MRes in Railway Systems Integration

College of Engineering, School of Civil Engineering

University of Birmingham

Coal by Rail:

Historic Trends and Transhipment Modelling

Author - Carl Brewer

Supervisor – Dr Andrew Tobias

Executive Summary

This paper presents a detailed account of the historic trends of coal transportation by rail in Great Britain over the last 50 years. The *Re-shaping Britain's Railways* report by the British Railways Board in 1963 highlighted increasing inefficiencies of freight transportation by rail, and consequently established the Merry-Go-Round (MGR) system at both coal terminals and coal pits, to improve speed and performance so rail would be able to effectively compete with road haulage for the transportation for freight (Jones, 2012).

Most recently, coal is increasingly imported to the UK to coastal ports from Europe and the rest of the World. As a consequence the movement of trains on the network combined with new coal locations have changed the distances and destinations of coal trains compared with before the report in 1963. Research has shown that it is not the amount that has increased, only the distance (Vanek and Smith, 2004). Historic data and research has been collated using national sources and statistics, and a Transhipment Model has been used to determine the optimisation transporting coal.

The data and the model have supported the statement that coal now accounts for more freight train journeys than ever before although the demise of the coal mines in the North East and the increase of power stations and ports in Yorkshire has altered the pattern of movements, in addition to the usage of yards and sidings to manage capacity along the busy mainlines. The UK still requires coal for its power stations but has sourced it increasingly from abroad.

Word Count: 13,835

Table of Contents

1 Introduction 1
2 Literature Review 2
2.1 Optimising Capacity 2
2.2 Transhipment Modelling 4
3 Moving Coal by Rail 7
3.1 Building the Railways 7
3.2 The Reshaping of British Railways 8
3.3 The Merry-Go-Round 13
3.4 The Decline of Coal Traffic and Production 17
4 Coal by Rail Today 25
4.1 Timetables and Routes 25
4.1.1 Sourcing data 25
4.1.2 General UK statistics 27
4.1.3 Scotland 33
4.1.4 Wales 33
4.1.5 North East 34
4.1.6 North West 35
4.1.7 Yorkshire 36
4.1.8 Midlands 36
4.1.9 South East 37
4.1.10 South West 38
4.2 The Transhipment Model 39
4.2.1 Graphical networks and models 39
4.2.2 Results 42
5 Conclusions 46
5.1 Findings 46
5.2 Recommendations 47
5.3 Review of Approach 48
5.4 Areas for Further Work / Research 48
6 Bibliography 50

List of Figures

Figure 1 - Example of Transhipment Model 6
Figure 2 - The British Railway System 1952 & 1985 9
Figure 3 – Freight moved by rail and share of freight 1953 – 2010........ 10
Figure 4 - Map of Coal Traffic flows 1964 12
Figure 5 - Map of Coal Traffic flows 1984 15
Figure 6 – British Coal Fields and Power stations 16
Figure 7 - Map of Domestic Coal Traffic flows 2011 23
Figure 8 - Map of Imported Coal Traffic flows 2011........ 24
Figure 9 - Data from FreightMaster 25
Figure 10 – Regional breakdown of Great Britain 26
Figure 11 – Top 8 Destinations by number of coal trains - 2011 31
Figure 12 – Traffic flow of coal trains 39
Figure 13 – Graphical Network of Loaded Trains 41
Figure 14 - Example of Distance Combinations 42

List of Tables

Table 1 - Density of Freight Traffic 10
Table 2 – Total tonnage coal traffic by transport 17
Table 3 - UK Coal Production and Number of Operational Mines 1963-2011 18
Table 4 – UK coal production and consumption 19
Table 5 – Coal moved by rail 1996 - 2011 20
Table 6 – Coal lifted by rail 1996 - 2011 20
Table 7 – Total rail freight moved and lifted 1953 - 2010 21
Table 8 – Number of Trains assumed Per Week 27
Table 9 – Total number of Coal Trains – 2011 27
Table 10 – Loaded Coal Trains – 2011 28
Table 11 – Unloaded Coal Trains – 2011 29
Table 12 – Total number of Loaded and Unloaded Coal trains by Rail Operator – 2011 .. 29
Table 13 – Origin and Destination Traffic by Region (%) - 2011 30
Table 14 – Pivot Table for Coal Traffic – 2011 32
Table 15 - Average share of total coal traffic by region - 2011 33
Table 16 – Aberthaw power station coal programme 1971-2011 34
Table 17 - No. of Coal trains to Fiddlers Ferry 1995-2011 35
Table 18 – Results from Transhipment Model 43
Table 19 – Train runs to Cottam Power Station 44

Glossary of Terms / List of Abbreviations

Term	**Explanation / Meaning / Definition**
BR	British Railways (Later British Rail)
BRB	British Railways Board
BTC	British Transport Commission
CEGB	Central Electricity Generating Board
DfT	Department for Transport
DoT	Department of Transport
EWS	English, Welsh and Scottish
GB	Great Britain (England, Scotland and Wales)
HMSO	Her Majesty’s Stationary Office
ISO	International Standards Organisation
MGR	Merry-Go-Round
NCB	National Coal Board
NR	Network Rail
SSC	Slow Speed Control
UK	United Kingdom (Great Britain and Northern Ireland)

1 Introduction

This paper presents a detailed account of the historic trends of coal transportation by rail in Great Britain over the last 50 years. The *Re-shaping Britain's Railways* report by the British Railways Board (BRB) in 1963 highlighted increasing inefficiencies of freight transportation by rail, and consequently established the Merry-Go-Round (MGR) system at both coal terminals and coal pits, to improve speed and performance so rail would be able to effectively compete with road haulage for the transportation of freight (Jones, 2012).

