The impacts on freight train operational performance of new rail infrastructure to segregate passenger and freight traffic

Woodburn, A.G.

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Allan Woodburn
Planning & Transport Department, University of Westminster, 35 Marylebone Road, London, NW1 5LS, United Kingdom

Abstract

Rail freight has an important role to play in improving the resource efficiency and sustainability of freight transport within the supply chain. The British rail network has seen considerable growth of both freight and passenger activity in the last 20 years, leading to concerns about its capacity to absorb continued growth. A number of infrastructure initiatives focused on increasing capacity and reducing conflicts have been implemented. This includes the North Doncaster Chord, opened in June 2014 primarily to provide a more direct route from the port of Immingham to the major Aire Valley power stations (i.e. Drax, Eggborough and Ferrybridge).

The paper analyses the freight impacts of the new chord, focusing on three key operational measures (i.e. train routing, scheduled journey times and train punctuality) during 10-week survey periods before and after the opening of the chord. The analysis is based on real-time data relating to coal and biomass trains operating between Immingham and the three power stations. This is a novel approach as the data have been made publicly available only recently, allowing a detailed investigation of the flows on this corridor at a highly disaggregated level. The use of this empirical method to assess the detailed rail freight operational impacts is an important element in the process of evaluating the effects of network enhancement. The results demonstrate improvements in each of the three operational measures, but also reveal a situation considerably more complex than that suggested by the published material relating to the justification for this new infrastructure.

Keywords: Rail freight; transport infrastructure; transport efficiency; disaggregated freight data; United Kingdom

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 2012 and its share of passenger kilometres increased from 5 per cent to 9 per cent in the same period (DfT, 2015). 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) due, for example, to the incidence of flat junctions between converging or diverging routes and to speed differentials between varied types of train. At the European level, there is a desire to develop a rail freight priority network, making rail a more attractive option for freight flows by improving capacity, journey times and other aspects of service quality (European Commission, 2007). International rail freight corridors are under development as part of the European Rail Network for Competitive Freight, concentrating on improving service quality through a focus on infrastructure capacity and performance (DG MOVE, 2011). The Strategic Freight Network (SFN) was introduced in the United Kingdom in 2007 (DfT, 2007) with similar national objectives and committed funding until at least 2019 (DfT, 2012).

Despite the focus on capacity and performance, detailed published analysis of the operational impacts of new infrastructure designed to remove such conflicts is lacking, particularly with regard to rail freight activity. This is surprising, since infrastructure enhancements have the potential to improve service quality and reduce costs, both critical issues for potential rail freight customers when making mode choice decisions (ORR, 2012; Directorate General for Internal Policies, 2015). The objective of this paper, therefore, is to evaluate the key rail freight operational impacts resulting from the opening in June 2014 of a new section of railway line in the United Kingdom, known as the North Doncaster Chord. The chord provides a more direct route for imported coal (and, latterly, biomass) traffic from the port of Immingham, on the Humber estuary on Britain’s east coast, to the three large Aire

Valley power stations. There is no financial or cost-benefit analysis in the public domain but, importantly for the project's justification, the chord has removed a bottleneck by providing a freight route independent of the busy East Coast Main Line (ECML), where capacity had been limited by the mix of fast passenger trains and slower freight trains (Network Rail, 2011). The segregation of these previously conflicting flows allows more, and possibly more reliable, passenger trains to operate on the ECML. While it is conceivable, perhaps even likely, that ECML passenger benefits were the main justification for the investment in the chord, this paper focuses specifically on the freight impacts.

The paper is methodologically innovative since it is based on the detailed analysis of real-time train running data captured for almost 2,000 freight trains in total during similar periods before and after the opening of the chord. This data source has only recently been made publicly available in Britain and no similar research from other countries has been identified from the published literature.

A review of relevant literature follows in Section 2. Section 3 then presents the background to the study, both regarding trends in recent British rail network activity and, specifically, the context for the North Doncaster Chord itself. Section 4 sets out the methodology adopted for this empirical investigation. The detailed results of the before-and-after survey relating to train routing, journey times and train punctuality are presented in Section 5, leading into a more detailed investigation of the 'after' survey in Section 6. A discussion of the implications of the study's findings is presented in Section 7. Section 8 ends the paper, setting out the key conclusions and the wider applicability of the research approach.

2. Literature review

Both cost and service quality are important in determining which mode of transport will be selected for freight flows. In reviewing the literature, Samimi et al. (2011, 859) found that the dominant attributes influencing freight mode choice were "accessibility, reliability, cost, time, flexibility and past experience with each mode". A survey of existing and potential rail freight customers in Britain (ORR, 2012) identified that on-time delivery was ranked as the second most important service attribute after cost/price. Other attributes ranked as being of high importance included network access, overall service quality and flexible service/recovery strategy. When questioned about rail's performance, on-time delivery and overall service quality were ranked highly by customers but cost/price and, particularly, flexible service/recovery strategy received low rankings despite being important attributes. Compared with passenger transport, where research regularly investigates the impacts of network changes on people's trip-making, journey opportunities and travel behaviour (see, for example, Bjarnason, 2014; Shaw et al., 2014), there is little detailed investigation of the impacts of infrastructure enhancements on freight transport activity, particularly within rail.

Rail network capacity, and how it is utilised, is an important determinant of train service performance. Capacity is influenced by infrastructure, traffic and operating characteristics (Abril et al., 2008). The focus of much of the published literature is on the modelling and simulation of capacity utilisation, often built on assumptions of traffic and operating characteristics which are narrowly defined. Urban passenger rail systems feature more strongly than mixed traffic railways, although some attention has been devoted to freight. Miller-Hooks et al. (2012) highlighted the effects of network resilience on service performance, taking account of planned capacity usage, robustness of the plan and flexibility to deal with disruptions. In common with this paper's focus, Liu & Kozan (2011) considered network operations and capacity constraints for a coal rail market, though in Australia and with the crucial difference that their coal flows were on a dedicated, self-contained network. Gedik et al. (2014) also focus on coal flows, assessing network vulnerability and disruption recovery in the USA; while the flows were not on a self-contained network, they used a freight-dominant network rather than a mixed traffic railway like Britain's. Other studies (see, for example, Godwin et al, 2007; Cacchiani et al., (2010); Kuo et al., 2010) have considered freight train scheduling and routing on a mixed traffic railway but develop modelling approaches not clearly linked to actual network operations. A more policy-focused investigation was conducted by Morvant (2015), examining the challenges posed by freight characteristics for operations planning on the French mixed traffic network and highlighting the need for greater awareness of the requirements of rail freight customers.

