An empirical study of the variability in the composition of British freight trains

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Abstract

As part of the broader sustainability and economic efficiency agenda, European transport policy places considerable emphasis on improving rail's competitiveness to increase its share of the freight market. Much attention is devoted to infrastructure characteristics which determine the number of freight trains which can operate and influence the operating characteristics of these trains. However, little attention has been devoted to the composition of the freight trains themselves, with scant published data relating to the practicalities of this important component of system utilisation and its impacts on rail freight viability and sustainability. This paper develops a better understanding of the extent to which freight train composition varies, through a large-scale empirical study of the composition of British freight trains. The investigation is based on a survey of almost 3,000 individual freight trains, with analysis at four levels of disaggregation, from the commodity groupings used in official statistics down to individual services. This provides considerable insight into rail freight operations with particular relevance to the efficiency of utilisation of trains using the available network paths. The results demonstrate the limitations of generalising about freight train formations since, within certain commodity groupings, considerable variability was identified even at fairly high levels of disaggregation.

1. Introduction

European transport policy favours a much increased role for rail in meeting the growing requirement for both freight and passenger movement (European Commission, 2011). In Britain, rail's share of the domestic freight market (measured in tonne kilometres) reached a low of 6 per cent in 1995 before rising to 9 per cent in 2010 and national rail's share of passenger kilometres increased from 5 per cent to 7 per cent in the same period (DfT, 2014). The growth in network activity is exacerbating the conflicts that arise from the operation of a mixed traffic railway (i.e. one that caters for both passenger and freight traffic). While there is a considerable body of literature relating to rail capacity utilisation, the emphasis has tended to be on analysis of train path provision and, to a lesser extent, path characteristics or path utilisation so as to maximise rail freight activity on a route or network. There is surprisingly little consideration of how well the freight trains themselves are utilised and how this varies, for example between and within flow types.

The timetabling process for freight trains tends only to crudely reflect variations in planned train capacity and actual on-train utilisation, if indeed any variability is included at all. In the British context, for example, Network Rail (2014a) plans train paths using timing loads which take account of factors such as train trailing weight, traction type, train length and maximum permissible speed. However, these are greatly simplified for ease of planning and to ensure that timetabled paths provide schedules which are usable by a range of different freight train types, even where the path is used by only one flow type. Given the increasingly competitive rail freight market in Britain and elsewhere in Europe, standardised train paths for freight trains of a designated maximum speed and trailing weight are becoming more common, particularly on international rail freight corridors. For example, pre-arranged paths with standard parameters to encompass access requests for most types of freight flow have been introduced on the Corridor Rhine-Alpine (2015). This high degree of standardisation in the scheduling of freight trains is logical from a planning perspective, but typically ignores the actual on-train utilisation of the train filling the path. No literature comprehensively assessing on-train utilisation across an entire country's network has been identified but Leyds (2012) found that, in the Netherlands, there was considerable variability in freight train operating speeds and tonnages along the studied Dutch rail corridors but that freight train paths were timetabled using a single standard. However, on-train capacity utilisation, and the extent to which it varies (e.g. by flow or by time), plays an important role in determining:

- the extent to which rail system capacity is being utilised: this is an important issue in countries such as Britain which have experienced considerable growth in rail freight activity and where network capacity concerns are emerging more frequently
- rail freight viability, given the high fixed costs involved in running freight trains and the challenges of reducing unit payload costs to make rail freight more competitive
- rail freight sustainability, since the quantification of sustainability impacts typically relies on the use of average factors based on top-down data and does not account for operational variability at a more disaggregated level.

These issues are discussed in more depth in Section 2. In the absence of published operational data for variables such as tonnage or number of unit loads at an individual train level across the entire British rail freight industry, this paper is based on a large-scale empirical study of the composition of British freight trains using the number of wagons per train as a proxy variable. While this measure has some shortcomings, identified in Section 3, it does permit an evidence-led approach to better understanding the nature of freight train composition across a country's entire rail freight market. Specifically, the twin research objectives are to understand the extent to which there is variability in freight train composition on the British rail network and to determine the level of disaggregation of rail freight activity that is required in order to find a high degree of homogeneity in composition. Essentially, the paper seeks to establish the level of granularity needed to be able to reasonably understand or predict the capacity provided on a freight train and to identify whether this differs by rail freight market segment: in other words at what level, if any, can one talk about a 'typical' freight train in terms of its composition? The objectives are satisfied through a large-scale empirical study of the composition of British freight trains.

The paper is structured as follows. The next section sets out the detailed study context, summarising the key issues from the academic and policy-based literature. Section 3 provides details of the materials and methods used for the primary research on British rail freight train composition, followed in Section 4 by analysis and discussion of the survey results. Section 5 discusses the paper's contribution by considering the practical implications of the research findings for understanding the impacts of the variability in freight train composition.

2. Study context

This section begins with a discussion of the categorisation of rail freight operations. It then considers the key aspects of the literature relating to the role of freight train composition in the use of rail system capacity and the viability and sustainability of rail freight.

2.1 Conceptual categorisation of freight train operations

It is possible to categorise the method of freight train working, with a caveat that the reality is generally not as straightforward as the conceptual frameworks in the literature suggest. From the literature base, Table 1 provides a range of examples of the categorisation of the types of rail freight operations.

Insert Table 1 here

For the core rail freight market, excluding mail/express freight and infrastructure traffic, the following categorisation summarises the key operational differences, although the precise terminology adopted varies depending on the source:

1. trainload – an entire train, usually of a single commodity (e.g. coal, steel), running from origin to destination without intermediate marshalling
2. wagonload – trunk trains operating between hub marshalling yards made up of single wagons (or small groups of wagons), generally with a mix of commodities and/or customers and with feeder trains between hubs and individual customers' terminals; this type of operation typically involves a wagon being re-marshalled several times en route from origin to destination
3. block wagonload – essentially an intermediate between trainload and wagonload, based on train portions (or blocks of wagons) combined for movement in full train loads and with portions exchanged at a smaller number of intermediate marshalling yards than is typical for wagonload.

Intermodal is sometimes considered as a separate category, but in terms of the method of working it fits into one of the aforementioned three categories. The three categories are discussed in Sections 4 and 5 in the context of the paper's analysis and discussion.

2.2 Rail system capacity

The study of rail capacity utilisation is multi-faceted, with complex interactions between infrastructure (e.g. number and characteristics of train paths available) and train operation (e.g. train lengths and load factors). Fundamentally, constraints on rail capacity limit the role that rail can play in achieving a more efficient and sustainable freight system. Detailed consideration of rail capacity issues in the academic literature relates mainly to network capacity and the availability of train paths (see, for example, Abril et al., 2008; Dicembre and Ricci, 2011; Malavasi et al., 2014; Witte et al., 2012). Other researchers have adopted a focus on particular attributes of capacity planning: see, for example, the challenges of integrating in real time the requirements of different actors on a mixed traffic railway (Goverde et al., 2013; Tschirner et al., 2014) or the issues relating to constraints at railway stations (Dewilde et al., 2013). In the modelling and simulation literature specifically considering rail freight, capacity analysis also tends to focus on network capacity constraints and, to some extent terminal capacity constraints (see, for example, Liu and Kozan, 2011).