Most recently, coal has been increasingly imported to the UK to coastal ports from Europe and the rest of the World. As a consequence the movement of trains on the network combined with new coal locations have changed the distances and destinations of coal trains compared with before the report in 1963. Research has shown that it is not the amount that has increased, only the distance (Vanek and Smith, 2004). Historic data and research has been collated using national sources and statistics, and a Transhipment Model has been used to determine the optimisation of the coal locations. Data can be collected from national statistics websites and public freight (coal) train timetables. The published freight timetables; in collaboration with Freightliner, detail the headcode, the departure time, origin, destination, type of traction and rolling stock. Furthermore, rail maps within these sources, illustrate routes colour-coded by FOC (freight operating company). However, these lines merely illustrate the routes to the reader, and not the number of train services occupying these lines. Put simply, the lines are not proportionate to the number of trains per route and therefore it is not an accurate reflection of the rail network and the current capacity along the various routes and mainlines. It is uncertain as to the amount of traffic each line assumes and whether the load as well as the distance has increased in the UK.

When considering longer distances made by coal trains, it is unclear whether such journeys indeed are optimised, and therefore traversing to the most efficient destination, or indeed starting at the most ideal origin. It is also unclear where the best located coal mines, ports and power stations are, depending where the train is from or going to and the load it carries.

This research project aims to address these issues by detailing the trends of coal by rail over the last 50 years, and significantly analysing the current data for comparisons. Using the data obtained, a transhipment model can be created to identify strategically the best way to move coal by rail and how this is really represented on the map based on frequency of service. Once the model has been successful tested and results obtained, observations can be made regarding optimum usage of coal trains, locations of origins and destinations and furthermore support to the notion that distance not weight has increased. As the rail system has reduced in length over the last 50 years but passenger traffic increased, observations and conclusions can be made to establish the impact, if any, on rail transportation in the coal industry.

2 Literature Review

2.1 Optimising Capacity

There is currently a shortage of coal freight literature available, perhaps due to lack of innovation in this area or for reasons unknown. This gap in the data does however suggest an opportunity for further exploration into the coal industry. Academic writing of general freight is more readily available. Many articles and studies have examined the potential of optimising and enhancing capacity on the railway. These have generally addressed passenger services in continental Europe. In terms of freight, studies more recently concern the wastage of empty wagons on the network. The number of coal trains on the network and various coal locations require strategic management to ensure that all locations have resources available, of the right load at the right time. Failure to provide this would cost FOC expensive fines. To optimise current freight services and to cope with potential increases in capacity and load, methods utilising empty wagons on the network could provide solutions. Research by Beurrier, et al. (1990) investigated empty railcars in France and used algorithms and simulations to predict movement and increase capacity. Whilst their model worked successfully, it was deemed impractical due to potential of inaccurate data and also human error, possible because it was built to a large scale. For a more strategic approach, Sherali & Suharko (1998) and Narisetty, et al. (2008) suggested pooling wagons and producing more efficient schedules, but the irregularity of freight operations on the UK network would mean such schedules would be difficult to implement and adopt consistently. Further research by Crainic, et al. (1990), Cheng & Lin (2004) and Sherali & Lunday (2011) was limited in potential due to the size of the research and modelling methods selected. Wagon pooling would also be difficult due to the current setup of the UK freight industry with private ownership of wagons, rolling stock and contracts for haulage, and the scale of the strategic operations to ensure that each coal location had the necessarily wagons at the right time would be challenging.

Perhaps strategic wagon pooling may not be a useful solution due to the current circumstances, but would provide useful enhancements to the rail network. To enhance the capacity, alternative methods could be adopted, but clarity on the current UK network needs to be established.

Woodburn's (2007) study of rail freight demonstrated that the number of tonne kilometres showed a general increase upwards however the number of tonnes lifted actually dipped. Woodburn suggests that one reason for this is where the freight is coming from, as freight is now coming from different locations, therefore not bearing any reflection on the actual tonnes lifted as a result. The rail industry needs to consider current aspects of freight operations like the loading/unloading times, allowing more frequent services, and upgrading the infrastructure to accommodate more freight on the railways. Only then may it be a more economical solution for businesses as currently road offers a more frequent and convenient service. The MGR system has sufficiently improved turn-around times, but there are still opportunities to improve. The notion that trains are travelling more but not necessarily carrying more is supported further by Vanek & Smith (2004). Their study three years earlier to Woodburn found that the, "…decline in domestic coal mining has led to an increase in shipments from coastal ports, which contributes to growth in rail freight traffic measured in tonne-km (DoT, 1996), although tonnes lifted have remained constant so that there may be little net economic benefit to the railways". Further research of coal train routes in the UK typifies this problem. Currently there are long distance coal trains operating from Scotland down to the South-East for example, and also from the North-West of England to the South-East (Rawlinson, 2011). These examples will be analysed in more depth in the following chapters.

The public published freight timetables provide maps at the back with all the current routes, but they are not proportional to the loads they carry, i.e. they cannot be considered as traffic flows, only to show all the routes used. This means that from a glance, it is not possible to know how much each route is used, which routes are most dense and routes that are rarely used. By obtaining this data, analysis can be made surrounding the optimum use of the network, which routes are most productive and where alternatives or recommendations can be made to make the most out of the system. The railway network, locations of origins and destinations have changed over the past 50 years. Routes and train loads have changed, thus asking the question if coal movements by rail are fully utilising both the rail network but also adequately using the hubs of origins and destinations. I.e. are we to assume that all traffic in the North, moves in the North, does coal imported from Scotland travel down to Power Stations in the South East? To explore this further we can analyse the historic trends that have shaped the system and created the traffic flows for today, before we analyse the state of the coal industry by rail in the modern era.

The present day data obtained from national statistics and the Freightmaster Timetable can be collated and analysed in tables and charts further by implementing a Transhipment Model. The model will provide some logic and optimum levels of the coal traffic, based on where the coal trains are going and where they start. There are various different quantitative modelling methods available and it is importance to select the most appropriate one to achieve the desired results (Brooks and Tobias, 1996).

