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Abstract

The growth in container shipping poses considerable challenges to efforts to reduce the negative externalities associated with freight transport. There are particular concerns about the impacts of the associated port-hinterland freight flows. Through empirical research, this paper examines trends in the operational efficiency of the British port-hinterland container rail freight market and to assess the impacts of any changes on the overall sustainability of this market. Original survey work conducted in 2007 and 2015 has allowed longitudinal and cross-sectional analysis of the characteristics of this market.

The survey findings reveal that rail's mode share of port container throughput (in TEU) has increased from 14.7 per cent in 2007 to 16.6 per cent in 2015 and it is likely that its share of the associated hinterland activity has also risen. Rail was carrying 25 per cent more TEU by 2015 without an increase in train service provision. Increases in mean train capacity and mean load factor were observed, leading to growth in the mean train load from 44 TEU in 2007 to 55 TEU in 2015. This considerable improvement in operational efficiency is expected to have reduced the negative externalities per unit of transport activity associated with the rail-borne hinterland container flows, though scope is identified for further improvements in sustainability.

KEYWORDS: Port-hinterland; rail freight; container flows; transport efficiency; United Kingdom

Highlights

- Empirical study of trends in British port-hinterland container rail freight market
- Observation surveys of container train services in 2007 and 2015
- Rail's share of port container throughput (in TEU) grew from 14.7% to 16.6%
- Average TEU load per train increased by 25%, with longer, better-filled trains
- Efficiency improvements highly likely to have sustainability benefits

1. Introduction

The growth in container shipping poses considerable challenges to efforts to reduce the negative externalities associated with transport activity. Containerisation has been a major catalyst for trade growth, with the standardisation of transport and handling equipment leading to lower unit transport costs and increased efficiencies (Levinson, 2008). According to UNCTAD (2015), estimated global container trade volumes increased from 69 million TEU[1] in 2000 to 171 million TEU in 2014 (UNCTAD, 2015), an average annual increase of almost 7 per cent despite the global economic downturn during the second half of this period.

While maritime transport itself is coming under increasing scrutiny for its environmental performance (Asariotis and Benamara, 2012; European Commission, 2013), there has for some time been concern about the negative economic, environmental and social impacts of the port-hinterland (i.e. landward) movement of freight, including container traffic (see, for example, Notteboom and Rodrigue, 2007; UNECE, 2009). In its vision for a "competitive and sustainable transport system", the European Commission (2011, 6) set out the need for the transport sector to use less and cleaner energy. Rail has an important role to play, particularly for medium- to long-distance freight flows, since typically it has lower negative externalities than road per unit of activity (Woodburn and Whiteing, 2015) and, in theory at least, can use non-fossil fuel energy sources on electrified routes (RSSB, 2007). Intermodal freight is believed to offer considerable growth potential for rail in the European Union (EU) (European Commission, 2015) and is the rail freight activity which has experienced the greatest growth in the United Kingdom (UK) in recent years (ORR, 2016).

Official statistics (ORR, 2016) provide evidence of efficiency gains in British rail freight. Freight transport may become more sustainable if these gains lead to an increase in rail's

[1] TEU = twenty-foot equivalent unit (i.e. a container with a length of 20')

mode share at the expense of road and/or reduce the negative externalities per tonne or container carried. The intermodal market, including port-hinterland container flows, is a challenging one for rail since it experiences considerable competition from road haulage, more so than in the bulk markets (e.g. coal, steel, construction materials) (ORR, 2006). However, the movement of consumer goods (and some other commodities) in unit loads has become an increasingly important part of freight transport activity. This paper aims to examine trends in the operational efficiency of the British port-hinterland container rail freight market and to assess the impacts of any changes on the overall sustainability of this market. Specifically, through empirical research, the paper seeks to answer the following research questions (RQs):

- RQ1: To what extent (if any) is the European policy objective to increase rail's share of freight transport activity being achieved in the British port-hinterland container market?
- RQ2: Has there been any change in the efficiency and sustainability of rail service provision within this market?

Published statistics at a sufficiently disaggregated level to inform the research are extremely limited. As a consequence, the paper's analysis relies heavily on original survey work conducted in 2007 and 2015, allowing longitudinal and cross-sectional analysis of the characteristics of the port-hinterland container rail freight market in Britain.

The paper is structured as follows. Section 2 identifies and discusses the relevant literature, followed in Section 3 by an account of the methods adopted to answer the research questions. Section 4 analyses rail's role in the British port-hinterland container market while Section 5 assesses changes in the efficiency of the rail operations in this market. In Section 6, the implications of the study's findings for port-hinterland sustainability are discussed, while Section 7 sets out the paper's conclusions. In essence, therefore, Section 4 focuses on RQ1 and Sections 5 and 6 deal with RQ2.

2. Literature Review

To place the study in context, this section reviews the key literature relating to rail freight sustainability (Section 2.1), rail in the port-hinterland stage of international supply chains (Section 2.2) and, specifically, port-hinterland rail freight efficiency (Section 2.3).

2.1 Rail freight sustainability

There is a broad consensus that rail is typically one of the more sustainable modes of freight transport and its use rather than road should be encouraged where appropriate. Ideally, logistics network design and sustainable logistics policies should go hand in hand (Zhang et al., 2016) so that the use of modes such as rail is built in at the planning stage. In reality, mode choice decision-making commonly takes place less strategically and in a more ad hoc manner (Directorate General for Internal Policies, 2015). This poses particular challenges for rail freight use when road haulage is the dominant surface transport mode (Woodburn, 2003).

It should be noted that the relative performance of the freight modes is not fixed, as changes in technical and operational characteristics over time or in different operating environments can alter the balance. In their study of Spanish freight transport trends between 1993 and 2007, Pérez-Martínez and Vassallo-Magro (2013) identified that, while rail retained a clear sustainability benefit over road per unit of freight transport activity, the gap had narrowed as road haulage had considerably reduced its external costs. Improving transport efficiency is a well-established route towards realising sustainability benefits within freight transport (see, for example, Arvidsson et al., 2013; Palander, 2016, Sanchez Rodrigues et al., 2015). It is therefore important that the rail industry seeks continuous improvement in its operations (Network Rail, 2013).