In comparison to route and network capacity utilisation, however, surprisingly little attention has been devoted to the issue of on-train capacity utilisation, with little published data relating to the practicalities of this important component of system utilisation. Boysen (2012) proposed a general rail capacity model, with parameters to take account of both weight and volume characteristics of freight trains given that load capacity per train is a critical component of system capacity. Within the context of the development of the high-capacity German-Scandinavian rail corridor, the capacity per train was then modelled for different sets of infrastructure standards and large potential improvements in load capacity were identified (Boysen, 2014). The relationship between the theoretical and actual capacity per train, and the extent to which the latter varies, features rarely in the literature. When it takes place at all, quantification of 'real world' on-train freight efficiency tends to occur at a very high level of aggregation and does not relate directly to capacity provision and utilisation. Based on official statistics (ORR, 2014), the payload of an average freight train in Britain increased from 214 tonnes to 404 tonnes over the decade from 2003/04 to 2013/14, but there is no indication of how this varied for different commodity flows. On occasion, disaggregated information at a flow or customer level is presented in the literature but the extent to which this is a simplification of reality is not always clear. Two contrasting examples are that of Tesco (Freight Best Practice, 2010a), where it is stated that each train between Daventry and Grangemouth carries exactly 28 containers, and The Malcolm Group (Freight Best Practice, 2010b), where reference is made to an average of 25 containers southbound and 24 containers northbound on its service on the same corridor. In a study of container trains linking ports to their hinterland terminals, Woodburn (2011) identified considerable variability in both on-train capacity provision and load factors in this specific rail freight market. Backåker and Krasemann (2012) focused on the carload (or wagonload) component of the rail freight market for a Swedish operator, assessing the challenges associated with fluctuations in daily volumes. Perhaps controversially, particularly for intensively used routes where there is pressure to use standard train paths, their results suggest that rail freight operators should be more flexible in running services matched to known demand. Freight train capacity was incorporated into the modelling process through service capacities with maximum tonnages and train lengths, though the key performance measures were total transport time and number of shunting activities.

It is evident that efficient use of rail capacity is a major objective in the pursuit of increasing rail's mode share of the transport market. Rail capacity limitations are an increasing concern, with growing attention being devoted to ensuring that there is sufficient capacity to cater for absolute growth in rail volumes and, more importantly, modal shift from road to rail. European transport policy supports the development of a rail freight priority network to make rail a more attractive option by improving capacity, journey times and other aspects of service quality (European Commission, 2007a). More than 500 reported bottlenecks affect the quality of logistics services (European Commission, 2007b); a particular action is to help to "achieve a better utilisation of transport infrastructure, including through vehicle management and load factors, and the pinpointing of infrastructure investments that would benefit freight" (European Commission, 2007c, 3). In Britain, rail projects feature strongly in the National Infrastructure Plan (HM Treasury, 2014) and Network Rail has developed an infrastructure investment plan for the 2014 to 2019 period (Network Rail, 2014b; 2014c) to cater for projected traffic growth. Perhaps not surprisingly, given its responsibility for Britain's rail infrastructure rather than freight train operations, Network Rail focuses in its Freight Market Study on network capacity and capability requirements for the following 30 year period (Network Rail, 2013b). The emergence of longer and/or heavier trains is anticipated, but with no discussion of the characteristics of existing trains across the different sectors of the rail freight market. The Logistics Growth Review (DfT, 2011) takes a broader perspective to the barriers to logistics growth, including investing in Strategic Rail Freight Interchanges (SRFIs) and in improving rail network capacity, performance and resilience.

The Strategic Freight Network (SFN) was introduced in Great Britain in 2007 (DfT, 2007) with similar objectives at the national level, aiming to remove network bottlenecks and improve capability, mostly through infrastructure enhancements (DfT, 2007; Network Rail, 2008). The SFN focuses on capacity measured in number and utilisation of train paths, but makes no explicit mention of how to achieve longer and/or heavier trains in a deregulated and privatised operating environment. Surprisingly, though, little attention has been directed towards assessing on-train capacity in rail freight other than with regard to certain infrastructure such as terminals and passing loops when considering train lengths.

2.3 Rail freight viability

Within the context of intermodal rail freight, but with more general application to rail, Bontekoning et al. (2004) emphasised the need to organise rail flows to make them efficient, profitable and competitive. Crevier et al. (2012) stressed the interrelationships between operations management and revenue management within rail freight including, among other factors, the optimisation of train composition. Increasing the amount of freight carried per train, as outlined in Section 2.2, is a critical way for rail freight operators to manage their cost base and improve their financial performance (Harris and McIntosh, 2003). Specific financial information is not published, but higher capacity freight trains have played a role in this efficiency improvement. The British port-hinterland container market provides evidence in support of this assertion. The number of containers carried by rail at Felixstowe, the largest container port, doubled between 2001 and 2011 with only a 25 per cent increase in the number of train services (Network Rail, 2013a). At Southampton, the second largest container port, on-train capacity increased by 19 per cent and train payload measured in twenty-foot equivalent units (TEUs) increased by 28 per cent following infrastructure enhancements in 2011 (Woodburn, 2013). There is considerable evidence from business surveys that unit transport costs are critical when making freight mode choice decisions (see, for example, ORR, 2012; FTA, 2014). Major retailers including Asda, Marks & Spencer and Sainsbury's have argued that rail freight needs to become more cost competitive if it is to play a greater supply chain role (FTA, 2012). The increasingly contestable rail freight market in Europe is leading to more intra-rail competition, which is an additional pressure for rail freight operators to remain profitable (CERRE, 2014).

2.4 Rail freight sustainability

As part of the National Atmospheric Emissions Inventory (NAEI, 2013) in Britain, exhaust emissions factors are provided for a range of pollutants for four different types of road goods vehicle (i.e. petrol light goods vehicles (LGVs); diesel LGVs; rigid heavy goods vehicles (HGVs; artic HGVs) for three different road types (i.e. urban; rural; motorway). With specific reference to greenhouse gas emissions, there is considerable disaggregation of goods vehicle types and load factors, with emissions factors being calculated from activity surveys and actual and test fuel consumption data (Defra, 2013). By contrast, British rail freight sustainability data take account only of the distinction between diesel and electric traction (ORR, 2014) which, given that more than 90 per cent of rail freight activity is diesel-hauled, offers little disaggregation. Other factors will affect the emissions for a given commodity flow or individual train. Defra (2013, 45) noted that "traffic-, route- and freight-specific factors are not currently available, but would present a more appropriate means of comparing modes (e.g. for bulk aggregates, intermodal, other types of freight)". The FTA (2014, 4) has called for the rail industry to "develop consistent measures for rail freight carbon generation consistent with road freight and also develop a standard environmental benefit measure".

Many of the claims of rail's environmental advantages over road are based on average emissions factors per tonne kilometre and take no account of the differing nature of rail freight flows. For example, Network Rail (2010) stated that rail produces 76 per cent less carbon dioxide (CO_2) than road, based on per tonne kilometre averages. Table 2 links together the efficiency and sustainability issues by demonstrating that there is considerable variability in both rail freight payloads themselves and the benefits over the use of road. However, there is a lack of clarity over how the relationship between the two variables was established.

Insert Table 2 here

Increasingly, carbon calculators such as EcoTransIT (2014) are offering more bespoke calculations of rail freight emissions, allowing different inputs for payload, train type, traction type, etc., but considerable knowledge about typical operating characteristics is required in order to get the most meaningful results and it is challenging to take account of variability in key measures.