2.2 Transhipment Modelling

Transhipment or Transportation Models determine best usage of routes by optimising availability, distance and capacity. Such models have been used to develop rail yards through to full National Networks, timetables and even location of depots at the planning stage. A simple Transhipment Model can help identify proportions and best usage of capacity and proximity. An example of how the data is captured can be seen in- Example of Transhipment Model Figure 1, the 1's and -1's indicate whether a location requires supply or demand, and the traffic value can determine each location's importance and usage within the model. This would be used in conjunction with obtaining data such as number of locations and distances between them.

In the model above, the M's, P's and D's represent coal mines, power stations and docks, thus the model has been used successfully to solve a problem similar to factual problem of moving coal by rail. All possibilities are entered into the table and the solver tool on Excel works out the optimum options based on distances or limits that are imposed. The results can be compared to actual traffic to see how much supply and demand each location should have.

If for example, you need to transport goods to A, B and C and each has various supply and demand characteristics, then a transhipment model using linear programming can enable most effective decisions to be made. Linear Programming (LP) is used for solving the best method or solution. The LP model can be effectively used in transhipment modelling to find the best outcome (Barlow, 1999). The objective of the LP is also to minimise cost or distance as the formula shows:

$$\text{Minimise } C_t = \sum_{i} \sum_{j \neq i} c_{ij} x_{ij} \quad \text{for all } x_{ij} \geq 0$$

$$\text{subject to the constraint } \sum_{j} x_{ij} - \sum_{k} x_{ki} = R_i$$

**Source: Barlow (1999)*

Each unit that moves between nodes in the network incurs a cost. If Ri > 0 then i is a supply or start node. If the node is equal to 0 this is determined as a transportation node. generally transportation/transhipment models need to balance between supply and demand, however in some circumstances it is possible to model with unbalanced data using dummy sources and defining these sources as potential or spare (Barlow, 1999).

The current UK rail network has many ports strategically placed around the UK, the most prominent for Coal import and export being Immingham and Tees (Department for Transport, 2006). It is not clear by analysing the current data whether the routes and train paths used presently are indeed making the best use of the available network. Thus a Transhipment Model will enable identification of which ports and coal mines are used to the optimum level, assuming that all coal trains are of same size and load. Additionally yards and sidings feature predominantly on the UK network and understanding in more detail with data can show how the yards are used, be it for loaded or unloaded wagons, where they have come from and where they are going to. A transhipment model could also determine which yards are strategically placed to support loaded and unloaded wagons and help keeping coal trains moving along the busy mainlines. Mu and Dessouky (2011) modelled improvments on schedules and timetables on the US Railroad using the transhipment model. Furthermore away from railway research, Shang and Kokossis (2004) successfully used the transhipment model for optimising multiperiod operations, while Wiles and van Brunt (2001) developed a model to identify the optimum location for transhipment depots.

Similarly using a fuzzy goal programming (FGP) model can provide flexibility when making decisions and finding solutions for different values of the same goal at the same time, such as in the petroleum refinery industry study (Sharma and Jana, 2009).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	From	To	Dist		D1	D2	D3	M1	M2	T1	T2	T3	T4	P1	P2	P3	P4	P5	P6		Traffic
2	T1	P1	20		0	0	0	0	0	-1	0	0	0	1	0	0	0	0	0		10
3	M1	T1	30		0	0	0	-1	0	1	0	0	0	0	0	0	0	0	0		25
4	T1	P2	20		0	0	0	0	0	-1	0	0	0	0	1	0	0	0	0		15
5	P2	T1	30		0	0	0	0	0	1	0	0	0	0	-1	0	0	0	0		0
6	P2	T2	30		0	0	0	0	0	0	1	0	0	0	-1	0	0	0	0		0
7	T2	P2	30		0	0	0	0	0	0	-1	0	0	0	1	0	0	0	0		0
8	D1	T2	30		-1	0	0	0	0	0	1	0	0	0	0	0	0	0	0		5
9	T2	P3	80		0	0	0	0	0	0	-1	0	0	0	0	1	0	0	0		5
10	T2	T3	110		0	0	0	0	0	0	-1	1	0	0	0	0	0	0	0		0
11	T3	T2	110		0	0	0	0	0	0	1	-1	0	0	0	0	0	0	0		0
12	M2	T3	20		0	0	0	0	-1	0	0	1	0	0	0	0	0	0	0		45
13	T3	T4	20		0	0	0	0	0	0	0	-1	1	0	0	0	0	0	0		45
14	T4	T3	20		0	0	0	0	0	0	0	1	-1	0	0	0	0	0	0		0
15	T4	P4	30		0	0	0	0	0	0	0	0	-1	0	0	0	1	0	0		35
16	T4	P5	20		0	0	0	0	0	0	0	0	-1	0	0	0	0	1	0		10
17	P5	T4	20		0	0	0	0	0	0	0	0	1	0	0	0	0	-1	0		0
18	P5	P6	60		0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1		0
19	P6	P5	60		0	0	0	0	0	0	0	0	0	0	0	0	0	1	-1		0
20	D2	P6	30		0	-1	0	0	0	0	0	0	0	0	0	0	0	0	1		25
21	D3	P6	40		0	0	-1	0	0	0	0	0	0	0	0	0	0	0	1		0
22																					
23			5600		-5	-25	0	-25	-45	0	0	0	0	10	15	5	35	10	25		
24					-999	-999	-999	-999	-999	0	0	0	0	10	15	5	35	10	25		

Solver	Set Target Cell	C23	to	Minimum
	by changing cells	U2:U21		
	subject to	E23:S23>=E24:S24		
		U2:U21>=0		

Cell	Formula	Copied to:
E2	IF($A2=E$1,-1,IF($B2=E$1,1,0))	E2:S21
E23	SUMPRODUCT(E2:E21,$U2:$U21)	E23:S23
C23	SUMPRODUCT(C2:C21,U2:U21)	

Figure 1 - Example of Transhipment Model

**Source: Tobias (2011)*

3 Moving Coal by Rail

3.1 Building the Railways

The earliest records of railways can be traced back to 1630s (Freeman and Aldcroft, 1985) where simple wagons pulled by horse were guided by crude grooves in the ground. They enabled coal to be efficiently manoeuvred around the collieries in the UK, predominantly in the North East of England and South Wales. However, it was the creation of the locomotive that enabled large quantities of coal and other goods to be shifted to ever increasing industrial and provincial towns throughout the UK, coinciding with the industrial revolution of the 19th Century.