Unlike the passenger side of the industry in Britain, where there has been an improving trend in the last 10 years, the published annual emissions per rail freight tonne kilometre over the same period have fluctuated between 26.4 and 30.9g/CO_2e (ORR, 2015), with no clear trend evident. The sustainability agenda within the rail industry, in the UK at least, suffers from a lack of clarity over its focus and direction (Rail Technology Magazine, 2014), although the national infrastructure manager (Network Rail) has made progress in setting out the agenda (Network Rail, 2013, 2015) and some of the rail freight operating companies (FOCs) have started to emphasise rail's environmental credentials. The Rail Sustainable Development Principles emphasise the role for rail in tackling sustainability issues, not least because "the railway's green credentials compare favourably with other modes" (RSSB, 2016, 12) and offer scope to reduce transport's carbon footprint. While there is little explicit mention of freight, operational efficiency improvements are promoted as a means of optimising the railway and reducing negative externalities. Other research (e.g. Toletti et al., 2015) has modelled the relationship between rail freight operational characteristics (e.g. train length), energy efficiency and thus sustainability, demonstrating considerable theoretical potential to make improvements.

2.2 Rail in the port-hinterland stage of international supply chains

According to Merk and Notteboom (2015), hinterland connections are a critical factor in port competitiveness and development. A prime consideration in the performance of hinterland transport activity is the modal split and, in particular, the role for rail within an intermodal system (Monios and Lambert, 2013). The ever-increasing size of container ships (in TEU capacity) pose challenges for the efficient operation both of ports themselves and their inland transport connections (Acciaro and McKinnon, 2013) since larger volumes of containers are typically unloaded from and loaded on to the largest ships per port call. This concentration of volume at particular points in time puts pressure on operations at ports themselves, and also on the port-hinterland connections.

In general, rail freight in Europe is regarded as under-performing against both its potential and the policy targets set (European Court of Auditors, 2016), despite the promotion of rail freight going back as far as the first Transport White Paper (European Commission, 1992). The reasons are numerous and varied, but include cost, service quality, restricted network coverage leading to a requirement for road for the “last mile”, limited priority for freight on a mixed-traffic railway (where freight often comes secondary to passenger), little progress in internalising the external costs of road freight and a general lack of coordination of government policies influencing freight mode choice (see, for example, Woodburn, 2003; European Commission, 2011; ORR, 2012; European Court of Auditors, 2016).

There is little explicit policy consideration of rail in port-hinterland flows but its importance in modal shift from road to rail is often implied through the emphasis on improving rail connections to ports (European Commission, 2011). To date, however, the use of EU funds in improving rail access to ports has been limited: specific problems identified include delays accessing ports by rail in Poland and poor quality, low-speed rail infrastructure linking ports and their hinterlands in France (European Court of Auditors, 2016). While not solely concerned with port-hinterland flows, the Rail Freight Corridors (RFCs) within the Trans-European Transport Network (TEN-T) are heavily focused on multimodal connections including those linking ports to their hinterlands (OJEU, 2010; European Commission, 2014). Comparing different types of externalities in Trans-European freight transport corridors, Janic & Vleugel (2012) calculated that modal transfer from road to rail offered considerable benefits in terms of reduced energy consumption, lower greenhouse gas emissions and less congestion. The potential performance of long intermodal freight trains, on corridors most likely serving ports, was investigated by Janic (2008). This study identified greater efficiencies and improved sustainability associated with longer trains, but only if there was sufficient volume available to make them a viable option.

From the literature, there are examples of rail succeeding in increasing its share of port-hinterland activity at specific ports. In Germany, Hamburg and Bremerhaven have increased the share of containers moving to/from the hinterland by rail and have rail shares considerably greater than the average for large European container ports (Acciaro and McKinnon, 2013). Gothenburg, the major container port for Scandinavia, has also been successful in developing hinterland rail volumes (Merk and Notteboom, 2015). While there have been many interventions to achieve these positive outcomes, the role of operational efficiency improvements is not clear. Also considering Gothenburg, Woxenius and Bergqvist (2011) investigated the reasons for rail performing better in the carriage of containers than road semi-trailers between port and hinterland, identifying that the characteristics of the container flows made rail more competitive in this market than in that for semi-trailers.

2.3 Port-hinterland rail freight efficiency

Much of the published analysis of rail freight performance takes a top-down approach using generalised data, largely because of the limited availability of disaggregated data at a commodity or flow level. In a study of Australian rail freight efficiency, Laird (1998) focused on two indicators: average unit revenues and average energy efficiency. Esters and Marinov (2014) found that energy consumption (and therefore emissions) per tonne kilometre decrease exponentially as load factor increases, although the gains are quite limited as the load factor increases beyond 25 per cent; this study considered rail freight as a whole.

Based on official UK data for tonnes lifted and number of freight train movements, the average number of tonnes carried per freight train increased from 231 tonnes to 364 tonnes in the decade from 2005/06 to 2015/16 (ORR, 2016). These specific numbers should be treated with some caution since the number of freight train movements also includes infrastructure trains while the tonnes lifted figure does not. This has been a consistent discrepancy so while the actual average tonnage per train will be underestimated this will be true of both time periods and the trend towards heavier train payloads is clear. The official statistics do not allow for any disaggregation in train payloads for different commodities or markets. It is therefore not possible to identify specific trends in the port-hinterland market without original data collection and analysis.

In the UK, efficiency improvements have been a key objective of rail infrastructure funding for the Strategic Freight Network (SFN). Much of the emphasis has been on corridors connecting ports and their hinterlands, with initiatives focused on loading gauge enhancement, train lengthening and route capacity (DfT, 2009; Network Rail, 2014). The UK, the growth in containerised traffic through ports represents a major opportunity for rail freight. As the Institution of Mechanical Engineers identified, “the economic case for targeted new rail freight infrastructure development and current infrastructure improvements is strong. In particular, deep-sea and container ports are already facing heavy levels of congestion and gauging problems mean that the rail-freight industry is unable to capitalise fully upon key market opportunities” (IMECHE, 2009, 12). While infrastructure improvements are important, the opportunities for improved operational efficiency should not be overlooked and, given the importance of port-hinterland freight flows, there is a need to better understand the nature of rail freight within this market. This paper builds on the identification of the 2007 ‘base case’ (Woodburn, 2011) which remains the main example from the literature of a detailed investigation of rail freight operational efficiency for port-hinterland container flows. The next section explains how the methodological approach has been developed.

