centres so that a complete supply chain cost can be produced.

The savings identified in the analyses represent the theoretical maximum, which it may not be possible to realise in practice. Once companies undertake tactical and operational assessments of the various transport initiatives, they may find the savings to be significantly lower. This may be due to factors such as the timing of deliveries, variability of load size and the incompatibility of company procedures and equipment. In addition there may be cultural or competitive issues between companies which will need to be overcome. There are many real and perceived barriers to logistical collaboration including legal compliance, establishing an equitable system for allocating benefits, and defining the nature of the relationship. There are also barriers to overcome within the rail freight sector who have to overcome the negative perceptions of shippers, and begin to innovate with new product offerings. Rail cannot rely on the discomfiture of its primary competition, road transport, as part of any strategy to regain and retain traffic. This has to be achieved on merit including radical changes to the technical, commercial and operating models. More of the same will not work if any significant share of the FMCG traffic is to be attracted and retained. However the results of this study should give the participating companies, and the FMCG sector as a whole, encouragement to develop multimodal collaborative strategies for sustainable logistics.

This study quantifies the comparative benefits in terms of cost and CO_2 of using rail as well as alternative types of road based vehicles. The rail element only considers full train load movements. Further research should also consider the cost and CO_2 opportunity of using wagon loads (shared user services) which, although likely to be more expensive than a full train, may elicit new outcomes. Also, there may be merit in being selective as to which regional consolidation centre should be located at a rail freight terminal.

As this was a self-select rather than random sample of companies, one must exercise caution in generalising on the basis of these results. The combined transport operations of the 10 companies, nevertheless, represent about 5% of all freight kilometres travelled in the UK, and it has been shown that significant cost and CO_2 savings can be achieved through collaboration.

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References

1. *Aberdeen Group (2013) 'Retail supply chain collaboration: why mid-market companies struggle to keep pace.'*
2. *AECOM (2010) 'Rail freight user survey: Final report', Produced for ORR, June 2010,* http://orr.gov.uk/__data/assets/pdf_file/0005/5459/freight-user-survey-2010.pdf *(accessed 2nd February 2017)*
3. *AECOM (2016) 'Future potential for modal shift in the UK rail freight market', prepared for the DfT, 1st September 2016*
4. *ARUP (2014) 'Review of revenue support freight grant schemes: summary report', IR002, Issue | 21 March 2014, DfT*