Networks of single track Freight lines connected industry to industry and the mainline to the ports. The thousands of miles of track provided a direct route and due to the separation from the national network, capacity could be maximised due to isolation from passenger operations. Power stations and factories were built in close proximity to their primary sources such as collieries and ports, reducing cost and time of transportation. As a result the UK was cluttered with minor freight lines chequered through the heartland of the country. Whilst local goods services were bustling along the ever increasing network, the railways also crucially connected primary industries to ports for international distribution. Ports like Grimsby and Cardiff were developed as they were strategically located to nearby collieries to export coal to coastline and short sea destinations. General goods were shipped by break bulk methods involving simple crates and nets to contain the load within (Whittaker, 1975). The railways were originally constructed to transport freight, however throughout the 1930s the railway era witnessed a shift of focus to passenger demand and services (Loft, 2006), with ever increasing locomotive power allowing for fast express trains to run from London to Glasgow.

Throughout the 19th and 20th Century, coal provided 90% of inland energy consumption in the UK (Callinicos and Simons, 1985). The railways therefore were crucial in the distribution of large volumes around the UK. As more coal was produced, the expectations and quality demanded increased. Customers wanted the best coal regardless of where it came from, and at what cost. Researchers found that coal from South Wales was regarded as better than that from the north of England. It was therefore not uncommon for coal from South Wales to be transported by train to the ports of Southampton and Birkenhead, and it was also the preferred coal for London (Morris and Williams, 1958). The demand for quality of coal and uncompromising attitude to securing this fuel regardless of geographic location, meant railways were imperative to the success of coal production and distribution. As production increased, more freight lines were created. However, this was not to last.

Unfortunately the devastating damage caused by the Second World War left the network in poor condition and by the 1950s the railway was in a state of decline. Much investment was needed at a time when money was sparse. Consequently passenger and freight numbers dwindled as costs mounted. To alleviate these problems BR released the *modernization plan* in 1955. The plan identified that freight needed to be moved by bulk, utilising the advantage that railways had over other transportation (British Transport Commission, 1955), however, the report was unsuccessful and failed to improve both services and costs on the railways (Loft, 2006), in fact Gourvish (1986) went as far to suggest the report was, "a hastily conceived and ... flawed response to the need to make up lost ground." The release of *The Reshaping of British Railways* eight years later would have radical implications regarding the movement of freight by rail in the UK.

3.2 The Reshaping of British Railways

The Reshaping of British Railways, known infamously as the Beeching Report after the then chairman Dr Richard Beeching (Loft, 2006) was released on 27th March 1963 (Jones, 2012). BRB proposed to streamline the network to reduce costs and so consequently, small industrial lines and connections were broken up and many cities and towns isolated as services were reduced. In total the railway shrunk by a third (British Railways Board, 1963) as much of Scotland, Wales and the coastal areas of the country lost valuable routes and networks. The comparative maps of 1952 and 1985 from Figure 2 below illustrate how the Beeching report reduced the railway system and geographically the impact on Britain's towns and cities. Of course, this did not happen overnight, and it was assumed that careful research was carried to select the appropriate routes and stations for closure. Upon careful viewing, one can see how Wales, the Midlands, the North East and Scotland lost valuable routes that could have significantly affected coal transportation both regionally and nationally.

Figure 2 - The British Railway System 1952 & 1985

**Source: Haywood (1999)*

The removal of these lines was predominantly due to lack of passenger demand and non-profitable railway stations, however these reductions affected freight operations and route planning. Importantly the report also signified the inefficiency of the freight traffic. Unfortunately to address rising costs and non-profitable services, BRB closed 4,000 routes miles for freight traffic between 1965 and 1973 (Gourvish, 1986). The report reaffirmed how inefficiently Britain was moving freight on its railways.

As Table 1 below shows, 42% of the route miles carry only 3% of freight traffic and therefore it was not a surprise the railway was losing money and failing to cover costs and maintenance. Moreover, 60% of stations served by goods handled less than 100 tons in the surveyed week, which equated to 9% of total tonnage for the UK (Gourvish, 1986).

Table 1 - Density of Freight Traffic

DENSITY OF FREIGHT TRAFFIC

Range - ton miles	Route Miles		Percentage of ton miles	
	Actual	Percentage of total		
	(Figures in brackets are cumulative)			
Less than 5,000 ton miles	7,221	42	3	
5,000-19,999 tons	4,061	24 (66)	13	(16)
20,000-39,999 tons	2,648	16 (82)	21	(37)
40,000-69,999 tons	1,779	10 (92)	25	(62)
70,000-99,999 tons	949	6 (98)	22	(84)
1000,000 ton miles and over	404	2 (100)	16	(100)
TOTAL	17,062	100	100	

**Source: Reshaping Britain's Railways (1963)*

The decrease in coal traffic on the railways was also attributed to the rising popularity of road haulage for freight. The introduction of road transportation during the 1950s (Harris and Schmid, 2003) meant goods could be moved door-to-door at a cheaper rate than the railway. Figure 3 illustrates the share of freight moved by rail has decreased from 42% to 9% in 2010.