3. Methodology

This research focuses on the use of rail within the port-hinterland transport activity for containers, concentrating on the trunk flows in the hinterland and not considering the efficiency or sustainability of road feeder services or internal port and terminal activities. The analysis is based on a mix of secondary and primary research, with the latter dominating. RQ1 is addressed through a combination of the two types, while RQ2 is investigated using primary research. The secondary data relating to rail's role in the British port-hinterland market were gathered from a review of relevant sources including reports and press releases from government, the rail industry, port authorities and consultants. The primary research involved the following:

- A database of rail freight service provision, compiled annually by the author since 1997, complementing the published data in trend analysis and utilised as a baseline for survey sampling.
- Original observation surveys of port-hinterland container trains in 2007 and 2015, with a consistent survey methodology being used for both periods. This methodology was described and justified in Woodburn (2011); only the most salient points are repeated here, together with issues relating to the longitudinal analysis. The key attributes of the surveys are as follows:
    - In each case, a representative week's worth of service provision was surveyed, taking account of port, rail freight operating company, direction of flow (i.e. import or export) and origin-destination pair.
    - This sample of a "representative week" was drawn from the population of port-hinterland container trains operating during the February to August period in each survey year.
    - The survey focused on the rail-served deep sea container ports (i.e. Felixstowe, Southampton, Tilbury, Thamesport (2007 only) and London Gateway (2015 only)); Thamesport lost its container train services in 2013 as

a result of the transfer away of much of the deep-sea business from the port (Brett, 2013) and the new port at London Gateway received its first container train service in the same year (Barrow, 2013).

- For each train, a record of train capacity and capacity utilisation (both in TEU) was made, with additional information such as locomotive type and container height also being recorded.

Original observation surveys were chosen because the rail freight operators were not willing to provide detailed data owing to commercial sensitivities in this competitive rail freight market; the author had discussions with operators prior to both the 2007 and 2015 surveys. In any case, having conducted the 2007 investigation using observation surveys, for consistency and comparability reasons it was sensible to use the same approach in 2015, even if data had been available from operators.

In particular, the observation surveys are fundamental to satisfying the research aim so it is vital that they are representative of the situation pertaining in the time periods under investigation. Annual rail-borne container volumes are not collated and published in a coordinated manner, but are available for Felixstowe and Southampton on an ad hoc basis from various sources. This has allowed checking of the primary research against the published data to ensure research validity. Taking Felixstowe, since published statistics broadly correspond to the survey periods and it is the most important of the ports, Table 1 demonstrates that the published statistics and the survey estimates have a high degree of convergence in both survey periods, with no more than a 4 per cent difference. The Port of Felixstowe has published two different rail-borne TEU totals for 2015, so the true figure is not clear. However, the closeness of the survey estimates and published statistics provides reassurance that the following analysis accurately reflects the situation pertaining to both time periods.

Insert Table 1 here

Table 2 provides an overview of the approach adopted to satisfy the overall research aim, mapping the information sources onto the analysis stages related to the two research questions which are investigated in Sections 4 to 6 of the paper.

Insert Table 2 here

4. Rail's role in the port-hinterland container market in Britain

This section focuses on RQ1, seeking to determine the extent (if any) to which the European policy objective to increase rail's share of freight transport activity is being achieved in the British port-hinterland container market. Trend analysis, largely concerned with the period from 2007 to 2015 but with some longer-term perspective, is structured sequentially. The analysis first considers port-hinterland container rail volumes and rail market share (Section 4.1), then moves on to examine rail share of container port throughput (Section 4.2) and finally to assess hinterland rail network and service provision (Section 4.3).

4.1 Port-hinterland container rail volumes and share of rail market

It is evident that port-hinterland container activity has grown in importance within the British rail freight market, with the 'domestic intermodal' commodity grouping in the published statistics being the fastest growing segment of the British rail freight market. Despite its name, this commodity grouping includes all intermodal traffic (with the exception of a small number of flows through the Channel Tunnel to/from mainland Europe) and is by far dominated by port-hinterland deep sea container traffic. It is not possible to disaggregate the published statistics but, from the author's database, port-hinterland container trains accounted for just over 80 per cent of 'domestic intermodal' trains in both 2007 and 2015 so the dominance is clear. As Figure 1 shows, between 1998/99 and 2015/16, 'domestic intermodal' volumes increased by 82 per cent at a time when the total rail freight market grew by just 2 per cent (ORR, 2016); total rail freight had grown by 28 per cent to 2014/15, but the collapse of the traditionally dominant coal commodity grouping in 2015/16 had a noticeable impact on the overall market size. As a consequence, 'domestic intermodal' increased its share from 20 per cent of total rail freight tonne kilometres in 1998/99 to 29 per cent in 2014/15, then jumping rapidly to 36 per cent in 2015/16 to become by far the most important of the commodity groupings.

Insert Figure 1 here

Impressive as these trends in intermodal rail freight volume and share of the rail market are, they do not in themselves demonstrate an increase in rail's port-hinterland mode share since they relate neither to the overall port throughput of containers nor to the overall level of freight activity generated to move containers in the hinterland. They do not even give any indication of changes in the actual number of containers or TEU carried by rail. Therefore, to determine whether rail's role in the hinterland market has changed requires the analysis of other published statistics in conjunction with the annual rail freight services database and the survey data collected in 2007 and 2015. To complicate matters, as is often the case with port container throughput and rail usage statistics, there is a lack of standardisation of units used. Some sources refer to the number of containers while others relate to the number of TEU, adding to the challenge of identifying trends in rail's share of container traffic. The TEU measure has been adopted as the standard where possible, since it is a better reflection of the transport requirements than number of containers given the variability in container length.