5. *Biermasz, J., Louws, M. (2014) 'CO3 position paper: Legal framework transformation', Deliverable D2.9, August 2014, www.co3-project.eu*
6. *Bina, L., Binsta, H., Brezine, E., Kumpost, P., Padelek, T. (2014) "Comparative model of unit costs of road and rail freight for selected European countries" European Journal of Business and Social Sciences, Vol 3, No. 4, pp127-136, July 2014*
7. *Butcher, L. (2009) 'Lorry sizes and weights', House of Commons Library, SN/BT/654*
8. *CO3, (2014) 'Final project report', August 2014, www.co3-project.eu*
9. *Comtois, C (2015) 'Sustainable Railway Futures : Issues and Challenges', (Editor Becky P.Y.Loo) Ashgate 2015. ISBN 13: 9781409452430*
10. *Consumer Goods Forum, Cap Gemini (2011) 'Future Value Chain 2020 - Building strategies for the new decade'.*
11. *Cruijssen, F., W. Dullaert and T. Joro (2010) 'Logistics efficiency through horizontal cooperation: The case of Flemish road transport companies', International Journal of Logistics Research and Applications* ***13*** *(3): 161-178.*
12. *Dadhich, P., Piecyk, M., Palmer, A., Greening, P., & Holden, R. (2015), Factors affecting vehicle utilisation: An analysis of the recent development in the UK FMCG distribution networks, Paper presented at 20th International Symposium on Logistics, Italy*
13. *DfT (2015) 'Transport statistics Great Britain 2015', RFS Table TSGB0402, P95*
14. *DfT (2016) 'Longer semi trailer trial evaluation: annual report 2015', September 2016*
15. *ECR Europe/McKinsey, (2012) 'The next generation: retailer and manufacturer collaboration survey 2012'*
16. *European Court of Auditors (2016) 'Rail freight transport in the European Union', Luxembourg: Publications Office of the EU., May 2016*
17. *Eurostat (2016) http://ec.europa.eu/eurostat/statistics-explained/index.php/Road_freight_transport_by_journey_characteristics (accessed 31st January 2017}.*
18. *EU (2011) 'White paper roadmap to a single European transport area – towards a competitive and resource efficient transport system', http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0144 (accessed 27th January 2017)*
19. *EU (2015) 'Freight on Road: Why EU shippers prefer truck to train', DG for Internal Policies. Policy Dept. B: Structural and Cohesion Policies, European Parliament, 2015 http://www.europarl.europa.eu/RegData/etudes/STUD/2015/540338/IPOL_STU(2015)540338_EN.pdf (accessed 11th January 2017)*
20. *Eye for transport (2010) 'European supply chain horizontal collaboration'*
21. *Gartner (2012) 'State of the industry: Opening address, retail and FMCG supply chain summit', Eye for Transport, Dusseldorf. 12th April 2012*
22. *Global Commerce Initiative and CapGemini (2011) 'Building strategies for the new decade: future value chain 2020', http://www.theconsumergoodsforum.com/files/Publications/2020-Future-Value-Chain-Report.pdf (accessed 12/2/2017)*
23. *Graham, L. (2011) 'Transport collaboration in Europe. Technical report', ProLogis Corporate*
24. *Greening, P., Piecyk, M., Palmer, A., McKinnon A. (2015) 'An assessment of the potential for demand side fuel savings in the heavy goods vehicle sector', Prepared for the Committee on Climate Change, December 2015*
25. *Health and Safety Executive (2012) 'Load security on double decks', Prepared by the Health and Safety Laboratory for the Health and Safety Executive, RR924 Research Report*
26. *Hingley, M., A. Lindgreen, D. Grant, and C. Kane (2011) 'Using fourth-party logistics management to improve horizontal collaboration among grocery retailers', Supply Chain Management: An International Journal 16(5), 316–327*
27. *Holter, A., Limatainen, H., McKinnon, A.C., Edwards, J. (2010) 'Double deck trailers: A cost benefit model estimating environmental and cost savings', LRN Conference 2010, Harrogate*
28. *IGD (2017) 'Tesco business update', Wembley, 17th May 2017*
29. *IRIS (2001) 'Final Report UK demonstrator ', Report Reference Contract JC98-5016, June 2001, PP 78-90, www.transport-research.info/sites/default/files/project/documents/iris.pdf*