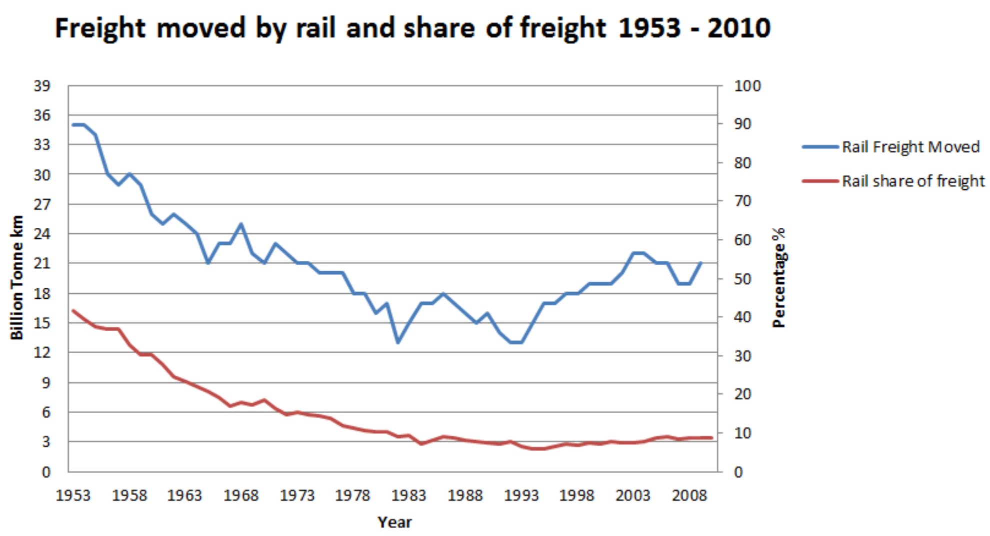


Figure 3 – Freight moved by rail and share of freight 1953 – 2010

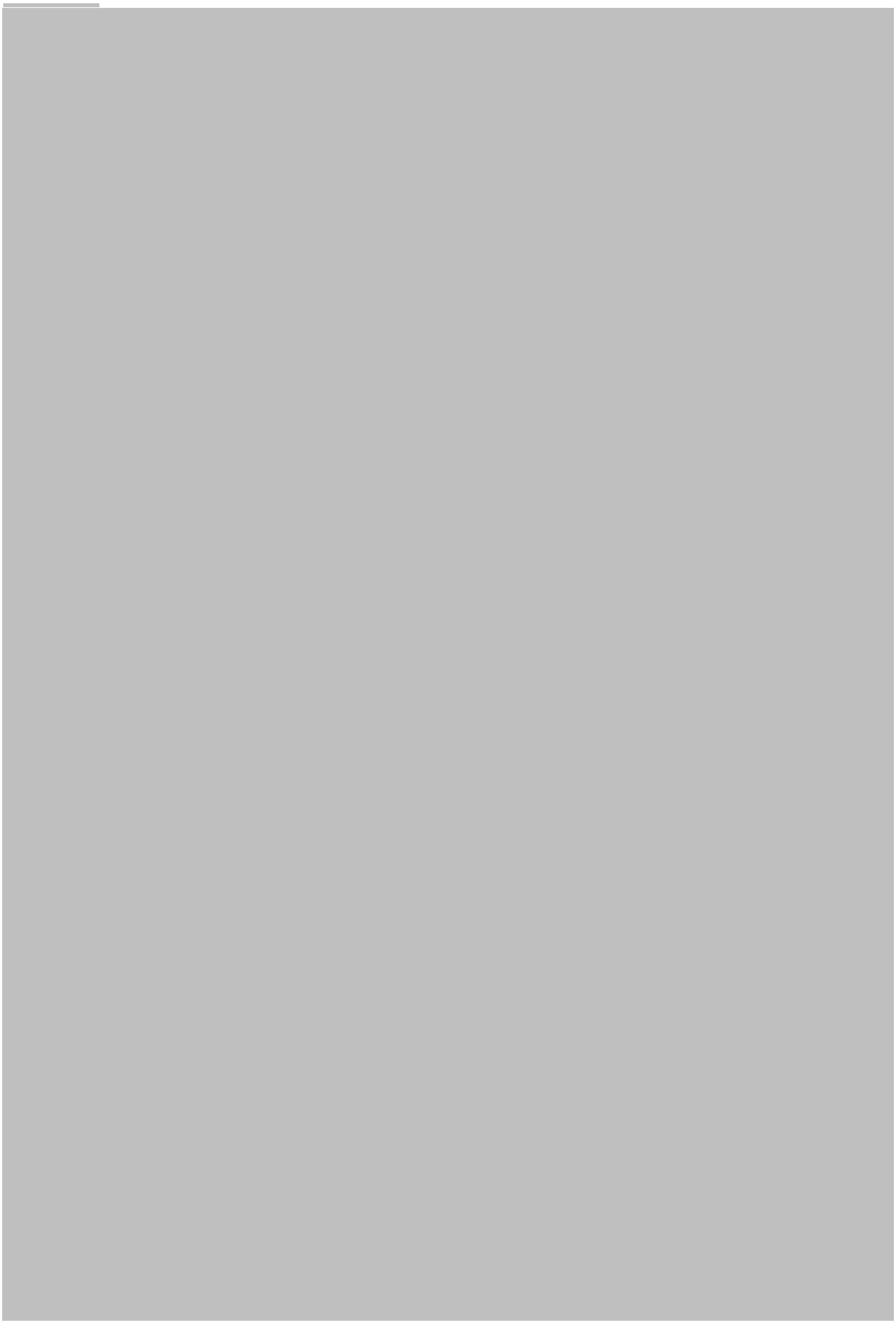
*Source: DfT (2012)

It is clear that the strong competition from road haulage assisted in the production of the Beeching report and the consequential closure of many lines. However Woodburn (2011) argued that there is potentiual for rail to grow today, by up to 38% and to eventually compete with road transportation, however to increase rail share, the railway needs to meet more industry requirements (Woodburn, 2003). One advantage the railway still possesses over road haulage is the potential to move more bulk goods and over a longer journey. The railways main advantages were its competitive, reliable and can move goods at high speeds (Lowe, 2005).