Understanding of the relationship between infrastructure enhancements and the impacts on freight mode choice decision making, operational efficiency and customer satisfaction is limited, particularly in the case of rail. Woodburn (2013) assessed the impacts on rail freight efficiency of network enhancements targeted at the port-hinterland container market, identifying considerable improvements in on-train capacity and train loads within this specific market. Other studies (e.g. Rowangould, 2013) have considered the wider economic and environmental impacts of public investment in rail freight infrastructure to try to achieve public policy aims of reducing the negative impacts of road freight. Olsson (2006) emphasised the high degree of integration of a railway system, with infrastructure enhancements planned in a coordinated way apparently having more of an impact than discrete route projects. As noted in Section 1, infrastructure improvements targeted at rail freight activity are receiving more attention in European public policy, increasing the need to understand the operational impacts. However, commercial sensitivities and limited data availability appear to be obstacles to the detailed investigation of the impacts of new or improved infrastructure on rail freight performance at an operational level. The research presented in this paper aims to further the understanding of this important subject.

3. Detailed study context

An increase in rail's share of both the freight and passenger markets in Britain over the last 20 years was noted in Section 1. More importantly for rail network operations, these increases have resulted in considerably greater use of the network, as can be seen from the comparison in Table 1 of changes between 1994/95 and 2014/15 for a range of key measures.

Table 1: Key measures of British rail activity: 1994/95 and 2014/15

Measure	1994/95	2014/15	% change
National rail network route length (km)	16,542	15,760	(5)
Passenger journeys (million)	735	1,654	125
Passenger kilometres (billion)	28.7	62.9	119
Passenger train kilometres (million)	340.5	532.4	56
Freight lifted (million tonnes)	97.3	110.5	14
Freight tonne kilometres (billion)	13.0	22.2	71
Freight train kilometres (million)	41.1	41.0	0

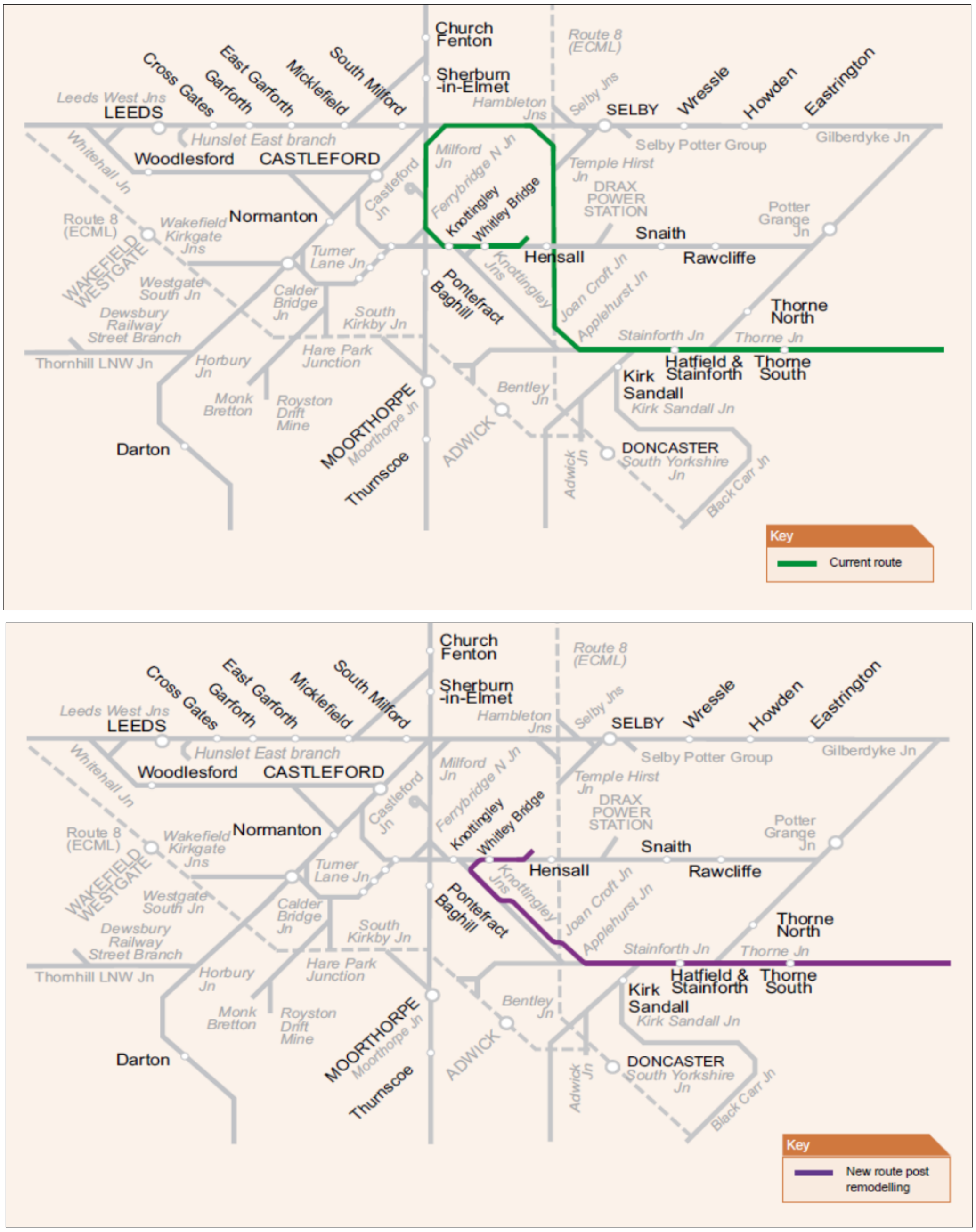
Source: DoT, 1996; DfT, 2015; ORR, 2006; ORR 2015a

The train activity measures (i.e. passenger train kilometres and freight train kilometres) demonstrate utilisation improvements since they have increased by substantially less than the measures directly relating to passengers and freight. In particular, it is noticeable that almost exactly the same number of train kilometres is needed to move a greater amount of freight, despite the large increase in the average length of haul reflected in the freight tonne kilometres statistic. By contrast, passenger train kilometres have grown considerably but at broadly only half the rate of the increase in journeys and passenger kilometres. The increasing activity is taking place on a network that has contracted in length by 5 per cent since 1994/95, leading to an increasing number of capacity bottlenecks and growing concerns about network operational resilience. Predictions for the 2014 - 2019 period foresee a further 15 per cent increase in passenger journeys (Network Rail, 2014a) and freight volume growth of 22 per cent (Network Rail, 2014b).