2.5 Summary of knowledge gaps

Linked to the capacity issues discussed in Section 2.2, the increasing emphasis on running longer and/or heavier freight trains offers clear opportunities to improve operational efficiency and sustainability, as discussed in Section 2.3, and to improve rail freight's environmental performance (see Section 2.4). However, the published literature offers only limited understanding of the nature and variability of on-train capacity provision and utilisation within rail freight, generally with little disaggregation of the market. For example, it is not possible to discern the relative contributions of structural change in the rail freight market and on-train efficiency improvements to the increase in the number of tonnes carried per train in Britain. As a consequence, evaluation of the impact of operational changes is hampered by the lack of a sufficient evidence base. The research presented in the remainder of this paper seeks to further the understanding of the current British situation, but with broader international relevance.

3. Material and methods

This paper considers the three main freight train operational types identified in Section 2.1 (i.e. trainload, block wagonload and wagonload) insofar as they feature in British rail freight activity. As Table 1 showed, block wagonload is not normally separately identified in Britain but it is possible to identify trains which exhibit characteristics of this type. Given that it is common elsewhere in Europe, it has been included in the analysis. In any case, the overwhelming majority of British rail freight activity involves trainload operation, so consideration of the other types is less of an issue than in many other countries. Of the specialist types of operation also identified, express freight services do exist but have been excluded since, with fewer than 10 mail trains per day, this category forms a negligible part of British rail freight activity.

To assess the extent and nature of variability in freight train composition, an iterative survey process was adopted based on increasing levels of disaggregation of rail freight activity. In total, a four-level survey of loaded freight trains was conducted between June 2013 and August 2014, recording details of the number and type(s) of wagons conveyed on each train surveyed. Ideally, data relating to mass load capacity and volume load capacity (Boysen, 2012) would have been analysed but this would require access to TOPS (Total Operating Processing System), the computing system used to track rail vehicles on the British network (Ellis, 2006). In the competitive rail freight market place, such official information relating to train length and payload was viewed as commercially sensitive by the operators contacted and direct access to TOPS was not forthcoming. Instead, number of wagons was considered to be the most suitable proxy since this information is obtainable by direct observation and from online sources aimed primarily at rail enthusiasts. A combination of these sources has been used in this analysis to ensure broad coverage of the entire British rail freight market. To ensure the validity of the online information, only that which originated from industry sources was used and, before proceeding with the full survey, a sample of more than 100 individual services was cross-checked against direct observations. No disparity was found for any of these trains, so the use of the online information enabled a much larger sample size than would have been possible from direct observations alone.

The starting point for the survey was the commodity grouping classification adopted for official statistics of rail freight moved (ORR, 2014). The number of trains sampled in each of the seven commodity groupings is shown in Table 3. A minimum threshold of 200 services was adopted for five of the seven commodity groupings. A lower threshold of 100 was applied to *Metals* and *Oil & petroleum*, the smallest two of the four bulk sectors. Despite *International* and *Other* in combination representing less than 10 per cent of rail freight volumes, these two commodity groupings are more varied in their commodities than the others so the higher threshold was applied. There are no published statistics revealing the number of trains operated within each commodity grouping but, for comparative purposes, the table includes two measures of rail freight activity, one official and one from the aforementioned database, to demonstrate the survey coverage. It should be noted that the database does not include coal trains, so care needs to be exercised when interpreting the information in this table column; it has been included to show the relative contribution of each of the other commodity groupings to the overall rail freight market but the percentages will be greater than the true situation as a result of the exclusion from the database of *Coal*.

Insert Table 3 here

When defining loaded freight trains for the purposes of sampling, the same convention was adopted as has been applied to the annual database of service provision compiled by the author since 1997. For the bulk commodities (i.e. *Coal*, *Metals*, *Construction* and *Oil & petroleum*), loaded services are easily identifiable by the direction of commodity flow (e.g. coal from port to power station; construction materials from quarry to storage depot); it is generally the case that all wagons are loaded. Within some components of *International* and *Other*, the flow characteristics mirror the bulk commodities, with a clearly identifiable direction of flow. For other components of these commodity groupings, plus *Domestic Intermodal*, all services are assumed to be loaded since in principle they are available to carry customers' traffic in both directions. However, the extent to which they are loaded is likely to be more variable than for the bulk commodities. Previous research focusing on the intermodal market (Woodburn, 2011) identified that it is rare for no containers (or other unit loads) to be carried on such trains and that intermodal trains in Britain have load factors of around 72 per cent. The situation regarding wagonload services is less well understood. It is likely that empty running is more prevalent for local feeder trains, but the limited role for wagonload and the survey focus only on trunk wagonload services, where at least part-loading of the train is likely, reduces the likelihood of totally empty trains being included.

Figure 1 provides an overview of the entire sampling approach across the four levels. The survey coverage of the flow groups sampled at the second and third levels and the origin-destination (O-D) pairs or specific services at the fourth level is shown. In each case, the minimum sample size adopted for inclusion at each level is also displayed.

Insert Figure 1 here

The selection of flow types for inclusion at the subsequent levels was based on a combination of a desire to investigate the characteristics of a range of different flow types (e.g. bulk trainload, wagonload, intermodal) and the availability of sufficient observations to allow meaningful analysis. The fourth level consisted of a mixture of O-D pairs and individual services. O-D pairs were analysed where there were frequent services (i.e. two or more loaded trains per day) between pairs of terminals, making it logical to consider them together. For example, there are typically six biomass trains per day between Tyne Dock and Drax power station and eight loaded container trains, four in each direction, on the Felixstowe to Doncaster corridor. After the original survey at the official commodity grouping level, targeted additional sampling was undertaken in order to boost the observations for the chosen sub-categories in order to meet the threshold sample size in each case. This was carried out sequentially at each level of disaggregation. Using the *International* commodity grouping as an example, the sample size of 203 observations was comprised of 127 intermodal and 76 non-intermodal observations, reflecting the relative importance of these two traffic types in service provision in the international category. For intermodal, the threshold for the next two levels was met already and additional sampling was required only at the individual service level (i.e. level 4) for services 4O57 and 4O93[1]. For non-intermodal, however, additional services were needed to meet the level 2 threshold of 100 and further services were sampled for levels 3 and 4 to meet those thresholds. As can be seen, with the exception of the *Metals* commodity grouping, increasingly greater disaggregation was achieved across the British rail freight market.

In total, 2,962 individual services were included in the sample, representing a major empirical investigation of the composition of British freight trains. Data from ORR (2014) on the number of freight train movements revealed that approximately 360,000 freight trains operated during the survey period: this total includes all freight trains and infrastructure trains. Assuming that 10 to 15 per cent of these trains were infrastructure trains rather than commercial freight trains, and that empty trains accounted for 35 to 40 per cent of the remaining freight trains (based on an estimate calculated from the annual database), it is likely that in the range of 1.4 to 1.7 per cent of loaded freight trains operating during the survey period were sampled.

The quantitative analysis of freight train composition is based largely on the number of wagons in the consist of sampled trains at each of the levels for each of the commodity flows shown in Figure 1. For each cell of the diagram, the mean number of wagons per train was calculated, together with the standard deviation, maximum and minimum number of wagons and the consequent range. Care needs to be taken when interpreting this information, particularly at the initial commodity grouping level, since there is considerable variety in the wagon fleet, ranging from short two-axle wagons to five-section articulated wagons. In itself, therefore, the number of wagons is not a definitive indicator of train capacity in either length or weight terms. Generally, wagon type variability reduces as the level of disaggregation increases. In addition, within important commodity groupings such as *Coal* and *Construction*, the majority of the wagon fleets have similar length and payload characteristics. For intermodal flows, an alternative measure of train capacity is the number of TEU (twenty-foot equivalent units) that can be carried. For intermodal flows with a mix of wagon types, this is a more accurate reflection of train composition and capacity and has therefore been calculated for all sampled trains in the *Domestic intermodal* commodity grouping and for intermodal trains within the *International* commodity grouping.