Two years later, in 1965, the BRB released the *Development of Major Railway Trunk Routes*, detailing proposals of liner trains and forecasting demand twenty years on (British Railways Board, 1965). Statistics were compiled and maps created to show the findings.

BR proposed two key changes that would revolutionise how freight would be moved by rail, namely *Freightliner* and the *Merry-Go-Round* (MGR). The introduction of Freightliner and the opening of Felixstowe as the UK's first Container terminal in 1967 enabled large goods to be moved over a longer distance quicker from ports and purposely built intermodal container terminals (Barrie, 1980). Bulk goods including coal would now be moved by container and International Standards of size allow for interoperability and global trade. Moving freight by rail significantly changed. Merry-go-round services were introduced to improve coal transportation (Freeman and Aldcroft, 1985) at current and new power stations, reducing loading and unloading times by adopting continuous operations and movement.

The BRB map below from the 1965 "The Development of the major railway trunk routes" report conveys how the system transported coal around the UK. Predominant ports and coal pits are strategically placed throughout the country. Connecting lines mean that journey times between origin and destination could be assumed to be minimal. The densest traffic occurred between and around the Midlands, with many coal pits around Nottinghamshire, Derbyshire and the East Midlands, in addition to the many coal mines in South Wales (Shannon, 2006). Note also the size of the Tees port hub, one of the main ports at this time for coal import, largely due to its close proximity to mainland Europe and also the accessibility onto the East Coast Main Line for quicker, direct distribution around Great Britain.



3.3 The Merry-Go-Round

After the Beeching report of 1963 and the proposals for improving coal services, BRB, who in collaboration with the NCB and CEGB revolutionised coal freight by rail by introducing the merry-go-round (MGR). The introduction of the Merry-Go-Round system for coal operations provided a more effective and efficient model, despite the reduction in coal production in the UK (Ashwoth, 1986). The first service to use the new MGR system was the coal train from Manston colliery to West Burton in November 1965 (Gourvish, 1986). Loaded trains from the ports and collieries continuously move through the terminal unloading coal into a tip underneath, and then out again returning unloaded to the port or colliery for the next load of coal. Diesel locomotives, still attached to their train, travel at 0.5mph, with 6 wagons emptied in 60 seconds (The Railway Magazine, 1965). The MGR thus saved time and created a more streamlined service. Six power stations are fully utilising the merry-go-round system today, namely Aberthaw, Drax, Didcot, Eggborough, Fiddlers Ferry and Ratcliffe (Department for Transport, 2006). The creation of the MGR service enabled traditional marshalling yards covering arcs of land, and shunting sidings alongside the mainline to be demolished as they were now surplus to requirements. This eased traffic congestion around collieries and major cities. The MGR system meant trains would move continuously through the loading/unloading stages, eliminating the need of sidings for marshalling and therefore reducing complex track layouts (Shannon, 2006). The locomotives required to full the coal trains would be fitted with Slow Speed Control (SSC) to enable them to move consistently at 0.5mph through the MGR. The innovative operation also eliminated idle wagons or locomotives at the collieries and power stations, as once the train was loaded or unloaded it would move off complete.

All the new power stations were designed to accommodate the MGR system due to collaborative input from BR, NCB and CEGB. Old power stations would be upgraded to incorporate the new system; however some issues regarding space and curvature of original track layouts would prevent all power stations adopting this method (Jones, 2012). At first, the NCB were reluctant to invest in the new MGR facilities, perhaps for the insecurities surrounding the declining coal market (Gourvish, 1986) and the possible alternative of road haulage at a cheaper price.

Between 1965 and 1969 the NCB closed nearly 200 pits, which equates to one closure per week (Callinicos and Simons, 1985). Even though demand for coal was percieved to have depreciated during the time, coal was still a necessitated comodity. By 1970 coal only provided 46.6% of the inland energy consumption, nearly halving in less than 25 years. Collieries in the UK were still served by the railways, however, after the miner's strike in 1984 (Callinicos and Simons, 1985) and by the time of privatization less than 20 pits remained (Monk-Steel, 2012). Those collieries that were still operational were consolidated to ensure productivity and safe-guarding them for the foreseeable future.

Coal has now been imported significantly in the last 40 years, in which time the UK has seen nearly 50% increase in imported coal (Department for Transport, 2006). The current power stations that use the MGR system are provided coal by the ports of Clydeport, Grimsby & Immingham and Tees & Hartlepool, which account for 53% of coal traffic (Department for Transport, 2006). Whilst some power stations are well placed to be served by ports inland power stations now require a longer journey for the coal train to reach it from the port. Such was the case at the end of the 1960s, where a large share of coal was imported to the port of Cardiff from America, that would be transported on to power stations at Didcot (Barrie, 1980), a distance of over 80 miles that would require trains to run on the busy Great Western Mainline. It is suggested therefore that the distance coal is moved has increased, not the amount lifted (Vanek and Smith, 2004). The movement of coal on the railways has reduced from collieries and pits, more frequently now to ports for imported coal to service the power stations. These Power stations were traditionally built nearby the coalfields and pits to allow for quick and efficient shuttle runs of coal trains and private freight-only lines.