In response to the growing demand, there is a considerable investment programme in the British rail network. Network Rail, the organisation with responsibility for the rail infrastructure, is authorised to spend £38 billion by 2019 to maintain and enhance the network (Network Rail, 2014b). There is ongoing funding from the dedicated Strategic Freight Network budget but also from other budgets that are not freight-specific. The North Doncaster Chord is just one of a number of similar infrastructure schemes providing short new sections of track on the British rail network. Other recently implemented schemes which provide greater flow segregation and fewer conflicting train movements include the Nuneaton North Chord (Network Rail, 2012) and the Ipswich Chord (Network Rail, 2014c). Further traffic segregation initiatives are under construction or planned at other locations, such as the Acton dive-under in west London to remove conflicts between Crossrail passenger trains and freight trains departing westwards from Acton yard (Network Rail, 2013). This type of infrastructure initiative is seen by policy makers and the rail industry as being vital to accommodating growing traffic volumes.

Turning to the North Doncaster Chord itself, it has been constructed primarily to segregate coal (and now biomass) trains running on a broadly east-west route between the port of Immingham and the Aire Valley power stations (i.e. Drax, Eggborough and Ferrybridge) from the north-south trains (including high speed, long distance passenger services) on the East Coast Main Line (ECML). The Immingham to Aire Valley coal flow forms one of the most intensive rail freight corridors in Britain. Volumes vary depending on coal requirements and supply chain arrangements but average around 100 train loads of imported coal on this corridor in a typical week; in the 59 weeks between 1 January 2007 and 16 February 2008 a total of 5,285 trains operated (DfT, 2008). Prior to the construction of the new chord, there were conflicting movements between these coal trains and other trains in the Doncaster area and on the stretch of the ECML just to the north of there. The upper diagram in Figure 1 shows the indicative routing prior to the use of the North Doncaster Chord, with coal trains coming in from Immingham through Thorne (to the right of the diagram) and looping round to end up at Drax, the largest of the three Aire Valley power stations. The other two power stations are located prior to Drax and just off this route. The lower diagram shows the indicative routing via the new chord, which is more direct and avoids the use of the ECML over the almost 14 miles between Joan Croft Junction and Hambleton South Junction.

Figure 1: Indicative rerouting on core corridor from Immingham to Aire Valley Power Stations



Source: Network Rail (2011)

In addition to the power station flows from Immingham, it has been established that the chord is also being used for a small number of other freight flows, primarily one or two coal trains per day from Hatfield Colliery to Drax, and other movements such as locomotives moving between depots. However, more than 90 per cent of the loaded trains using the new route are those under investigation in this research and, given that these flows formed the justification for the investment in the chord, no further explicit consideration has been given to these other flows.

4. Research methods

The analysis in this paper is based on a comparison of real-time freight train data[1] of the situation 'before' and 'after' the opening of the North Doncaster Chord. Figure 2 presents an extract of the real-time data for one particular train, showing the scheduled and actual timings for the first part of the journey from the port of Immingham to Ferrybridge power station.

Figure 2: Extract of real-time information for a specific train

644L 2230 Immingham Esl (Flhh) to Ferrybridge C Pwr Stn Flhh

Runs on 28th January 2014

Schedule Information

- **VAR** schedule UID **H66698**
- Runs **FSSuX** between **27/01/2014** to **30/01/2014**
- Service code **57620170**

Operational Information

- Schedule from **ITPS**
- Timed for **60mph** max
- **Diesel** locomotive, trailing load **2200** tonnes

Realtime Status

- TRUST ID **21644LC828**
- Running as **644L**
- Activated **28/01/2014 20:30**

		WTT		Realtime			Route		Allowances		
Location	**Pl**	**Arr**	**Dep**	**Arr**	**Dep**	**Dly**	**Line**	**Path**	**Eng**	**Pth**	**Prf**
Immingham Esl (Flhh)			2230		**2230**	RT			2	2	
Humber Road Jn		pass	2238	pass	**2234**	4E				10	
Ulceby [ULC]		pass	2256	pass	**2243**	13E					
Brocklesby Jn.		pass	2258	pass	**2245**	13E	ML				
Barnetby [BTB]	3	pass	2306	pass	**2254**	12E	FL				
Wrawby Jn		pass	2307	pass	**2256**	11E					
Brigg [BGG]		pass	2312	pass	**2300**	12E					
Kirton Lime Sdgs		pass	2323	pass	**2313**	10E					
Kirton Lindsey [KTL]		pass	2325	No report							
Northorpe S.B.		pass	2330	pass	**2319**	11E					
Gainsborough Central [GNB]		pass	2345	No report					1		
Gainsborough Trent Jns		pass	2348½	pass	**2336**	12E			2		

Source: realtimetrains.co.uk

[1] Real-time freight train running data are publicly available from realtimetrains.co.uk, mostly on an anonymised basis

To maintain consistency, a 10 week period at the same time of year was surveyed in each case, with the ‘after’ survey period commencing more than six months subsequent to the opening of the North Doncaster Chord so as to allow time for its use to bed in. All coal trains operating directly from Immingham to each of the three power stations (i.e. Drax, Eggborough and Ferrybridge) were surveyed in both periods. Since May 2014, imported biomass has also been moved on the same axis from Immingham to Drax, reflecting the conversion of some of its generating capability from coal to biomass (Drax Group, 2016). These trains were included in the ‘after’ survey since they are essentially similar in nature to, and replace some of, the coal flows. The survey periods were as follows:

- Sunday 19 January 2014 to Saturday 29 March 2014 for the ‘before’ survey
- Sunday 18 January 2015 to Saturday 28 March 2015 for the ‘after’ survey

Some trains operate via an intermediate location (e.g. a yard where they are staged over the weekend), so it was not always possible to ascertain whether they are destined for one of the three power stations in the study; such trains have been included in the study where it was possible to match the two journey stages. For the ‘before’ period, data were gathered for 1,029 trains, though in 25 cases there was missing information relating to departure time, arrival time and/or intermediate routing. Therefore, the valid ‘before’ sample was 1,004 trains. For the ‘after’ period, 976 out of 978 trains had complete information relating to these key journey attributes. The total number of trains was similar but, as Table 2 shows, the composition varied substantially in terms of the power stations served with no trains at all to Ferrybridge in the ‘after’ period. In the subsequent analysis, the ‘Immingham to Aire Valley power stations’ flow is considered as a single entity since this was the justification for the North Doncaster Chord but, reflecting the different power station composition between the ‘before’ and ‘after’ periods, the analysis also considers the specific origin-destination flows.

Table 2: Composition of 'before' and 'after' surveys, by number of trains to each power station

	Before		After	
Destination	No.	*%*	No.	*%*
Drax	416	*41*	723	*74*
Eggborough	353	*35*	253	*26*
Ferrybridge	235	*23*	0	*0*
Total	1,004	*100*	976	*100*

Source: author's surveys based on data from realtimetrains.co.uk; totals do not always add up to 100% due to rounding

For each train, the following information was captured: date/day of operation; scheduled departure time; actual departure time; route; destination power station; scheduled arrival time; actual arrival time; freight operating company (FOC); and nature of schedule (i.e. standard schedule, varied schedule or short-term planned schedule). This allowed the establishment of the base case with regard to three key criteria (i.e. train routing, scheduled journey time and punctuality) followed by an evaluation of the impacts of the use of the North Doncaster Chord on the operation of coal and biomass trains from Immingham to the Aire Valley power stations.

The analysis considers only the loaded coal trains, since they operate at a lower maximum speed (60 mph/97 kph) than do the empty trains (75 mph/121 kph) and consequentially their impacts on train paths on the ECML are greater. Ideally, empty trains returning from the power stations to Immingham would also have been included in the analysis in order to provide a more complete picture of the rail-borne operation under study. Unfortunately, this was impractical for a number of reasons relating to the limitations of the real-time data. Firstly, a higher proportion of empty trains did not operate directly from power station back to Immingham, unlike the vast majority of loaded trains which did operate directly from port to power station. Rakes of empty wagons often travel to an intermediate yard (e.g. at Doncaster or Milford Junction) after discharging their load at the power stations, either for maintenance or for staging until needed for the next loaded trip. Secondly, there was no reliable method to allow inward empty and outward loaded trains at Immingham to be paired accurately given the large number of trains being handled there. Allied to this, some wagon rakes were inter-working between Aire Valley power station flows and services to other power stations, so not all rakes of wagons were captive to the Aire Valley corridor. An empty train from Drax may have arrived at Immingham and been loaded for West Burton power station, for example. Finally, real-time data are only available for a period of seven days, so there were time constraints for interpreting and capturing the data for empty trains as well as for the loaded services. In combination, these limitations unfortunately ruled out the possibility of meaningfully incorporating the empty services, although some related issues are raised in the analysis.

5. Comparative analysis of 'before' and 'after' survey periods

This section presents the results from the 'before' and 'after' survey periods relating to the three key assessment criteria: train routing, scheduled journey times and train punctuality. The results are presented for the flows from Immingham to each power station separately and overall for the group of Aire Valley power stations; given the lack of any trains to Ferrybridge power station in the 'after' survey period, the latter are indicative only and need to be treated with caution. As such, it is more meaningful to separately compare the 'before' and 'after' survey results for Drax and Eggborough power stations.

5.1 Train routing

As discussed in Section 3, the freight-related case for the North Doncaster Chord was predicated on the pre-existing route from Immingham to the Aire Valley being that shown in the upper diagram in Figure 1. Analysis of the 'before' survey revealed that the reality was considerably more complex, with 10 routing variants between Immingham and the Aire Valley leading to 20 unique routing and destination combinations. However, three of these combinations accounted for 61 per cent of trains and eight of them in total accounted for less than 3 per cent. In total, 73 per cent of 'before' trains were routed via Thorne but just 60 per cent (of the entire 'before' sample) used the key section of the ECML between Joan Croft

Junction and Hambleton South Junction. Almost all of the trains that avoided this section of the ECML instead used it to the south, in the Doncaster area, having reached there by one of three different routes. Only 20 trains had no interaction at all with the core ECML route. The ‘after’ survey period had almost as many routing variants (i.e. nine) but fewer routing and destination combinations (15), largely because of the lack of any trains destined for Ferrybridge. However, the top three routings accounted for 75 per cent of trains and the bottom eight routings covered just 3 per cent. Prior to the opening of the chord, the shortest distance route involved a reversal at the yards south of Doncaster, but extra time was needed in the schedule for the locomotive and driver to change ends. The proportion of trains changing direction at Doncaster dropped from 11 per cent ‘before’ to less than 2 per cent ‘after’ given the more direct routing offered by the new chord.

Table 3 compares the interactions between the surveyed freight trains and the ECML in both survey periods, revealing a very substantial reduction in the proportion of trains using either section of that route. Given the routing complexities, one train ‘before’ and nine ‘after’ actually used both sections of the ECML. The overwhelming finding is that the proportion of trains avoiding the ECML completely increased from 2 per cent to 64 per cent. By definition, all trains avoiding the ECML in the ‘after’ period used the North Doncaster Chord, though four of these continued via the Leeds area for weekend stabling and therefore did not travel directly to their destination. Overall, 64 per cent of trains in the ‘after’ period followed the new routing via the North Doncaster Chord direct to the destination power station.