A more qualitative assessment of the variability of freight train composition supports the quantitative analysis so as to deepen the understanding of the extent and nature of this variability, particularly in relation to the mix of wagon types. This is particularly helpful in understanding the characteristics of freight trains in commodity groupings (and sub-groups) where there is less homogeneity in flow types, as can be seen from the next section. As before, the author's rail freight database provided useful supporting information, together with online information sources including the Working Timetable (Network Rail, 2014a) and realtimetrains.co.uk which provides real time running information for all trains (including freight) on the national rail network. While mention is made in the following discussion of numerous specific flows and locations, it is not necessary to be familiar with them to understand the analysis and its implications. This level of detail has been included for those with a good knowledge of the British rail network.

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[1] The codes 4O57 and 4O93 are examples of train identification numbers (also known as train reporting numbers, train headcodes or, in the Working Timetable (Network Rail, 2014a) as 'signal ID') for specific services; other four character train reporting numbers are referred to later in the paper when referring to specific services

4. Analysis of variability in freight train composition

In this section, the results of the survey are presented, separated into two sub-sections for ease of presentation and comprehension. Section 4.1 deals with sampling levels one to three, while Section 4.2 focuses on the O-D pairs and individual services.

4.1 Commodity grouping level and sub-group levels 1 and 2

Table 4 presents the survey results for the first three of the four levels of analysis. At the commodity grouping level, the mean number of wagons ranges from 16.67 for *Other* up to 23.88 for *Oil & petroleum*. The mean in the *Other* category is brought down by the automotive flows, though this highlights the shortcomings of looking only at the number of wagons since the majority of automotive wagons are four- or five-section articulated ones. However, the sampling of wagonload services included only trunk ones between marshalling yards and excluded the feeder ones (i.e. those operating between marshalling yards and individual terminals); the latter typically have fewer wagons than the former, but owing to their exclusion this is not reflected in the mean. The impact of the exclusion of feeder services will be limited because they generally operate over short distances. In any case, as was stated earlier, this research does not set out to be fully representative of the entirety of the British rail freight market.

Insert Table 4 here

Considering the commodity grouping level first, with the exception of *Coal*, which has a low standard deviation and a small range of number of wagons per train, considerable variability in train composition is evident at this most aggregate level. This is the case even for those other groupings with exclusively trainload operation. For all other commodity groupings, the range in the number of wagons per train was 25 or more, with considerable variability around the mean. This is not unexpected since the flows within many of the commodity groupings can be heterogeneous in nature. The *Other* grouping includes trainload flows as diverse as biomass, forest products, china clay, potash and rock salt along with the aforementioned automotive (also in trainload) and wagonload traffic, using a wide variety of wagon types. The *International* grouping includes all through freight trains between Great Britain and mainland Europe, covering both intermodal and non-intermodal flows but both operating as trainloads; metals products dominate the non-intermodal segment, but there are other traffics including mineral water, china clay and chemicals.

Despite *Coal* exhibiting little variability at the commodity grouping level, there is a noticeable difference in mean at the third level between the flows to power stations, which form the vast majority of coal trains from Immingham, and the smaller flow to Scunthorpe steelworks. No train destined for Scunthorpe had more than 21 wagons, with the overwhelming majority being formed of 18 wagons. By contrast, the mean number of wagons on the power station flows was just over 22. Despite there being five main coal wagon types, as denoted by their classification codes, they vary little in their dimensions or maximum payload, certainly in comparison with the other commodity groupings. The *Construction* commodity grouping is an interesting one as it alone shows no discernible reduction in variability as the disaggregation increases from level one to level three. The sampled sub-groups (particularly 3.1.1 Mendips to London and South East (L&SE) terminals via Acton) are not typical of the grouping since many of the trains between the Mendip quarries at Merehead and Whatley operate as 'jumbo' services to Acton yard in west London, so are essentially block wagonload services conveying portions for more than one terminal in the L&SE area. The effects of this on train composition are discussed in Section 4.2 in the context of the individual services concerned.

Considering the survey results for *Oil & petroleum* and *Domestic intermodal*, both commodity groupings show a reduction in variability as the level of disaggregation increases. In *Oil & petroleum*, this is particularly noticeable between levels two and three. At level two, some of the minor flows from Lindsey oil refinery, particularly those of fuel oil to power stations and a railway depot, are of relatively small volumes. These flows are removed at level three, leaving the major flows from Lindsey to the large petroleum storage depots. In particular, there is a dramatic reduction in the range of the number of wagons since the high volume flows to storage depots rarely have fewer than 20 wagons per train. For *Domestic intermodal*, the overall mean number of wagons reflects the balance of a higher mean for port-hinterland flows and a lower mean for the truly domestic services. In part, though, this is a consequence of the wagon mix in the different sub-groups, which is discussed in more detail in Section 4.2. Within the truly domestic intermodal sub-group, where there are only two wagon types both similar in nature, the intra-Scottish services have fewer wagons than the others. In all cases within *Domestic intermodal*, both standard deviation and range decrease as the level of disaggregation increases. For services in the *International* category, the level of variability decreases with increasing disaggregation on the non-intermodal side, particularly for mineral water where there is very little change across the sample, but increases for intermodal mainly as a result of some very short automotive intermodal services. Once they are stripped out at the third level (i.e. 5.2.1 in Table 4) the variability is halved. There is a noticeable difference within the *Other* commodity grouping between the trunk wagonload services, where considerable variability was observed (and is discussed more fully in Section 4.2), and the trainload biomass and automotive sub-groups where variability was much less.

4.2 Origin-destination (O-D) pair and individual service levels

Tables 5 and 6 respectively show the survey results for the sampled origin-destination (O-D) pairs and individual services. In both tables, the 'parent' commodity grouping information is shown to allow comparisons to be made with Table 4. Table 7 summarises the TEU capacity results for the various intermodal flows at all four levels.

Insert Tables 5, 6 and 7 here

Only two of the sampled flows exhibited no variability at all in freight train composition, these being the Immingham to Cottam coal O-D pairing (see Table 5), where all trains consisted of 23 wagons, and the Daventry to Coatbridge Anglo-Scottish domestic intermodal service 4S44 (see Tables 6 and 7), where all trains had 14 wagons and a total capacity of 56 TEU. One of the Intra-Scottish domestic intermodal services, 4H47 Mossend to Inverness, had 10 wagons with a total capacity of 40 TEU for 63 of the 64 observations with a single observation with just 9 wagons and a train capacity of 36 TEU. Considering the entire survey sample for this greatest level of disaggregation there is only a small variation around the mean number of wagons for O-D pairs and individual services, with a range typically in single figures. The two main exceptions to this are within the *Construction* commodity grouping, where there is a mix of trainload and block wagonload operation, and for the trunk wagonload sub-group of *Other*. The subsequent discussion considers the characteristics of these two exceptions in more detail to better understand the reasons for the high variability even at this level of disaggregation, in the context of some specific aspects of freight train operations.

Nine individual services met the threshold for inclusion in the analysis of the Mendip quarries to L&SE terminals traffic, these being all of the services operating on a daily or almost daily basis on that corridor. Seven of the nine services operated to or via Acton yard in west London, a hub for construction flows in the South East, often as block wagonload trains conveying a portion (i.e. a wagon group) for each of two or three individual terminals. From the survey data, in combination with real-time train information, it was in most cases possible to estimate with a degree of certainty the number of portions per train. From the full level three sample of 294 observations, Table 8 presents the data on train composition based on the number of portions.