4.2 Rail share of container port throughput

Table 3 presents the breakdown of estimated annual rail-borne container volumes at each port and in total in both survey periods. All three ports served in both periods experienced increasing volumes, though the rate of growth differed considerably. Felixstowe, with the greatest throughput in 2007, experienced the highest growth rate while Tilbury, with the lowest volume in 2007, grew at the slowest rate. However, caution must be exercised when considering the Tilbury and London Gateway estimated volumes for 2015. The ports are co-located, at only around 15 kilometres apart, and the major intermodal rail freight operator, Freightliner, was running a daily shuttle service in each direction at the time, transferring containers between the ports to enable a wider range of destinations to be served. This is expected to be a temporary arrangement while London Gateway goes through its early expansion phase. During the 2015 survey period, a proportion of the volume on some trunk trains emanating from or destined to these ports will actually have been handled at the other port, but there is no way to accurately discern the extent of this.

Insert Table 3 here

Having established the rail-borne estimates for the two years, rail's likely share of port TEU throughput can be calculated by combining the estimates with published statistics. As Figure 2 shows, rail's estimated share of container throughput at British ports increased from 14.7 per cent in 2007 to 16.6 per cent in 2015. The diagram also shows the changes at each of the rail-served ports, though only Felixstowe and Southampton have official statistics relating solely to a single port. Container throughput statistics for Tilbury and London Gateway are reported as London, and those for Thamesport as Medway. These are the dominant container ports within these statistical groupings, but the official statistics may include some container activity at other ports in these respective areas.

Insert Figure 2 here

As mentioned in Section 3, with examples in Table 1, statistics relating to container activity by rail are published by Felixstowe and Southampton on an ad hoc basis. There is often a discrepancy between published rail mode share and the raw figures relating to rail volumes and port container throughput. There are several factors contributing to the discrepancy, such as the exclusion from the throughput total of container volumes transhipped at the port (i.e. arriving and leaving by sea, rather than moving to/from the port by a land mode) or a lack of clarity over the units by which the activity is being measured. The consistent and rigorous methodology applied to the data shown in Figure 2 provide confidence that an accurate position regarding rail's share of lift-on/lift-off (LoLo) TEU port throughput has been derived for the two years and, as a consequence, that the trends identified overall and at each port are reflective of reality. Published statistics for rail volumes at Felixstowe and Southampton show an upward trend in rail mode share and thus align with the analysis presented here.

4.3 Hinterland rail network and service provision

While the previous sub-section has provided evidence of an increase in rail's mode share of port container throughput, it falls short of being able to determine whether rail has been increasing its share of the corresponding hinterland freight activity. Ideally, to understand the trends in efficiency and sustainability, an assessment of the relative road and rail shares of hinterland activity, measured in TEU kilometres or tonne kilometres, would be carried out. Gaps in the published statistics make such an assessment nigh on impossible, particularly given the lack of data relating to road activity. This sub-section attempts to understand what has been happening with regard to the hinterland rail flows. It starts by considering the port-hinterland rail network in each of 2007 and 2015, then moves on to examine the nature of the service provision over the network.

Figures 3 and 4 respectively show the networks for port-hinterland container train services in 2007 and 2015. While the networks display a high degree of similarity, there were some notable changes between the two time periods:

- As noted already, the withdrawal of service provision at Thamesport and the commencement of operations at London Gateway
- The introduction of services to two inland terminals (i.e. Bristol and Burton-on-Trent), plus Tees Dock replacing nearby Wilton
- A reduction in direct services between the ports and Coatbridge, although the direct services in 2007 passed through the Crewe hub so the change was more operational than strategic

Insert Figure 3 here

Insert Figure 4 here

As Table 4 shows, the changes in container train service provision were greater than the comparison of the network diagrams in Figures 3 and 4 suggest. While the total number of weekly trains in 2007 and 2015 was almost identical, the distribution between the ports varied considerably. Felixstowe experienced a 23 per cent increase in the number of container train services between 2007 and 2015, while both Southampton and Tilbury witnessed respective 16 per cent and 20 per cent declines in the number of services. Felixstowe has consolidated its leading role with an increase from 44 per cent of container train services in 2007 to 54 per cent in 2015.

Insert Table 4 here

To assess whether the changes in service provision have constituted a shift in rail's role in the port-hinterland market, the weighted average distance from port to inland terminal (and vice versa) has been calculated for the two years. This is complicated somewhat by the fact that not all services operate directly between port and inland terminal, with some feeder services as shown in Figures 3 and 4. Table 5 shows that, fundamentally, there was no difference in the average hinterland distance for a container train, particularly when the feeder services are taken into account. Given that the containers on feeder trains originated from or were destined to the ports served by the trunk trains, it is logical to include them in the weighted average distance since the distinction between trunk port trains and feeder ones is an operational consideration.

Insert Table 5 here

4.4 RQ1: Summary of findings

The preceding analysis has provided a considerable body of evidence to support the assertion that rail has increased its share of freight transport activity in the British port-hinterland container market. The combination of published statistics and original survey findings demonstrates that rail's mode share of port container throughput (in TEU) has increased overall and at both Felixstowe and Southampton, where the published data allow sufficient disaggregation. It is harder to draw any conclusions about the observed increase in rail's share at London given the inclusion of London Gateway along with Tilbury in the 2015 survey, whereas in 2007 Tilbury was the only rail-served container port in London. The subsequent analysis of hinterland rail activity strongly suggests that rail's share of overall hinterland activity has also increased, since the rail network and service provision were little changed by 2015 compared with 2007. This assumes no noticeable change in the nature of the hinterland flows by road, but unfortunately there are no data to allow this assumption to be verified.

The European policy target makes specific mention of the transfer of flows of 300 kilometres or more from road to rail, since rail typically becomes more competitive as distance increases. However, there is evidence that in the market under investigation there have been gains over distances below this threshold. Based on equivalent road distance, the proportion of services with a distance of less than 300 kilometres increased from 38 per cent in 2007 to 41 per cent in 2015. While not a major change, it is noteworthy to see growth in the shorter distance market. This may be a peculiarity of British geography, in particular the location of distribution centres, since the distances from ports to the terminals in the important Midlands area are generally less than 300 kilometres.

Comparison of Tables 3 and 4 reveals an interesting development, in that 25 per cent more TEU were being moved by rail in 2015 than in 2007, but with a virtually static level of train service provision. This implies a considerable improvement in efficiency, the details of which are investigated in the next section.

5. Rail freight efficiency in the port-hinterland container market

To deal with RQ2, identifying the nature of any change in the efficiency and sustainability of rail service provision within this market, this section analyses changes in train capacity, load factors and, thus, train loadings between the 2007 and 2015 survey periods. The sustainability impacts of observed changes are then discussed explicitly in Section 6.