Table 3: Percentage of trains using East Coast Main Line (ECML) in 'before' and 'after' survey periods

Routing	Before	After
Joan Croft Jn to Hambleton South Jn	60	19
Through Doncaster	38	17
No use of ECML	2	64

Source: author's surveys based on data from realtimetrains.co.uk; n (before) = 1,004, n (after) = 976

Table 4 shows the change in weighted average distances between the 'before' and 'after' survey periods. The shortest route in the 'before' survey was 62.96 miles and the longest was 112.16 miles, so the longest was almost 80 per cent further than the shortest. Excluding Ferrybridge, to allow more meaningful comparison with the 'after' survey, the distance range was 66.03 miles to 101.30 miles. In the 'after' survey, the shortest distance was that using the North Doncaster Chord to Eggborough, at 55.30 miles, and the longest again was 112.16 miles. Comparison of the survey periods reveals a 13 per cent reduction in the weighted average distance to Drax and a 7 per cent reduction to Eggborough. Using t-tests to compare the weighted average distances overall and for each of Drax and Eggborough shows that the reductions are statistically significant in all three cases with p values of less than 0.0001.

Table 4: Weighted average distance (in miles) in 'before' and 'after' survey from Immingham to power stations

Destination	Before	After	% change
Drax	76.80	66.44	(13)
Eggborough	69.41	64.71	(7)
Ferrybridge	70.51	-	-
Overall	72.73	65.98	(9)

Source: author's surveys based on data from realtimetrains.co.uk; calculations from Network Rail (2015a)[2]; n (before) = 1,004, n (after) = 976

5.2 Scheduled journey times

[2] note that distances are measured from Humber Road Junction (Immingham) to the entrance of each power station using the National Electronic Sectional Appendix (Network Rail, 2015a)

For both the ‘before’ and ‘after’ survey periods, Table 5 summarises the average scheduled journey time between Immingham and each of the power stations as well as the overall weighted average. Those trains that were staged at an intermediate location have been excluded from the calculation due to the lengthy layover times, so the sample sizes are slightly reduced.

Table 5: Weighted average scheduled journey times (in hh:mm) between Immingham and power stations

Destination	Before	After	% change
Drax	04:13	03:45	(11)
Eggborough	03:50	03:32	(8)
Ferrybridge	03:57	-	-
Overall	04:01	03:42	(8)

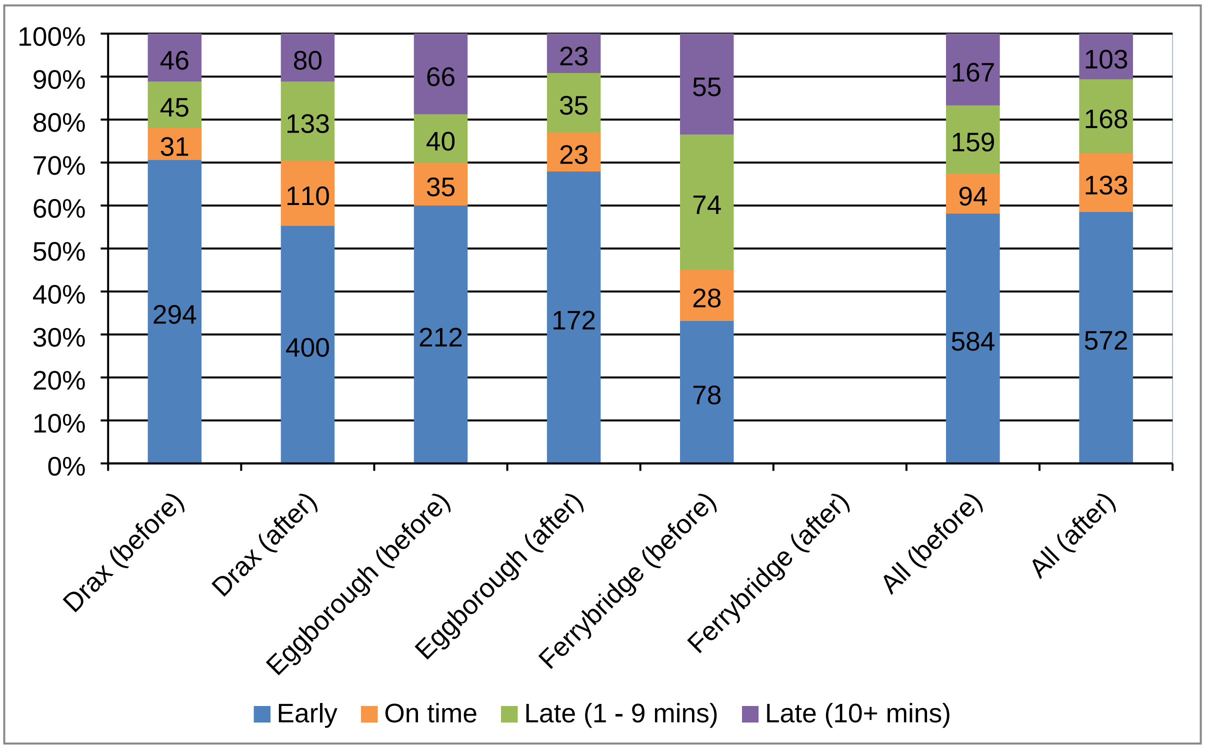
Source: author’s surveys based on data from realtimetrains.co.uk; n (before) = 990, n (after) = 963

Scheduled journey time reductions of the magnitude of 8 to 11 per cent were identified when comparing the ‘after’ study to the ‘before’. T-tests were conducted to compare the means, with the reduction in average scheduled journey time being highly significant (p value less than 0.0001) overall and for each of Drax and Eggborough. Excluding the ‘before’ Ferrybridge services from the analysis has a minimal impact, the overall reduction increasing from 8 to 9 per cent in this case. The weighted average journey time reduction was marginally less than the weighted average distance reduction and, in comparing Tables 4 and 5, the scheduled average speed decreased very slightly (and not significantly) from 18.1 mph ‘before’ to 17.9 mph ‘after’; this may have resulted from a reduction in the distance travelled on the section of the higher speed ECML.