Insert Table 8 here

The distinction between trains passing through the Acton hub and those operating directly to terminals was found not to be as clear cut as expected. Service 6L21 regularly conveyed two portions despite not calling at Acton yard, with one portion being dropped off elsewhere en route close to its destination terminal. Equally, a considerable number of trains calling at Acton had wagons for a single terminal so no splitting into portions was needed. While some services were more likely to have one, two or three portions, there was considerable variability in this across the sampled services, presumably as a consequence of a combination of customer and operational requirements. It is evident that the number of train portions better reflects the variation in train composition than does the specific individual service, given the lower variability displayed in Table 8 than in Table 6. Single and triple portion trains were found to have less variability than double portion ones.

Not all train services maintain a consistent formation throughout from origin to destination, with certain services posing particular challenges. For a number of reasons, either demand-led (e.g. customer requirements to serve more than one terminal or multiple customers' flows being carried on one train) or supply-led (e.g. terminal layout or capacity constraints), trains may not operate directly from origin to destination in a fixed formation. Examples were identified where portions were taken from a terminal to a nearby marshalling yard to be combined into a single longer train (e.g. automotive exports from Oxford to Southampton are moved to Didcot in two portions and combined there) or split at a yard for portion deliveries to the customer's terminal (e.g. the petroleum train from Grangemouth to Dalston is normally split into three portions at Carlisle yard). A slightly different example concerns the domestic intermodal trains between Daventry and Purfleet which normally drop off or collect wagons en route at Ripple Lane. Some port-hinterland trains also attach or detach portions en route. In most of these cases, the train operates at its full length for the vast majority of the distance travelled, so the impacts on rail network utilisation are minimal. The possible exception is the trunk wagonload sub-group, where train composition can change several times throughout a train's journey and result in considerable variability in the number and type of wagons.

To explore this issue with one of the trunk wagonload services, 6O15 from Mossend to Eastleigh was surveyed on two different sections of route (see Table 6), its first section from Mossend to Carlisle and its final section from Didcot to Eastleigh. This long distance service calls at three intermediate locations (i.e. Carlisle, Warrington and Didcot) to pick up and/or drop off wagons as necessary. Of the survey observations, 14 involved the same specific train being surveyed on the first and last route sections. The train formation was never the same upon departure from Didcot to that when it had left Mossend and in only two of the 14 cases were even any of the same wagons on the train leaving Didcot that had been in the train's consist when leaving Mossend. On the other 12 occasions, the train formation was entirely different on the two sections of route. On departure from Mossend, 6O15 was observed to mainly convey empty automotive wagons while its formation after Didcot tended to be more mixed, with regular traffic including containers, enclosed vans, fuel tanks and empty automotive wagons.

Different wagon formations, and therefore varying commodity flows and trains of variable length, were also observed on different days of operation of certain services, again primarily with the trunk wagonload sub-group. In some cases, as with service 6O15 discussed above, it was difficult to discern a clear pattern although certain wagon types were more likely to be carried on some days than others. This reflects the interconnectedness of wagonload operations, where wagons may transfer from one service to another at marshalling yards and some services operate only on certain days of the week, giving a predictable pattern to some flows. Of the individual services shown in Table 5, 6M76 demonstrates well the day-to-day variability that can be found. This service is always scheduled to depart from Mossend at 21:36, normally running three or four nights per week. It operates to Warrington when running on a Monday and Wednesday, while if it runs on a Tuesday (which is very irregular) or Thursday it extends to Wembley (London). Table 9 summarises the sampled flows and train composition on leaving Mossend for the different days of operation, revealing considerable differences between the days of operation.

Insert Table 9 here

By contrast, service 6A29 from Newport to Didcot, which runs five nights per week, has greater stability in the flows carried, with two dominant ones, but considerable daily variations in the number of wagons for these flows. For 25 of the 26 observations of this train, enclosed wagons were being moved from Bridgend to Dagenham but the number of these varied from 2 up to 17. For 20 of the 26 observations, intermodal traffic from Barry Docks, believed to be destined for the ports of Southampton and/or Tilbury, was carried; the number of intermodal wagons ranged from a minimum of two up to a maximum of 20. Other flows, including steel and petroleum wagons, were carried less frequently. From this analysis of 6O15, 6M76 and 6A29, it is evident that any meaningful discussion about the composition of trunk wagonload services in particular needs to be contextualised with regard to the section of route, day of operation and any other salient characteristics of that service.

5. Practical implications of research findings for understanding rail freight activity

This paper has sought to understand the extent to which there is variability in freight train composition on the British rail network and to determine the level of disaggregation of rail freight activity that is required in order to find a high degree of homogeneity in composition. The preceding analysis of the survey results has demonstrated the complexities associated with understanding the characteristics of freight train composition. This is true even in Britain where a far greater proportion of trains operate as block trainloads (i.e. directly from origin to destination) for individual customers than in most other European countries, where multi-customer wagonload or block wagonload services make up a considerable proportion of rail freight provision. Given the data challenges of a study such as this, and taking account of the limitations associated of the number of wagons as a measure of freight train composition, definitive conclusions are not always possible. However, the analysis of such a large sample of freight trains allows evidence-based recommendations to improve knowledge and practice within rail freight operations. With the notable exception of *Coal*, all of the official commodity groupings have been found to exhibit considerable variability in train composition. As Table 4 showed, the nature of operation did not have a clear bearing on the extent of the variability at this first level of disaggregation of the rail freight market: *Oil and petroleum* and *International*, both fully trainload, exhibited similar variability to other groupings that included block wagonload and wagonload operation. It is clear from the survey evidence that there is considerable variability in the formation of certain types of rail freight service, even for trainload operation of specific flows, and it is difficult to talk of a ‘typical’ freight train at the commodity grouping level.

The second objective formed the major part of the research, exploring different segments of the British rail freight market at increasing levels of disaggregation. While the research has shown that there is no such thing as a typical British freight train in terms of its composition when measured by the number of wagons as a proxy for on-train capacity, in many cases there is little variability when disaggregated to the O-D pair and individual service level. In other cases, though, there remains considerable variability even at this level of disaggregation and it has not always been possible to understand the reasons for this even when taking the type of freight train operation into account. To develop a more nuanced understanding of why differences in freight train composition exist, particularly where these cannot readily be explained by the data currently available, it would be beneficial to conduct interviews with rail freight companies and their customers. However, as mentioned earlier, the consideration of on-train capacity provision and utilisation is often viewed as a commercially sensitive topic within a liberalised rail freight environment.

The fact that such high variability in freight train composition exists suggests that there are inefficiencies in the use of available network capacity, since services with short formations are consuming train paths which in many cases are capable of handling longer trains within the route and traction limits. There are likely to be many reasons for the observed variability, even at high levels of disaggregation within some commodity groupings. The causes will often be a mix of supply (e.g. terminal and route operational constraints) and demand (e.g. variability in customer requirements) factors. However, in theory at least, there is the potential to increase considerably the volume of rail freight moved without recourse to additional network capacity which is normally expensive to provide. In reality, it is likely to be challenging to better match on-train capacity to the supply of train paths but the findings from this research strongly suggest that more attention should be devoted to better understanding the reasons for the observed variability and the consequent sub-optimal use of available network capacity. Equally, rail stakeholders (e.g. policy makers, infrastructure managers, passenger train operators) should be educated so that they understand the inherent variability of certain commodity types in the extent to which they utilise a train path.