As Table 6 demonstrates, the observed mean TEU capacity per train increased by 16.5 per cent between 2007 and 2015. The increases at Southampton and Tilbury were almost double that at Felixstowe, leading to lower overall variability in mean train capacity between the ports by 2015. Both Felixstowe and Southampton exhibited mean train capacities just exceeding 70 TEU in 2015.

Insert Table 6 here

Table 7 reveals the extent to which the train capacity was utilised, with an increase in the average load factor from 72 per cent in 2007 to 78 per cent in 2015. Again, the increases at Southampton and Tilbury far exceeded the minimal gain at Felixstowe, but the latter still displayed the highest load factor in the 2015 survey. The load factor at London Gateway was very similar to that at Tilbury, its close neighbour, with both being considerably lower than at Felixstowe and Southampton.

Insert Table 7 here

Combining the train capacity and load factor data from Tables 6 and 7, Table 8 shows the trend in the average number of TEU carried per train for each port. There was a 25 per cent increase overall. Very considerable improvements were experienced at both Southampton and Tilbury, with the former almost reaching the average load of Felixstowe in 2015. The difference in 2015 between the two major ports and the other two is noticeable.

Insert Table 8 here

6. Implications for port-hinterland container flow sustainability

While the operational efficiency analysis was based on data from rigorous primary research, the evidence relating to the associated sustainability impacts is less conclusive but an informed assessment of the implications is possible. From the combination of an increase in rail's mode share of British port-hinterland container volumes and the surveyed improvements in rail freight operational efficiency, it can be inferred that there have been substantial overall sustainability benefits.

The specific impacts of rail's mode share increase are difficult to determine with certainty due to a lack of sufficient information. Ideally, statistics for hinterland road volumes would be included in the analysis to allow a more nuanced assessment, but unfortunately such data are not available. It is reasonable to assume that rail's share of actual hinterland activity (in tonne kilometres) has increased at least in line with its share of port TEU throughput since, at 200 kilometres, rail's average length of haul in Britain is more than double that of road (DfT, 2015) and, from the networks shown in Figures 3 and 4, the typical port-hinterland rail distance is longer still. Consequentially, the negative impacts of hinterland transport activity per tonne kilometre are likely to have reduced. Had rail's mode share remained at the 2007 level, approximately 185,000 fewer TEU would have moved by rail in 2015 than was actually the case. Assuming that they would otherwise have moved by road, with an average length of haul of 275 kilometres (similar to those in Table 5) and an average of 6.4 tonnes per TEU (based on DfT, 2016), using the most reliable and up-to-date cross-modal greenhouse gas (GHG) emissions factors available (DECC, 2016) leads to an estimated CO_2e saving in 2015 of around 34,000 tonnes. This calculation is necessarily indicative as a result of incomplete information, but it does demonstrate the sustainability benefits resulting from modal shift to rail.

These calculations were based on modal averages for road haulage and rail freight. However, this research has demonstrated clearly that rail has become more efficient in the port-hinterland container market as trains have become longer and better filled, so it is likely that the negative externalities per tonne kilometre have reduced and the sustainability benefits for the rail haulage may be underestimated. That 25 per cent more TEU were being carried per train in 2015 compared to 2007 demonstrates a considerable improvement in rail’s efficiency and, by implication, sustainability in this market. A direct relationship between port container throughput and rail’s fortunes in the hinterland market is evident. Felixstowe and Southampton, the two largest container ports, display average train loadings far greater than at the ports with smaller container throughput. As such, concentrating deep sea container activity at a small number of ports increases the likelihood of rail gaining mode share at the expense of road, since it allows rail to achieve the critical mass require for viable operation. As yet, it is too early to judge whether volumes at London Gateway will increase to such an extent that it rivals its two large competitions, though the available port capacity is gradually being increased (DP World, 2016).

Without access to data relating to energy consumption at a disaggregated level the sustainability impacts of the improved operational efficiencies cannot be calculated explicitly. However, some developments can be identified. Freightliner has recently introduced its PowerHaul diesel locomotive which it claims provides greater haulage capability, reduced fuel consumption and better environmental performance (Freightliner, 2009); some services in the 2015 survey were hauled by this new locomotive type. Both Freightliner and GB Railfreight have introduced new wagons designed to better align wagon platform lengths and container dimensions (VTG, 2012).

There is clearly more that could be done, though, to further improve the sustainability of the rail operations in the port-hinterland container market. For example, there is a heavy reliance on fossil fuels since the vast majority of services are diesel-hauled throughout, even those operating entirely or predominantly “under the wires” where electric traction could be used. Different sources vary, but electric traction is widely reported as being ‘greener’ than diesel haulage, with the elimination of local air pollutants from the point of transport use and a considerable reduction in greenhouse gas emissions per unit of activity (European Court of Auditors, 2016). Of the rail-served ports, only Tilbury offers the capability of electric haulage into the terminal itself and a small number of services make use of this. In addition, some services from Felixstowe to the North West and Scotland use electric traction for the majority of the distance and feeder services between Crewe and Coatbridge, and some from Crewe to local North West terminals, are electrically hauled. However, the growth of service provision at non-electrified London Gateway at the expense of Tilbury, and the rerouting of some Felixstowe services away from the electrified route via London, has reduced the potential for using electric traction. Several route electrification schemes are in progress (Network Rail, 2016), but these are aimed primarily at passenger train services and will not offer obvious potential for port-hinterland container trains. Freightliner is the only one of the three FOCs active in the port-hinterland container market to use electric locomotives on these services.

Other issues that complicate the sustainability assessment and require further investigation include the sometimes more circuitous than necessary routings in the hinterland as a result of capacity constraints on the more direct route, with extra distance implying additional energy consumption and consequent emissions. However, this may be offset by a smoother train path on the longer route, with less start-stop operation and holding of container trains in passing loops to allow passenger trains to overtake. The effects on efficiency and sustainability are therefore likely to be case-specific.