5.3 Train punctuality

In addition to interpreting the train schedules themselves, it is important to assess how well the trains performed in reality (i.e. comparing the actual to the planned) since this is closely linked to network capability and resilience. Two complementary punctuality measures have been analysed: actual power station arrival time relative to schedule; and average delay incurred en route. For the first measure, Figure 3 compares the actual and scheduled arrival times at each power station and overall for both the 'before' and 'after' survey periods.

Figure 3: Actual vs scheduled arrival times at destination



Source: author's surveys based on data from realtimetrains.co.uk; n (before) = 1,004, n (after) = 976; data labels show number of trains in each time category

Despite the routing conflicts with passenger trains that the North Doncaster Chord was designed to alleviate, the observed freight train punctuality in the 'before' period compared favourably with the national Freight Performance Measure (FPM) pertaining at the time. The FPM, which has subsequently been dropped as the preferred measure of freight performance but continued to be published in 2014-15, classified arrivals less than 10 minutes late as 'on-time'; in 2013-14 Quarter 4 (Q4) (which covered slightly longer than, but included all of, the 10 week 'before' survey period), the national FPM was 75.9 per cent (ORR, 2014). For the 'before' survey period, 83.4 per cent of trains met the FPM threshold and even the relatively poorly performing Ferrybridge arrivals slightly exceeded the national

FPM. The national FPM for 2014-15 Q4, containing the 'after' survey period within the quarter, increased by 3.6 percentage points to 79.5 per cent (ORR, 2015b). The equivalent for 'on-time' arrivals for surveyed trains in the 'after' period was 89.4 per cent, representing an increase of 6.0 percentage points and therefore exceeding the improvement at the national level.

Table 6 shows the average delay per train incurred en route; any trains taking the scheduled duration or less were allocated a zero delay. When using a t-test to compare the incurred delays across the entire 'before' and 'after' samples, the 13 second reduction was not statistically significant, since in both samples the majority of services suffered no delays en route at all. When considering only the sub-samples of trains experiencing an en route delay, there was a larger reduction in the average which was very significant ($p = 0.0081$).

Table 6: Average delay per train incurred en route (hh:mm:ss)

	Before	After
Average delay incurred en route (across full sample)	00:07:38	00:07:25
Average delay incurred en route (sub-sample of trains exceeding scheduled journey time)	00:21:35	00:15:44

Source: author's surveys based on data from realtimetrains.co.uk

From the real-time data it is possible to develop an understanding of the location where delays were incurred. For trains that arrived late by 10 minutes or more at the destination power station, Table 7 shows where in the journey the initial delay of this amount was incurred. In situations where a train's delay fell below 10 minutes later in the journey it was excluded from the analysis. This is a fairly crude method of delay allocation but, in the absence of access to commercially sensitive delay attribution data, it provides a consistent approach to the identification of the location of delay. The point of initial delay that had a direct bearing on a delayed arrival of 10 minutes or more has been allocated to one of five categories: late departure from Immingham; delays en route prior to reaching the ECML;

delays en route in the vicinity of the ECML itself; delays in the section between the ECML and the mainline connections to the power stations; and delays on the final approach to the power stations themselves.

Table 7: Location of initial delay for services arriving late (by 10 minutes or more) at power station

	Before		After	
Location of initial delay	No.	*%*	No.	*%*
At Immingham	71	*43*	31	*30*
En route (Immingham – ECML)	5	*3*	5	*5*
En route (ECML area)	34	*20*	1	*1*
En route (ECML – power station approaches)	35	*21*	47	*46*
On power station approaches	22	*13*	19	*18*
Total	167	*100*	103	*100*

Source: author's surveys based on data from realtimetrains.co.uk

When comparing the two periods it must be borne in mind that, broadly speaking, the proportion of trains arriving 10 minutes or more late reduced from one in six to just one in ten (see Figure 3). In the 'before' period, more than half of the late arrivals (56 per cent) resulted from delays at one or other end of the journey, with late starts from Immingham dominating. Just one-fifth of the delayed trains incurred their delays on the ECML leg of the journey, mostly for trains passing through the Doncaster area rather than those using the longer stretch of the ECML to the North. Some of these trains appeared to be delayed during stopovers in the Doncaster yards, where driver and locomotive changeovers often take place, rather than on the ECML itself, so the genuine delays incurred on the ECML may well have been even less. The data source does not allow identification of the root cause of delays and it may well be that, for example, some delayed departures from Immingham resulted from late incoming empty trains delayed by network congestion or other factors. From the evidence available, though, it appears that network congestion and conflicts with passenger trains were not major contributors to direct delays of Immingham to Aire Valley coal and biomass trains. In the 'after' period, the Knottingley area (on the section of route between the ECML and the power station approaches) accounted for the highest proportion of delays; differentiation between the different ‘after’ routes is provided in the next section.

6. ‘After’ survey: analysis of North Doncaster Chord versus alternative routings

This section further develops the analysis of the ‘after’ survey data. Given that a sizeable minority (36 per cent) of trains did not use the new route via the North Doncaster Chord (see Table 3), direct comparisons can be made of the performance of different routings in the same time period. In Table 8, the results for the key measures of average scheduled journey time, percentage of trains arriving within 10 mins of schedule and average delay per train incurred en route (for trains experiencing an en route delay) are summarised for those trains routed via the North Doncaster Chord and those not. The latter group is then broken down into the two main routes which together accounted for 93 per cent of the 338 trains which did not use the North Doncaster Chord.