It is recommended that policy makers engage fully with the rail industry, particularly with rail freight operators and infrastructure managers, to treat capacity holistically so as to develop a better understanding of the potential to influence the on-train capacity rather than simply consider infrastructure capacity measures. There may be some circumstances, such as when route capacity is scarce, when a mechanism could be devised where a train path would be awarded to the operator or flow that would make best use of that path. This may be difficult to action across different commodities, though possibly a 'best practice' case for each commodity grouping (or sub-group) could be established for potential flows to be measured against. Of course, the number of wagons per train is just one indicator of efficiency and it would be better to consider whether other measures, most likely using non-public data, would be more appropriate. This could be extended to consider the rail market in its entirety, particularly one using a mixed traffic network such as that in Britain, since a possible limitation of this paper is that it considers freight trains in isolation. With particular reference to rail system capacity, where passenger and freight trains on many routes share the same infrastructure, it would be beneficial to consider the train capacity and loading variability of all trains to identify ways to maximise the use of scarce network capacity and generate the greatest economic and sustainability benefits. This is an important question both for policy makers and the rail industry, since it relates to the relative priorities afforded to passenger and freight trains. The research findings make a wider sustainability contribution in that the variability in operating characteristics is likely to affect rail freight's sustainability impacts. As noted in Section 2.4, Defra (2013) argued for more appropriate rail freight emissions factors for different types of activity rather than a global factor for all rail freight. The survey data analysed in this paper suggest that a standard emissions factor for *Coal* is likely to be meaningful, but further disaggregation would be required for the other commodity groupings. The variability in train composition would need to be related to unit energy consumption.

Finally, it would be interesting to replicate this study in one or more mainland European countries (e.g. France or Germany) to determine the extent to which these findings are specific to Britain or can be generalised. The greater role for block wagonload and wagonload operation elsewhere would make replication more of a challenge, but more multi-customer operation and more en-route marshalling of flows may be expected to lead to even greater variability in train composition. However, the increase in trainload rail freight activity elsewhere in Europe may lead in future to a market more similar to that pertaining in Britain now, so this paper's results should be of relevance beyond the specific country case study. In the British context, combining the analysis in this paper with previous research, it is proposed to conduct further in-depth research focusing specifically on the *Domestic intermodal* commodity grouping, since this is an increasingly important and competitive component of the rail freight market. This will allow a more detailed investigation of the factors influencing train composition and utilisation on an O-D pair basis.

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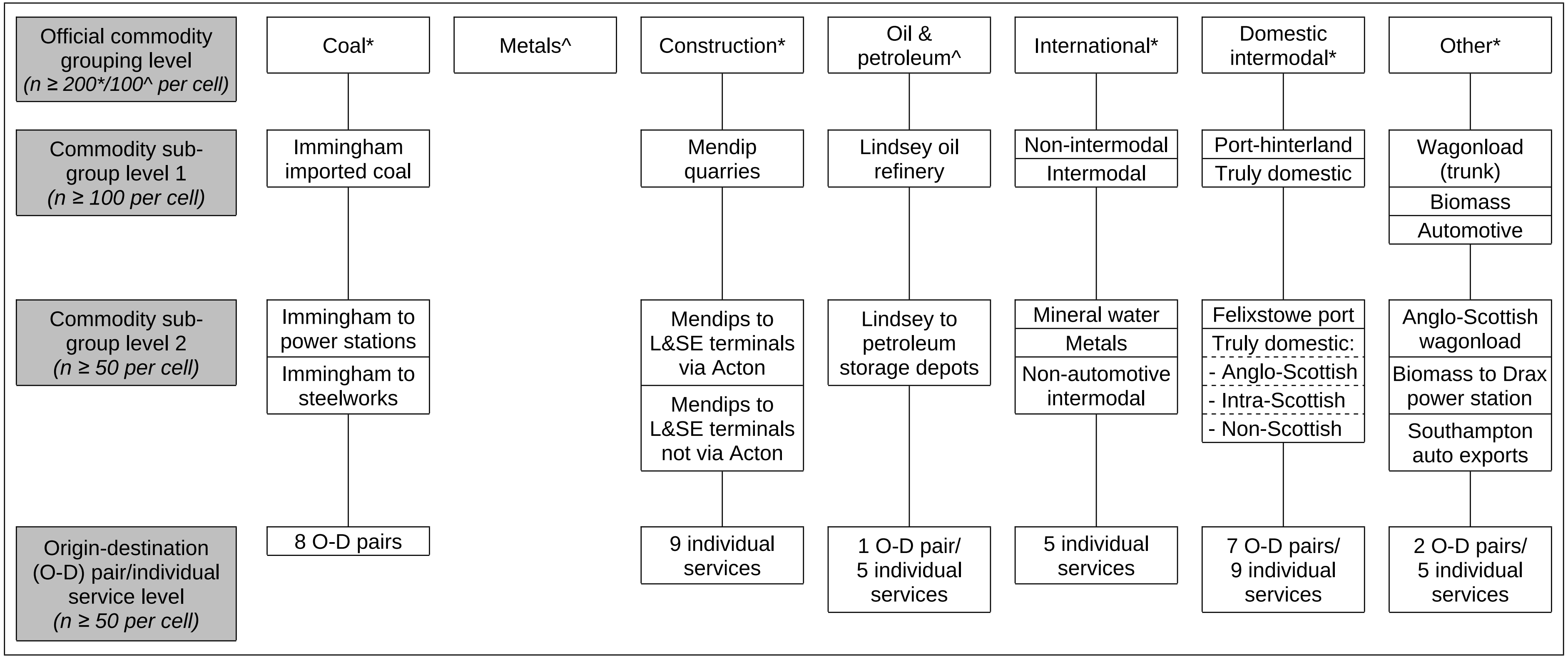
Figure 1: Overview of sampling of freight train composition at each level



Source: based on author's survey

Table 1: Examples of freight train categorisation

Source	Rail markets covered	Freight train types
Fowkes & Nash (2004)	Britain (all)	Trainload; less than trainload; mail and parcels; infrastructure
Goundry (2003)	Britain (all)	Trainload; train portions; wagonload
Kombiconsult & K&P Transport Consultants (2007)	Europe (intermodal)	Full trainload (direct train; shuttle train); Less-than-trainload (Y-shuttle train; liner train; group train; turntable traffic; gateway traffic; megahub/mainhub production; mixed intermodal/conventional traffic)
Kreutzberger (2008)	Europe (intermodal)	Functional categorisation (direct bundling; complex bundling; hybrids of direct and complex bundling) Physical categorisation (e.g. shuttle train; block train; wagon group train; wagonload train) Rail-rail exchange categorisation (e.g. flat shunting; gravity shunting; transhipment)
Network Rail (n.d.)	Britain (all)	Trainload; wagonload; intermodal; express freight
PwC (2014)	Europe (wagonload)	Single wagonload; ‘new wagonload’
Rail Freight Group (n.d.)	Britain (all)	Bulk; intermodal (port); intermodal (domestic); intermodal (Channel Tunnel); other
UIC (2009)	Europe (all)	Full/block train; single wagon; intermodal
Woxenius (2007)	Europe (intermodal)	Direct trains; shuttle trains; hub-and-spoke networks

Table 2: Potential for a fully loaded train to remove lorries

Commodity	Fully loaded train potential (tonnes)	Equivalent no. of heavy goods vehicles
Coal	1,500	52
Metals and ore	1,000 – 2,500	60
Construction materials	1,500 – 3,000	77
Oil and petroleum	2,000	69
Consumer goods	600 – 1,100	43
Other traffic	1,000 – 1,500	43