RQ2 set out to ascertain whether there has been any change in the efficiency and sustainability of rail service provision within the port-hinterland container market. The analysis in Section 5 demonstrated considerable operational efficiency improvements between 2007 and 2015, with a 25 per cent increase in rail volumes and rail's mode share of port container throughput increasing from 14.7 per cent to 16.6 per cent being absorbed without an increase in the number of train services operated. The sustainability implications are less clear-cut but there is good reason to believe that the changes identified have reduced the negative impacts of the transport activity for moving containers in the hinterland.

7. Conclusions

Using the UK as a case study, this paper has investigated the freight transport activity, and its impacts, in the increasingly important port-hinterland container market. With limited published information at a sufficient level of disaggregation, the investigation has drawn heavily on original surveys conducted in 2007 and 2015 which have allowed longitudinal analysis to take place. The combination of the increase in rail mode share and the operational efficiency improvements identified in this study strongly support the assertion that the negative externalities per unit of transport activity in the hinterland have been reduced. The preceding analysis identified an indicative CO_2e saving in 2015 of around 34,000 tonnes as a result of the increase in rail's share of the UK port-hinterland container market since 2007. That calculation was reliant on the use of official modal averages due to a lack of specific emissions data for the road and rail operations to serve the port-hinterland container market. Further investigation of the sustainability impacts of the improved rail freight efficiency would be desirable but there are commercial sensitivities associated with gaining such data in a competitive market such as this, where there is both intermodal and intra-modal competition.

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Table 1: Comparison of published statistics and survey estimates of rail-borne container volumes at Felixstowe

Year	Rail-borne container volumes (in TEU) from: Published statistics	Survey estimates *	Difference (published – survey)
2007	625,000 (approx.) [a]	651,902[d]	(4%)
2015	910,000[b]/936,000[c]	900,050[d]	1-4%

* - survey results grossed up to annual estimate (based on 50 weeks per year)

Source: Network Rail (2010)[a]; Port of Felixstowe (2016a[b]; 2016b[c]); author's surveys[d]

Table 2: Relationship between information sources and research analysis stages

	Information source: Published information	Annual rail freight database	Observation surveys
RQ1: To what extent (if any) is an increase in rail's share of the British port-hinterland container market being achieved?			
Rail volumes and share of rail market	X		
Rail share of container port throughput	X		X
Hinterland network and service provision		X	X
RQ2: Has there been any change in the efficiency and sustainability of rail service provision within this market?			
Rail efficiency measures			X
Assessment of sustainability impacts	X		X

Table 3: Annual estimates of rail-borne container flows (in TEU), 2007 and 2015 surveys

Port	2007 survey	2015 survey	% change
Felixstowe	651,902	900,050	38.1
London Gateway	-	61,850	n.a.
Southampton	446,324	537,400	20.4
Thamesport	91,700	-	(100.0)
Tilbury	74,650	83,550	11.9
Total	**1,264,576**	**1,582,850**	**25.2**

Source: author's surveys

Table 4: Typical weekly container train service provision at each port in each survey period

Port	**2007**	**2015**
Felixstowe	257	315
London Gateway	-	30
Southampton	231	194
Thamesport	40	-
Tilbury	50	40
Total	**578**	**579**

Source: author's surveys

Table 5: Weighted average straight line distance for port-hinterland container train services, 2007 and 2015

Distance for:	**2007**	**2015**
Port services (km)	273	280
Port services including feeders (km)	259	277

Source: author's surveys; distances derived from freemaptools.com

Table 6: Mean TEU capacity provided per train, by port

Port	**2007 survey**	**2015 survey**	**% change**
Felixstowe	62.71	70.08	11.8
London Gateway	-	67.07	n.a.
Southampton	57.93	70.98	22.5
Thamesport	61.63	-	n.a.
Tilbury	54.24	65.33	20.4
Total	**59.99**	**69.89**	**16.5**

Source: author's surveys

Table 7: Mean capacity utilisation per train (TEU carried as % of TEU capacity), by port

Port	2007 survey	2015 survey	% change
Felixstowe	80.27	81.39	1.4
London Gateway	-	60.86	n.a.
Southampton	66.73	78.69	17.9
Thamesport	73.78	-	n.a.
Tilbury	54.67	62.91	15.1
Total	**72.20**	**78.14**	**8.2**