30. *Islam, D.M.Z., Ricci, S., Nelldal, B. L., (2016) 'How to make modal shift from road to rail possible in the European transport market, as aspired to in the EU Transport White Paper 2011', European Transport Research Review, 8(3) 2016 1-14*
31. *Kim, N. S., Van Wee, B., (2011) The relative importance of factors that influence the break-even distance of intermodal freight transport systems, Journal of Transport Geography, doi:10.1016/j.jtrangeo.2010.11.001*
32. *Knight, I., Newton, W., McKinnon, A., Palmer, A., Barlow, T., McCrae, I., Dodd, M., Couper, G., Davies, H., Daly, A., McMahon., Cook, E., Ramdas, V. and Tylor, N. (2008) 'Longer and/or longer and heavier vehicles (LHVs): A study of the likely effects if permitted in the UK – final report' TRL Ltd. Crowthorne*
33. *Lambert, D., M. Emmelhainz and J. Gardner (1999) 'Building successful logistics partnerships', Journal of Business Logistics,* ***20****(1), 165-181*
34. *Leach, D. Z., Savage, C. J. and Maden, W. (2013) 'High-capacity vehicles: an investigation of their potential environmental, economic and practical impact if introduced to UK roads', International Journal of Logistics Research and Applications, 16(6), 461-481.*
35. *Mason, R., C. Lalwani and R. Boughton (2007) 'Combining vertical and horizontal collaboration for transport optimisation', Supply Chain Management: An International Journal* ***12****(3): 187 – 199*
36. *McKinnon, A.C. (1989) 'Physical Distribution Systems' Routledge, London.*
37. *McKinnon, A.C. (2005) 'The economic and environmental benefits of increasing maximum truck weight: the British experience', Transportation Research Part D: Transport and Environment, vol 10, no. 1, pp. 77-95. DOI: 10.1016/j.trd.2004.09.006*
38. *MDS Transmodal (2012) 'Impact of changes in track access charges on rail freight traffic', Stage 1 Report, ORR*
39. *OECD (2011) 'Moving freight with better trucks: Improving safety, productivity and sustainability' OECD publishing, http://www.oecd-ilibrary.org/transport/moving-freight-with-better-trucks_9789282102961-en (accessed 11th January 2017)*
40. *Office of Rail and Road (2015) 'ORR System Operation Consultation: FTA response', 16th October 2015, http://orr.gov.uk/__data/assets/pdf_file/0003/19704/orr-system-operation-consultation-october-2015-fta-response.pdf (accessed 2nd February 2017)*
41. *Office of Rail and Road (2016) 'Freight Rail Usage 2015-16 Q4 Statistical Release', 19th May 2016 (Revised 23 November 2016), http://orr.gov.uk/__data/assets/pdf_file/0012/22008/freight-rail-usage-2015-16-quarter-4.pdf (accessed 20/2/2017)*
42. *PACT (2000) 'Final Report of a Feasibility Study within the PACT programme', PACT Contract no: B1-B97-B2 7060-SIN 7264-SUBPACT, Stockholm, 2000*
43. *Palmer, A., McKinnon A. (2011) 'An analysis of the opportunities for improving transport efficiency through multi-lateral collaboration in FMCG supply chains', LRN 2011, Southampton, September 2011*
44. *Palmer, A., Saenz, M.J., van Woensel, T., Ballot, E. (2012), 'Characteristics of collaborative business models', CO3 deliverable 3.1, www.co3-project.eu*
45. *RHA (2013) 'Road Haulage Association cost tables 2013', Prepared by DFF International*
46. *Ritter, T., Wilkinson, I., Wesley (2004) 'Managing in Complex Business Networks', Industrial Marketing Management* ***33****: 175-83.*
47. *Simatupang, T. and R. Sridharan (2002) 'The collaborative supply chain', International Journal of Logistics Management,* ***13****(1), 15-30*
48. *SteadieSeifi, M., Dellaert, N. P., Nuijten, W., Van Woensel, T., & Raoufi, R. (2014) 'Multimodal freight transportation planning: A literature review', European Journal of Operational Research, 233(1), 1-15. doi:10.1016/j.ejor.2013.06.055*
49. *Surtees, P. (2013) 'A veteran collaborator's perspective on how to collaborate', Presentation to ELUPEG workshop, January 2013*
50. *TruckTrain (2017) http://www.trucktrain.co.uk/, (accessed 8th February 2017).*
51. *Verelst, M. (2017 '1st workshop on logistics cloud - carbon footprint reduction in freight transport and logistics', Collaborative Innovation Days, Diamant Conference & Business Centre, Brussels, European Commission & ALICE, 31st March 2017*

52. *Woodburn, A.G. (2012) 'Intermodal rail freight activity in Britain: where has the growth come from?', Research in Transportation Business & Management: Airport Management. 5, pp. 16-26.*
53. *WSP (2011) 'Longer semi-trailer feasibility study and impact assessment: final summary report', http://www2.dft.gov.uk/pgr/freight/research/longersemitrailer (accessed 16th November 2016)*