Table 8: Analysis of performance by route in ‘after’ survey

Routing	Average scheduled journey time (hh:mm)	% of trains arriving within 10 mins of schedule	Average delay per train incurred en route* (hh:mm:ss)	No. of trains
North Doncaster Chord	03:24	89.1	13:03	625
Not North Doncaster Chord	04:15	90.0	21:17	338
o/w Scunthorpe-Hambleton	*04:39*	*94.4*	*13:10*	*178*
o/w Brigg-Doncaster-Askern	*03:40*	*88.7*	*28:33*	*136*
Overall	03:42	89.4	15:44	963

Source: author’s surveys based on data from realtimetrains.co.uk; * - of sub-sample of trains exceeding scheduled journey time

Considering average scheduled journey time first, t-tests comparing the North Doncaster Chord average with the other averages shows that the journey time via the chord is significantly shorter than for the alternative routes (all p values less than 0.0001). The average scheduled journey time for all trains was 03:42, while it was 03:24 for those using the most direct routing via the North Doncaster Chord (Drax 03:23, Eggborough 03:24). The new routing was 15 per cent quicker than the weighted average (04:01) in the ‘before’ survey, and 25 per cent faster than the weighted average (04:15) in the ‘after’ survey for trains not using the North Doncaster Chord. While the scheduled average speed for trains using the direct route via the North Doncaster Chord in the ‘after’ survey was 17.9 mph, the same as the overall ‘after’ average, 92 of the trains using the North Doncaster Chord had scheduled times that were quicker than the fastest by an alternative routing. For both Drax and Eggborough, the shortest scheduled journey time using the North Doncaster Chord was 02:14, giving scheduled average speeds of 27.9 mph and 24.8 mph respectively, while 02:37 was the fastest scheduled timing by an alternative route.

With an FPM of 89.1 per cent (see Table 8), the North Doncaster Chord trains exhibited a slightly lower ‘on-time’ performance than those trains using other routes (90.0 per cent). However, the relatively small number of trains arriving 10 minutes or more late combined with the location of initial delay for the different routing options suggests that these figures should be treated with caution. 35 per cent (24 of 68 trains) of the late arrivals via the North Doncaster Chord resulted from late departures from Immingham, compared with 20 per cent (7 of 35 trains) of the late arrivals using other routings. Arguably more representative of delays associated with each route is the average delay incurred en route, also shown in Table 8. By this measure, the North Doncaster Chord route is significantly better than the flows going by all of the other routes combined (p less than 0.0001) but there is no statistical difference between the average delay on the North Doncaster Chord route (13:03) and the main ‘before’ route via Scunthorpe, the ECML and Hambleton (13:10).

7. Implications of study findings

In broad terms, the outcomes of the research are in line with expectations, with clear operational improvements resulting from the new infrastructure. However, the investigation has revealed some interesting findings that deserve more detailed discussion. These can be categorised as relating to:

- The complexity of train routing
- Meeting customer requirements: implications for cost and train performance
- The role of exogenous factors

Each of these is now considered in turn.

7.1 Complexity of train routing

Fundamentally, the complexity of train routing combinations in both the 'before' and 'after' survey periods is an interesting outcome which challenges the (simplistic) picture set out by Network Rail in its publicity material relating to the justification of the North Doncaster Chord. In part, the message portrayed is understandable, since it is not easy to represent the myriad routing combinations in a clear manner, but it does not accurately reflect reality. Specifically, it is perhaps surprising that only 64 per cent of trains in the 'after' survey made use of the new, direct routing afforded by the North Doncaster Chord. The reasons behind a significant minority of trains continuing to use pre-existing routes are varied. It is likely that there are pathing constraints elsewhere on the new route since trains in both directions between the North Doncaster Chord and Drax and Eggborough power stations have to traverse a single track connection in the Knottingley area, where the route changes from a north-westerly trajectory to an easterly one in the lower diagram in Figure 1. The extent of this constraint is not documented formally, but discussions with staff from two of the freight operating companies (FOCs) operating over the route have confirmed that this short single track section does limit operational flexibility. Of all the route sections (see Table 7), this section of the North Doncaster Chord routing accounted for the greatest proportion of trains experiencing delays. In addition, from both the original survey data and the Engineering Access Statement (Network Rail, 2015b), it can be seen that there are periods when the direct route is unavailable to allow for infrastructure maintenance. For example, the route through Scunthorpe was blocked for several weekends during the ‘after’ survey period, precluding access to the North Doncaster Chord. Finally, the FOCs themselves have reasons to not send all possible trains over the new route. They continue to send trains via a range of alternative routes to build in operating resilience by retaining train crew route knowledge so that they are better able to respond to planned and unplanned route closures. In some cases, the alternative routes pass train crew depots, locomotive maintenance facilities and freight yards (e.g. in the Doncaster area) so it can be operationally convenient to use these routes where drivers or locomotives need to be changed or where en route train staging is required to meet customer demands or scheduling constraints.

It is clear that the new routing has removed considerable numbers of coal (and now biomass) trains from the ECML both on the route north of Doncaster and, despite not being mentioned in the publicity material, in the Doncaster area itself. Doncaster station is “one of the worst capacity pinch-points on the ECML and requires major enhancements to the infrastructure” (Modern Railways, 2015), so the more than halving (down from 38 per cent to 17 per cent) of the proportion of surveyed trains passing through this location is a positive outcome with likely benefits for freight (and passenger) customers.

7.2 Meeting customer requirements: implications for cost and train performance

As discussed in Section 2, the literature identifies cost and service performance, notably on-time arrival, as key customer requirements. Without access to commercially sensitive contractual information, it is not possible to determine the cost implications, if any, of the North Doncaster Chord for the customer. For the rail freight operators, there are opportunities for operating cost reductions as a result of the more direct routing and shorter journey times. Specifically, in a competitive rail freight market such as that for the electricity supply industry, asset utilisation is likely to be a key determinant of operating costs, since locomotives and rolling stock in particular are expensive assets. Although the average journey time via the North Doncaster Chord has been found to be significantly shorter than via the alternative routes, the potential exisis for still greater journey time reductions. It may be that the timetable had not been optimised in the ‘after’ survey period and/or potential journey time reductions have been traded-off against improved service performance. Despite more than six months having elapsed between the opening of the chord and the ‘after’ survey taking place, schedules had possibly not been revised based on actual performance given the lengthy development period for each timetable iteration. It will be interesting to see whether the FOCs seek to further reduce the average scheduled journey time in due course to improve staff and asset utilisation and reduce unit operating costs.