Source: Network Rail (2013a)

Table 3: Survey sampling at commodity grouping level (i.e. level one) and relationship with operational rail freight activity measures and freight train type

Commodity grouping	Survey sample size (and % of level 1 sample)[1]	Rail freight market share (% of tonne-km; 2013/14)[2]	% of loaded freight trains (Jan 2014 est.)[3]	Freight train type(s)
Coal	235 (18)	36	-	Trainload
Metals	118 (9)	8	13	Trainload; block wagonload
Construction	219 (16)	16	24	Trainload; block wagonload
Oil & petroleum	121 (9)	6	4	Trainload
International	203 (15)	2	3	Trainload
Domestic intermodal	234 (18)	27	39	Trainload; block wagonload
Other	204 (15)	6	17	Trainload; wagonload

Source: author's survey[1]; ORR (2014)[2]; author's database[3]

Table 4: Composition of sampled freight trains (for official commodity grouping level and commodity sub-group levels 1 and 2)

Official commodity grouping (and sampled sub-groups)	**Sample size**	**Mean**	**Std. dev.**	**Minimum**	**Maximum**	**Range**	**Freight train type(s)**
		No. of wagons per train					
1. Coal	235	21.83	1.51	18	24	6	Trainload
1.1 Immingham imported coal	339	21.81	1.55	18	24	6	Trainload
1.1.1 Immingham to power stations	315	22.07	1.28	18	24	6	Trainload
1.1.2 Immingham to steelworks	53	18.36	0.81	18	21	3	Trainload
2. Metals	118	20.74	5.31	4	34	30	Trainload; block wagonload
3. Construction	219	23.56	8.18	8	43	35	Trainload; block wagonload
3.1 Mendip quarries	108	25.25	9.48	14	44	30	Trainload; block wagonload
3.1.1 Mendips to L&SE terminals via Acton	218	27.50	8.90	14	46	32	Block wagonload
3.1.2 Mendips to L&SE terminals not via Acton	76	25.42	9.67	16	43	27	Trainload; block wagonload
4. Oil & petroleum	121	23.88	6.62	5	30	25	Trainload
4.1 Lindsey oil refinery	176	26.25	4.85	5	30	25	Trainload
4.1.1 Lindsey to petroleum storage depots	167	27.11	3.10	18	30	12	Trainload
5. International	203	17.80	6.18	2	40	38	Trainload
5.1 Non-intermodal	115	18.52	4.27	7	23	16	Trainload
5.1.1 Mineral water	52	20.44	1.16	16	23	7	Trainload
5.1.2 Metals	80	18.46	4.46	10	23	13	Trainload
5.2 Intermodal	127	17.19	7.10	2	40	38	Trainload
5.2.1 Non-automotive intermodal	57	15.82	3.55	12	27	15	Trainload
6. Domestic intermodal	234	19.98	5.26	8	36	28	Trainload; block wagonload
6.1 Port-hinterland	179	21.93	4.18	12	36	24	Trainload; block wagonload
6.1.1 Felixstowe port	171	21.29	3.79	13	31	18	Trainload; block wagonload
6.2 Truly domestic	281	13.67	2.96	7	19	12	Trainload; block wagonload
6.2.1 Anglo-Scottish domestic	151	15.32	1.85	11	19	8	Trainload
6.2.2 Intra-Scottish domestic	91	9.48	1.11	7	12	5	Trainload
6.2.3 Non-Scottish domestic	54	14.22	1.94	10	18	8	Trainload; block wagonload
7. Other	204	16.67	7.39	3	41	38	Trainload; wagonload
7.1 Wagonload (trunk)	193	15.56	6.62	3	42	39	Wagonload
7.1.1 Anglo-Scottish wagonload	58	14.17	6.12	4	42	38	Wagonload
7.2 Biomass	111	22.15	2.24	11	25	14	Trainload
7.2.1 Biomass to Drax power station	84	22.36	1.37	20	25	5	Trainload
7.3 Automotive	101	9.24	2.70	3	17	14	Trainload
7.3.1 Southampton automotive exports	57	8.25	1.41	3	10	7	Trainload

Source: author's survey

Table 5: Composition of sampled freight trains (for origin-destination (O-D) pairs)

O-D pairs (with "parent" groupings – see Table 3)	**Sample size**	**No. of wagons per train**					**Freight train type**
		Mean	**Std. dev.**	**Minimum**	**Maximum**	**Range**	
1.1.1 Coal: Immingham to power stations							
Immingham – Cottam power station	49	23.00	0.00	23	23	0	Trainload
Immingham – Drax power station	52	21.60	1.64	18	24	6	Trainload
Immingham – Eggborough power station	67	22.42	1.08	20	24	4	Trainload
Immingham – Ferrybridge power station	26	21.42	1.14	19	23	4	Trainload
Immingham – Ratcliffe power station	32	21.66	1.23	19	23	4	Trainload
Immingham – Rugeley power station	39	20.59	0.59	19	21	2	Trainload
Immingham – West Burton power station	50	22.92	0.40	21	23	2	Trainload
1.1.2 Coal: Immingham to steelworks							
Immingham – Scunthorpe steelworks	53	18.36	0.81	18	21	3	Trainload
4.1.1 Oil & petroleum: Lindsey to petroleum storage depots							
Lindsey – Kingsbury	67	29.25	1.85	19	30	11	Trainload
6.1.1 Domestic intermodal: Felixstowe port flows							
Felixstowe – Doncaster (2-way)	34	16.50	3.42	13	22	9	Trainload
Felixstowe – Hams Hall (2-way)	29	27.24	2.21	20	31	11	Trainload
Felixstowe – Lawley St. (2-way)	38	22.79	3.05	18	30	12	Trainload
Felixstowe – Leeds (2-way)	26	16.58	1.81	13	19	6	Trainload
6.2.1 Anglo-Scottish domestic flows							
Daventry – Coatbridge (2-way)	80	14.29	0.56	12	15	3	Trainload
Daventry – Mossend (2-way)	44	15.59	2.48	11	19	8	Trainload
6.2.3 Non-Scottish domestic flows							
Daventry – Purfleet (2-way)	27	14.56	2.69	10	18	8	Block wagonload
7.2.1 Other: biomass to Drax power station							
Tyne Dock - Drax	51	21.57	0.94	20	23	3	Trainload
7.3.1 Other: Southampton automotive exports							
Halewood – Southampton Jaguar cars	36	8.64	0.93	4	9	5	Trainload

Source: author's survey

Table 6: Composition of sampled freight trains (for individual services)