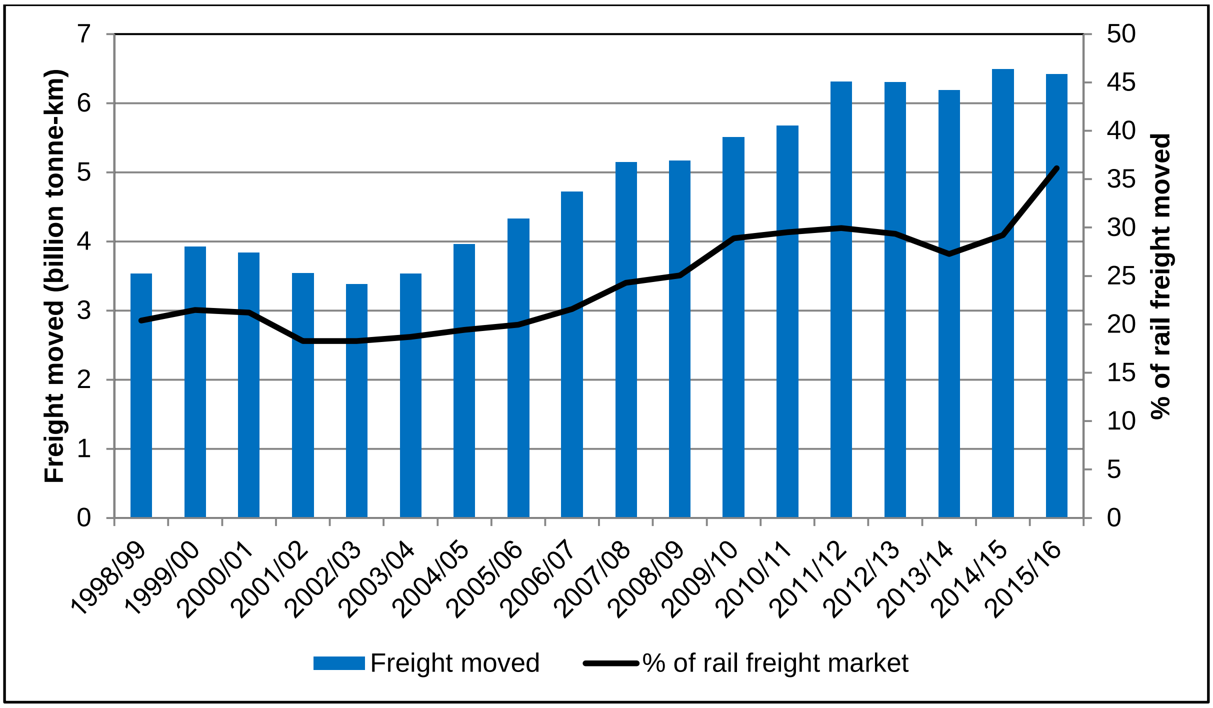
Source: author’s surveys

Table 8: Mean TEU load per train, by port

Port	2007 survey	2015 survey	% change
Felixstowe	50.73	57.15	12.7
London Gateway	-	41.23	n.a.
Southampton	38.64	55.40	43.4
Thamesport	45.85	-	n.a.
Tilbury	29.86	41.78	39.9
Total	**43.76**	**54.68**	**25.0**

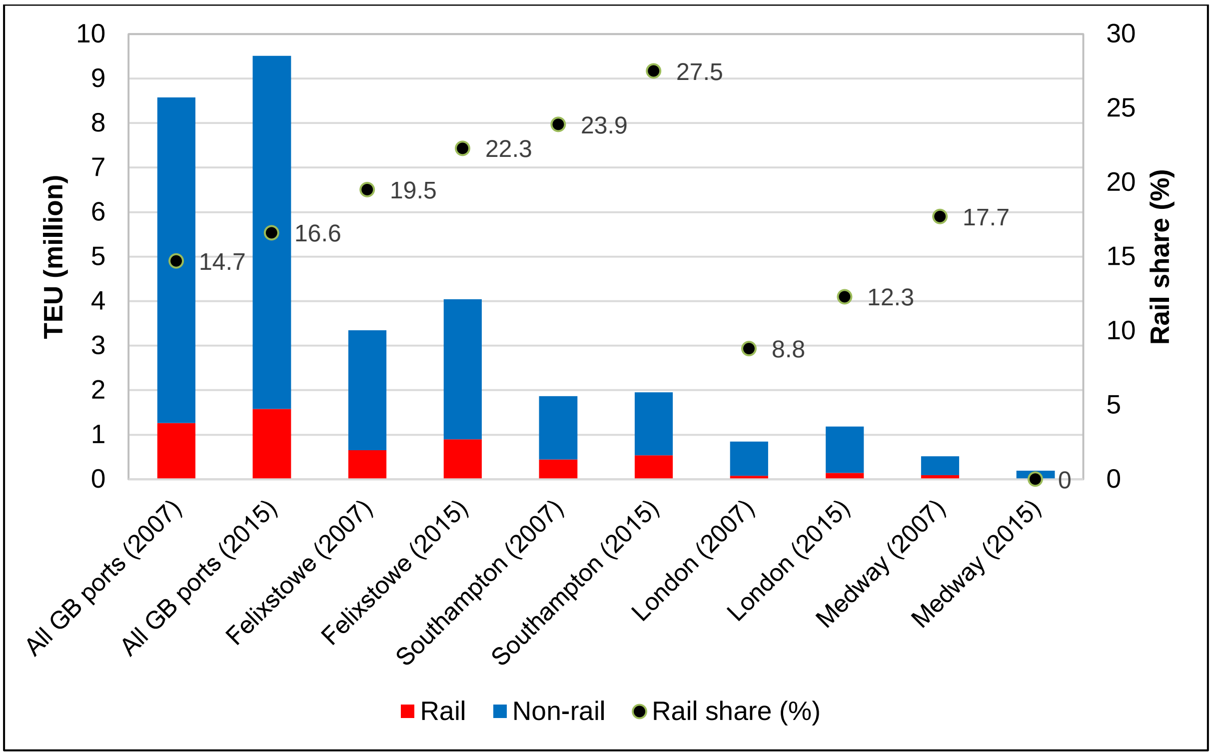
Source: author’s surveys

Figure 1: Domestic intermodal rail freight moved and share of rail freight market (1998/99–2015/16)



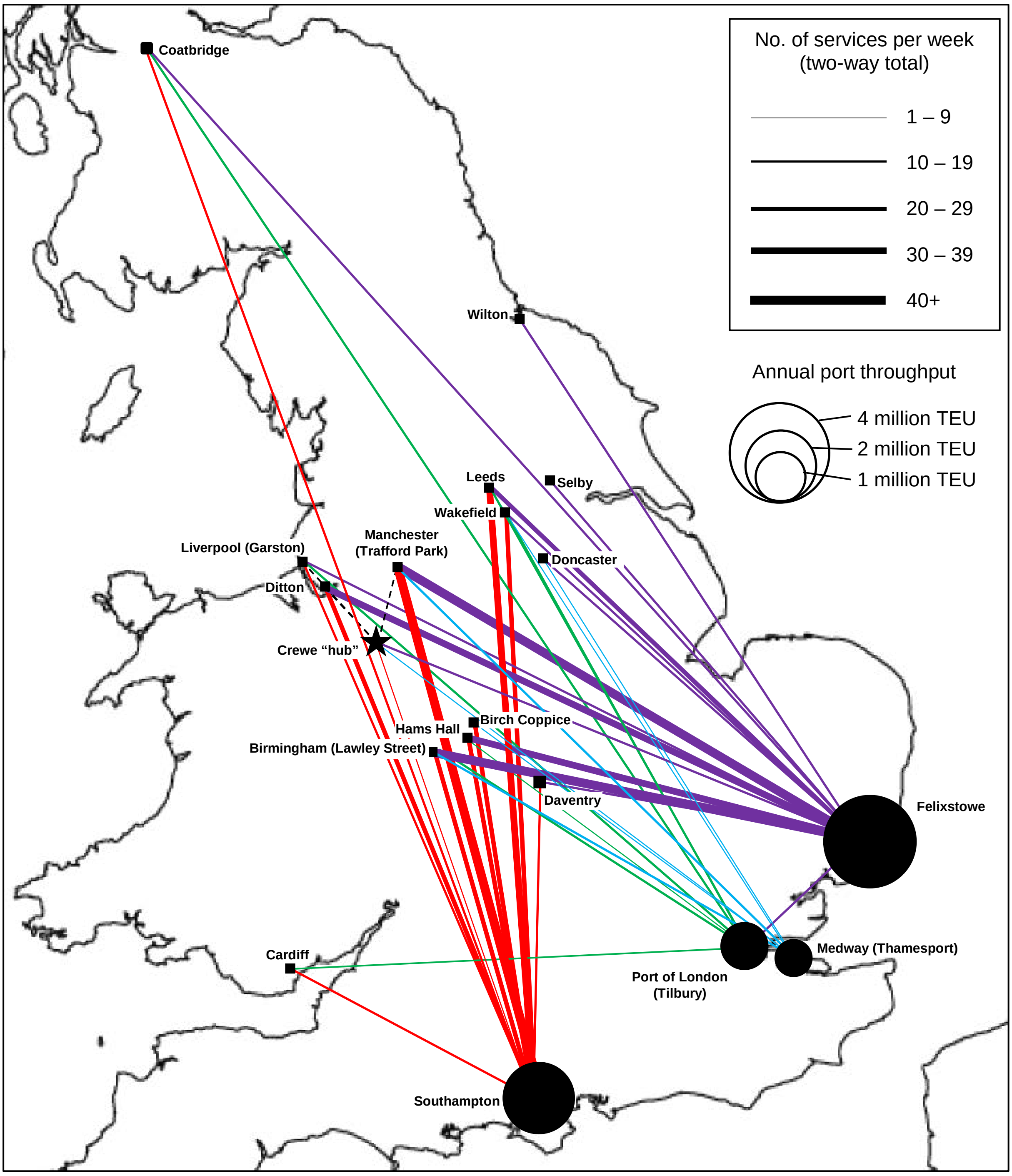
Source: based on ORR (2016)