While perhaps not as time-critical as other freight flows (e.g. fast-moving consumer goods for supermarkets), on-time rail freight service performance is an important issue in the electricity supply industry. According to DfT (2008), the coal is generally unloaded and taken straight into the furnace, although stockpiles are often available to cope with any supply disruption. With the emerging biomass flows, there is less opportunity for stockpiling as it needs to be kept dry and protected (DfT, 2016). Perhaps more importantly, delayed arrivals at the power stations can reduce overall terminal utilisation and throughput due to congestion. Given the intensity of the use of the terminals at either end of the flow, it may be that potential reductions in journey times have been sacrificed to ensure higher on-time performance. From a quick assessment, it is evident that many trains have considerable periods of stationary time built into their schedules, generally at junctions or intermediate yards and sidings, and this reduces the scheduled average speed. For example, many trains have a driver change en route and rail network constraints, such as the aforementioned single line connection at Knottingley, may also lead to sub-optimal train paths and longer journey times.

The network constraints identified in Section 7.1 emphasise the importance of considering wider network characteristics (e.g. along an entire corridor) when making an investment decision, rather than focusing on a single pinch point. Further investigation is needed, but it seems that the benefits of the segregation of passenger and freight flows offered by the North Doncaster Chord cannot be fully realised for the coal and biomass flows because of constraints elsewhere on the corridor, notably the single track section near Knottingley. This analysis has focused on the key freight flow impacted by the North Doncaster Chord. However, as noted earlier, perhaps the key reason for the investment was improved capacity and performance for passenger trains on the ECML. The lack of consideration given to infrastructure constraints elsewhere along the Immingham to Aire Valley freight corridor adds weight to the view that passenger benefits may have been the main justification. Additional long-distance passenger services are planned once the full ECML improvement programme has been completed. Comparing passenger performance statistics for Q4 in 2013-14 and 2014-15 reveals that the main operators using the ECML north of Doncaster (i.e. East Coast, Cross Country, First Hull Trains and Grand Central) were four of the top five most improved operators (of 22 in total) for both the Public Performance Measure (PPM) and Cancellations and Significant Lateness (CaSL) (ORR, 2015b). However, it is not possible to ascertain from published data any specific effect of the North Doncaster Chord on this improved performance and it was beyond the scope of this study to gather real-time data for passenger trains on the ECML.

7.3 The role of exogenous factors

Longer-term analysis of the operational impacts, particularly with regard to train routing, journey times and service performance, would be worthwhile. However, the longer the time period the more it is likely that exogenous variables will affect the case study flow. Even in the one year period between the 'before' and 'after' study, there were some noticeable changes:

- The suspension of coal trains between Immingham and Ferrybridge power station
- The introduction of biomass trains between Immingham and Drax power station

The reasons for these developments are not rail-related but it is worthwhile summarising them to demonstrate the challenges in appraising both the viability of possible infrastructure initiatives and, for those that come to fruition, whether or not the intended outcomes have been achieved. These specific changes are part of a bigger restructuring of the electricity supply industry in the United Kingdom, which is having a major effect on coal flows. The British government has announced its intention to phase out most coal-fired power generation by 2025 (DECC, 2015) as part of its ongoing policy to decarbonise electricity generation. Prior to this announcement, other policies (notably the large rise in the Carbon Floor Price on 1 April 2015) had influenced the coal market (ORR, 2016) and led to the closure or retrenchment of a number of power stations: both Eggborough and Ferrybridge had experienced a decline in output. Ferrybridge has since closed (SSE, 2016) and Eggborough is expected to have a much reduced role in electricity production (Eggborough Power Ltd, 2015). In contrast, Drax has supplanted an increasing proportion of its coal generation by biomass, with three of its six generating units having been converted (Drax Group, 2016). Using the most up-to-date statistics at the time of writing, rail-borne coal volumes were 54 per cent lower in the last four quarters (i.e. 2014/15 Q4 to 2015/16 Q3) than in the same four quarters two years earlier. On the Immingham to Aire Valley corridor, the focus of this study, by early-2016 just Drax was being served and the number of biomass trains considerably exceeded coal services. A one-week snapshot of real-time data revealed total train movements were down, but only by around 25 per cent compared with the ‘after’ survey period one year before. Such a fundamental change in the nature of the rail freight market reduces the value of a longer-term detailed impact study, although key operational impacts may still be comparable. While the speed of change in the British electricity supply industry could not readily have been predicted, if seeking to replicate this study elsewhere it would be advisable to consider the extent to which exogenous variables may influence the validity of such a ‘before’ and ‘after’ study. In this research, train service provision between Immingham and the Aire Valley power stations was sufficiently similar in the two survey periods to allow meaningful analysis of the effects of the new rail infrastructure. However, there are no long-term guarantees that Immingham will continue to serve Drax, although there has been considerable investment in biomass handling facilities at Immingham. A final point relates to the potential to use the North Doncaster Chord for traffic other than the key flow upon which the freight element of the project justification was built. Currently, there is little obvious additional traffic, and that which exists and could transfer (e.g. steel and occasional petroleum flows) may not have a secure future due to changes in those industries. The Port of Grimsby and Immingham has the highest port throughput of any in the United Kingdom and there may be scope to introduce new rail-borne flows which would use the North Doncaster Chord (e.g. intermodal traffic on the Trans-Pennine corridor).

8. Conclusions

This paper set out the objective to evaluate the key rail freight operational impacts resulting from the implementation of the North Doncaster Chord. The use of data at the level of the individual train, with a consistent methodology for both the 'before' and 'after' survey periods, has allowed an evidence-based evaluation of a number of important criteria relating to operational performance. This evaluation has demonstrated improvements in train routing, scheduled journey time and train punctuality. Specifically, the North Doncaster Chord routing performs better than the alternatives in that it has shorter average scheduled journey times and at least as low an average delay per train incurred en route as the former main route. It is clear that what appears to be a fairly straightforward bulk rail freight flow actually displays considerable complexity, notwithstanding the wider changes taking place in the electricity supply industry. Competitive rail freight markets, increasingly common in Europe and elsewhere, pose challenges for in-depth research such as this because of commercial sensitivities. This paper has demonstrated the value of publicly available real-time rail freight data for assessing the operational performance impacts of a new infrastructure initiative, with obvious potential for such data to be used in other studies which require an evidence base.

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