Individual services (with "parent" groupings - see Table 3)	**Train headcode**	**Sample size**	**No. of wagons per train**					**Freight train type(s)**
			Mean	**Std. dev.**	**Minimum**	**Maximum**	**Range**	
3.1.1 Construction: Mendips to L&SE terminals via Acton								
Merehead – Acton Yard	7A09	42	31.64	5.93	15	37	22	Trainload; block wagonload
Merehead – Acton Yard	7A15	30	22.30	7.26	15	35	20	Trainload; block wagonload
Merehead – Acton Yard	6A17	32	18.59	3.01	15	33	18	Trainload; block wagonload
Merehead – Acton Yard	7A91	37	34.81	7.18	14	46	32	Trainload; block wagonload
Merehead – Acton Yard/Grain	7O93	27	28.74	8.80	14	44	30	Trainload; block wagonload
Whatley – Acton Yard	6A20	28	29.82	8.38	18	42	24	Trainload; block wagonload
Whatley – Acton Yard	6A71	25	23.68	8.67	17	39	22	Trainload; block wagonload
3.1.2 Construction: Mendips to L&SE terminals not via Acton								
Whatley – Dagenham Dock	6L21	40	32.00	9.19	21	43	22	Trainload; block wagonload
Whatley – St. Pancras	6M20	26	18.23	1.58	16	25	9	Trainload
4.1.1 Oil & petroleum: Lindsey to petroleum storage depots								
Lindsey – Jarrow	6N03	26	28.46	2.00	20	30	10	Trainload
Lindsey – Kingsbury	6M24	32	29.41	1.10	25	30	5	Trainload
Lindsey – Kingsbury	6M57	35	29.11	2.34	19	30	11	Trainload
Lindsey – Rectory Junc.	6M11	25	22.88	1.51	18	24	6	Trainload
Lindsey – Westerleigh	6V98	36	26.31	1.14	23	27	4	Trainload
5.1.1 International: non-intermodal (mineral water)								
Channel Tunnel – Daventry	6B20	52	20.44	1.16	16	23	7	Trainload
5.1.2 International: non-intermodal (metals)								
Margam – Channel Tunnel	6O32	29	20.55	1.45	14	22	8	Trainload
Scunthorpe – Channel Tunnel	4O28	28	12.96	0.84	10	16	6	Trainload
5.2.1 International: non-automotive intermodal								
Daventry – Channel Tunnel	4O93	25	13.60	0.71	11	14	3	Trainload
Hams Hall – Channel Tunnel	4O57	40	15.15	1.19	12	17	5	Trainload
6.2.1 Domestic intermodal: Anglo-Scottish domestic flows								
Coatbridge – Daventry	4M34	33	14.18	0.46	14	16	2	Trainload
Coatbridge – Daventry	4M82	34	14.24	1.30	10	16	6	Trainload
Daventry – Coatbridge	4S44	27	14.00	0.00	14	14	0	Trainload
Daventry – Grangemouth	4S49	27	15.85	1.29	14	18	4	Trainload
Daventry – Mossend	4S43	73	17.40	0.88	15	19	4	Trainload
Grangemouth – Daventry	4M30	25	15.64	2.12	8	18	10	Trainload
Mossend – Daventry	4M48	25	17.68	0.85	17	19	2	Trainload
6.2.2 Domestic intermodal: Intra-Scottish domestic flows								
Grangemouth – Aberdeen	4A13	60	8.80	1.41	6	12	6	Trainload
Mossend – Inverness	4H47	64	9.98	0.13	9	10	1	Trainload
7.1.1 Other: Anglo-Scottish wagonload								
Didcot – Mossend (ex Didcot)	6X65	27	16.81	5.53	6	27	21	Wagonload

Mossend – Eastleigh (ex Mossend)	6O15	28	14.96	5.83	9	42	33	Wagonload
Mossend – Eastleigh (ex Didcot)	6O15	25	11.60	7.02	2	29	27	Wagonload
Mossend – Warrington/Wembley	6M76	30	13.70	9.82	1	33	32	Wagonload
7.1 Wagonload (trunk)								
Newport – Didcot	*6A29*	*26*	*20.15*	*7.11*	*8*	*35*	*27*	*Wagonload*

Source: author’s survey

Table 7: Composition of sampled intermodal freight trains (measured in TEU)

Official commodity grouping and sampled sub-groups/flows	**Sample size**	**TEU capacity per train Mean**	**Std. dev.**	**Minimum**	**Maximum**	**Range**	**Freight train type**
5. International							
5.2 Intermodal	127	57.23	12.36	8	80	72	Trainload
5.2.1 Non-automotive intermodal	57	58.32	6.61	44	72	28	Trainload
Daventry – Channel Tunnel (4O93)	25	54.40	2.83	44	56	12	Trainload
Hams Hall – Channel Tunnel (4O57)	40	60.60	4.75	48	78	30	Trainload
6. Domestic intermodal	234	62.50	11.53	28	90	62	Trainload; block wagonload
6.1 Port-hinterland	179	64.93	10.36	28	90	62	Trainload; block wagonload
6.1.1 Felixstowe port	171	65.11	8.90	48	90	42	Trainload; block wagonload
Felixstowe – Doncaster (O-D 2-way)	34	59.97	8.71	52	75	23	Trainload
Felixstowe – Hams Hall (O-D 2-way)	29	80.93	6.05	67	90	23	Trainload
Felixstowe – Lawley St. (O-D 2-way)	38	67.95	9.16	55	90	35	Trainload
Felixstowe – Leeds (O-D 2-way)	26	54.65	6.49	42	63	21	Trainload
6.2 Truly domestic	281	54.68	11.84	28	76	48	Trainload; block wagonload
6.2.1 Anglo-Scottish domestic	151	61.30	7.38	44	76	32	Trainload
Daventry – Coatbridge (O-D 2-way)	80	57.15	2.22	48	60	12	Trainload
Daventry – Mossend (O-D 2-way)	44	62.36	9.92	44	76	32	Trainload
Coatbridge – Daventry (4M34)	33	56.73	1.86	56	64	8	Trainload
Coatbridge – Daventry (4M82)	34	56.94	5.22	40	64	24	Trainload
Daventry – Coatbridge (4S44)	27	56.00	0.00	56	56	0	Trainload
Daventry – Grangemouth (4S49)	27	63.41	5.17	56	72	16	Trainload
Daventry – Mossend (4S43)	73	69.59	3.51	60	76	16	Trainload
Grangemouth – Daventry (4M30)	25	62.56	8.48	32	72	40	Trainload
Mossend – Daventry (4M48)	25	70.72	3.41	68	76	8	Trainload
6.2.2 Intra-Scottish domestic	91	37.93	4.44	28	48	20	Trainload
Grangemouth – Aberdeen (4A13)	60	35.20	5.65	24	48	24	Trainload
Mossend – Inverness (4H47)	64	39.94	0.50	36	40	4	Trainload
6.2.3 Non-Scottish domestic	54	56.89	7.76	40	72	32	Trainload; block wagonload
Daventry – Purfleet (O-D 2-way)	27	58.22	10.78	40	72	32	Block wagonload

Source: author's survey

Table 8: Composition of sampled construction freight trains from Mendip quarries to London & South East (L&SE) terminals (by estimated number of train portions)

No. of train portions	**Sample size**	**No. of wagons per train**				
		Mean	**Std. dev.**	**Min.**	**Max.**	**Range**
1	146	18.98	2.92	14	25	11
2	118	33.61	5.49	18	43	25
3	30	39.63	3.49	31	46	15

Source: author's survey

Table 9: Typical composition of trunk wagonload service 6M76 (Mossend to Warrington/Wembley) by day of operation

Day	**Sample size**	**Mean no. of wagons**	**Description of typical flows (i.e. on 50% or more of daily observations)**
Monday	10	8.40	Mossend to Hams Hall (loaded intermodal); Mossend to Runcorn (empty chemicals); Mossend to Warrington (empty automotive)
Tuesday	1	12.00	Mossend to Dagenham (empty automotive)
Wednesday	9	8.56	Mossend to Hams Hall (loaded intermodal); Mossend to Warrington (empty automotive)
Thursday	10	23.80	Aberdeen to Workington (loaded calcium carbonate); Irvine to Channel Tunnel (empty china clay); Mossend to Runcorn (empty chemicals)
Total	**30**	**13.70**	

Source: author's survey