Figure 2: Estimated rail share of lift-on/lift-off (LoLo) container TEU throughput (all Great Britain (GB) ports and at each rail-served port, 2007 and 2015)



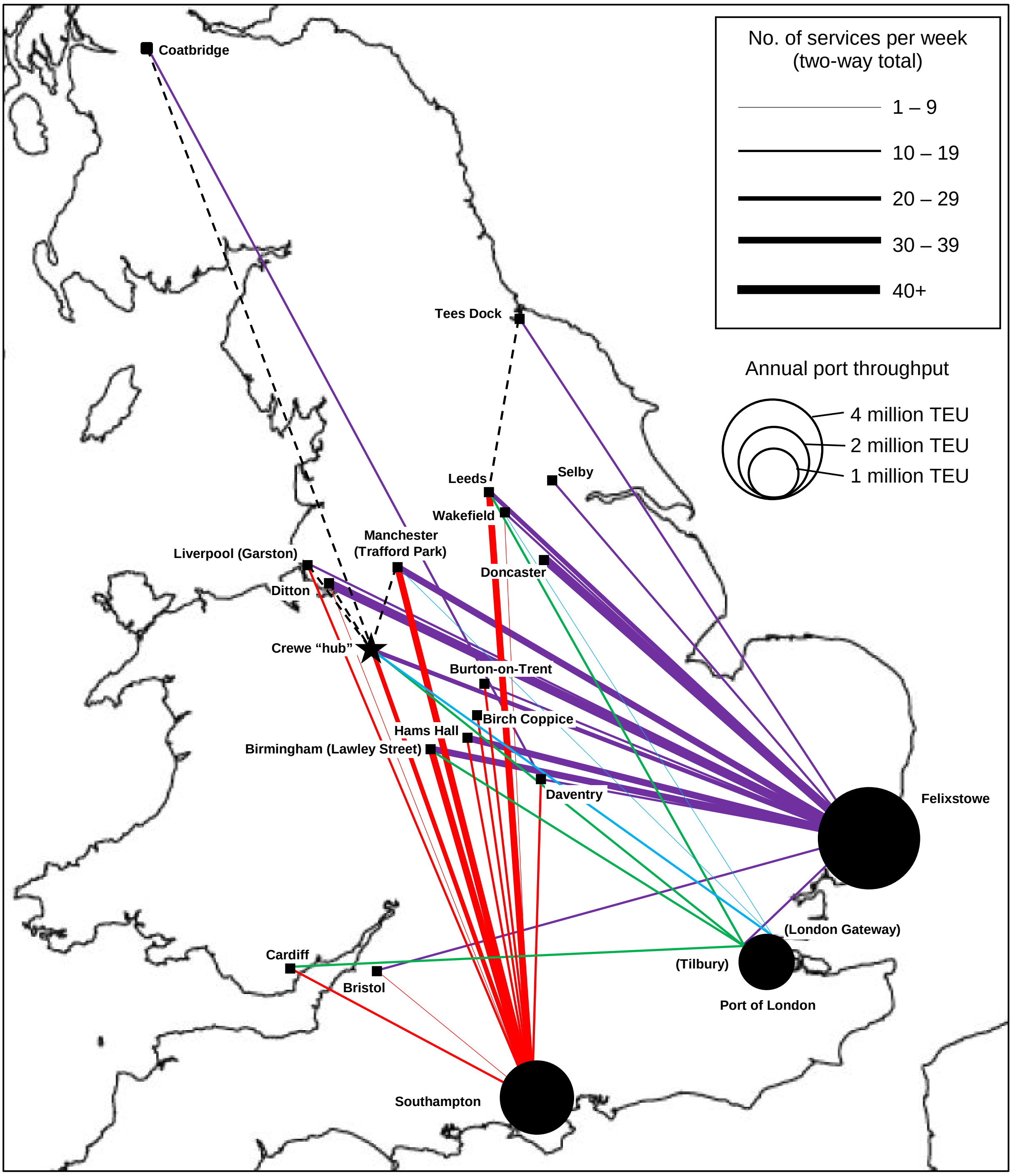
Source: author's surveys, DfT (2008), DfT (2016)

Figure 3: Indicative map of container train services to/from the key container ports (2007)



Source: based on author's database, DfT (2008), DfT (2016); dashed lines denote feeder services

Figure 4: Indicative map of container train services to/from the key container ports (2015)



Source: based on author's database, DfT (2008), DfT (2016); dashed lines denote feeder services