However modern power stations like Drax power station was purposely built in partnership with the NCB and BRB and thus created not only with MGR facilities but also close to the productive Selby colliery. The distance of only 18 miles from Selby colliery, sufficiently reduced costs and time of moving coal by rail. It is also strategically located very close to the port of Hull, and Grimsby and Immingham for exporting and if required in the future importing coal. After the Beeching cuts, forecasts were made to assume how future, streamline routes would look. The below map, again taken from the 1965 report mentioned previously, illustrates how the network was projected to look in 1984 based on presumed demand and supply and the creation of regional trunked routes. The assumption was that coal flows would move shorter distances. Subsequently Tees port would only serve the North-West and Scotland, and midland coal flows would only move on trunk routes in and around the midlands. In theory this was logical method of minimising long distances and optimising routes and capacity.

Figure 5 - Map of Coal Traffic flows 1984

**Source: BRB (1965)*

Figure 6 below indicates where the current power stations and coal fields are located in Britain. It is clear that most are strategically placed (with the exception of Didcot) to coal fields but also the ports for potential to import and export coal. It is also worth comparing to Figure 5, as the proposed trunk routes could be easily integrated into the map below.

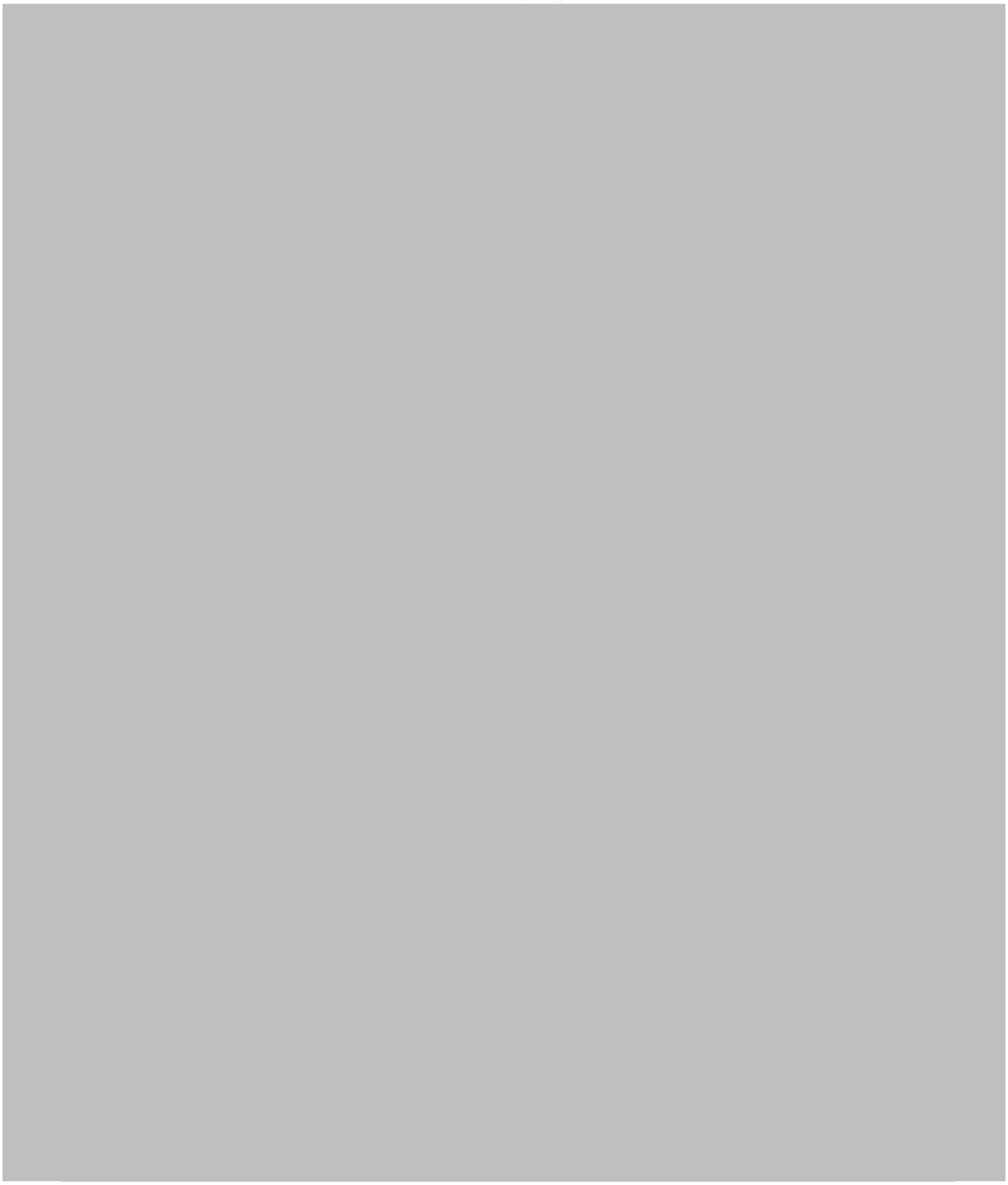


Figure 6 – British Coal Fields and Power stations

*Source: Monk-Steel (2012)

3.4 The Decline of Coal Traffic and Production

Coal production and therefore the movement of coal by rail was in a state of decline for more than 30 years prior to the Beeching report in 1963. What was once a prosperous market that provided lucrative traffic to the railways was painfully compressed to a fraction of production the coal industry proudly generated. In 1913, in South Wales alone approximately 600 railway lines connected the surrounding collieries. Within 70 years there were less than 60 (Barrie, 1980). In 1963 there were 620 collieries in Great Britain, of which 600 were connected by rail, emphasising the importance of rail transportation (British Railways Board, 1963). The UK mines were closing as production dramatically decreased. British coal exports halved from 1913 to 1938 through trade depression and the development of oil-fired ships (Freeman and Aldcroft, 1985). Both Griffin (1981) and Callinicos and Simons (1985) support this statement, with the latter attributing this development to the discovery of the North Sea Gas. Furthermore, steam locomotives were gradually phased out with the introduction of diesel and electric locomotives, relying now on alterative fuels that were cheaper and more efficient. Mamurekli (2010) reaffirmed the main reasons why coal sufficiently reduced in the UK was due to high competition from oil and gas, the change in energy demands to electricy and significantly, the price of imported coal for his study on fuel utilization. The development of road transport during this period inevitably would claim a share of the traffic, as the table below from 1961 shows:

Table 2 – Total tonnage coal traffic by transport

	Million tons
Rail	133
Road	39
Private Line	9
Canal	3
Other	5
TOTAL	189

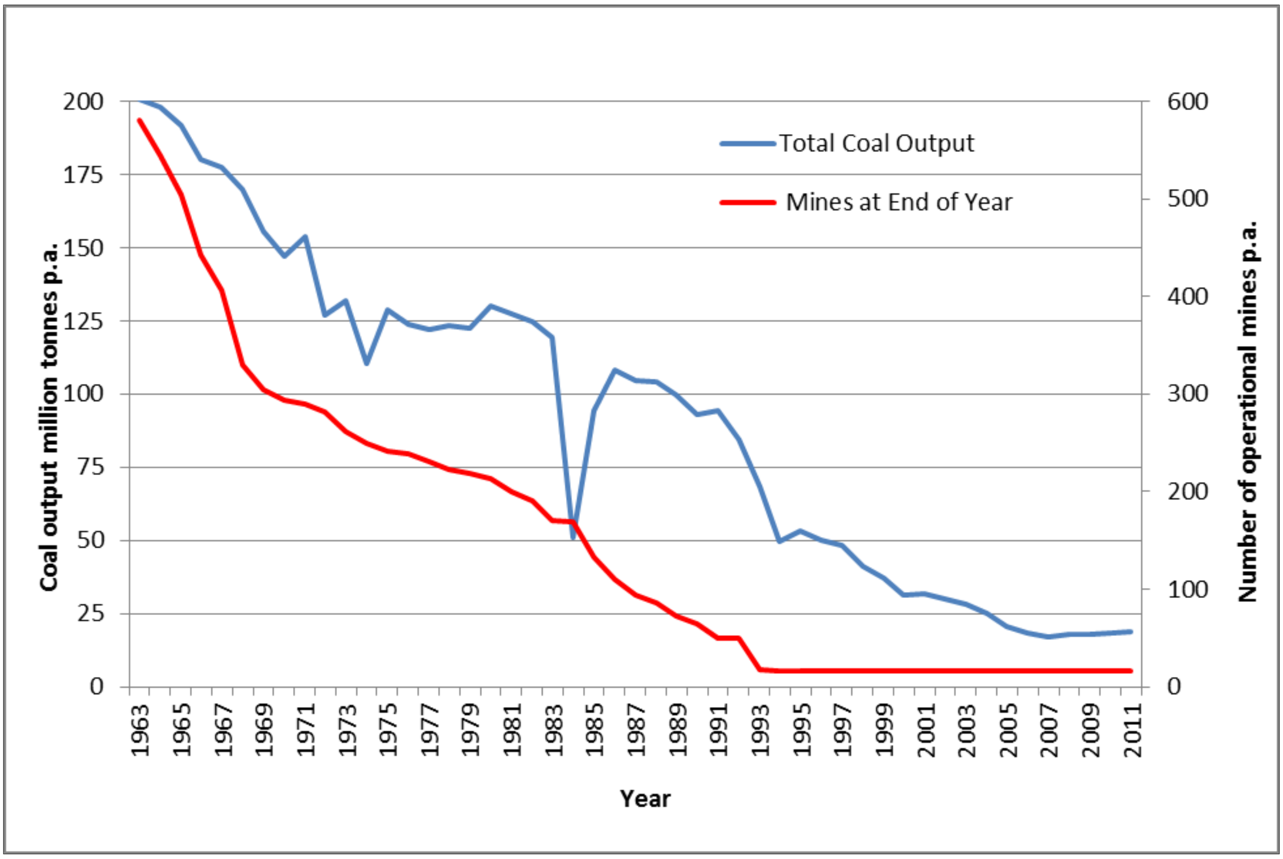
**Source: BRB (1963)*

Whilst coal still provided a valuable service for the railways to operate, these external factors resulted in reduced coal services by rail. To maintain what was still profitbale Ashwoth (1986) suggested that in the early 1960s the local coal merchants and the railways negotiated on focusing operations regarding the handling of coal to fewer, larger and better equipped depots, thus streamlining the system.

Clearly this worked in the favour of the railways, as BR intended to close many stations and routes to cut costs, and would also coincide with the release of Reshaping of British Railways in 1963 by the BRB (British Railways Board, 1963). The report identified the intention to axe many small branch lines from collieries to ports, to ease BR's financial situation, but more importantly proved that only the long distant coal trains were profitable (Haywood, 2007). These were the services that BR needed to invest in to maintain profits and operations.

However, the closure of the intermediate lines that served the coalfield condemned the coal industry's fate as production decreased and many coalfields and pits closed down. This is seen in the table below; note in particular the consequence of the miners' strike of 1984 on the UK coal production for that year.

Table 3 - UK Coal Production and Number of Operational Mines 1963-2011



**Source: DfT (2012)*

Table 4 also displays the decline of UK coal production and consumption from 1960 to 1998, and how reducing the services from the non-profitable coalfields, was in hindsight a correct decision, as the railways would have continued to make substantial losses if they continued to serve those coalfields.

Table 4 – UK coal production and consumption

COAL STATISTICS

Total UK coal Production and consumption, millions of ton(ne)s. (Consumption inc imports)

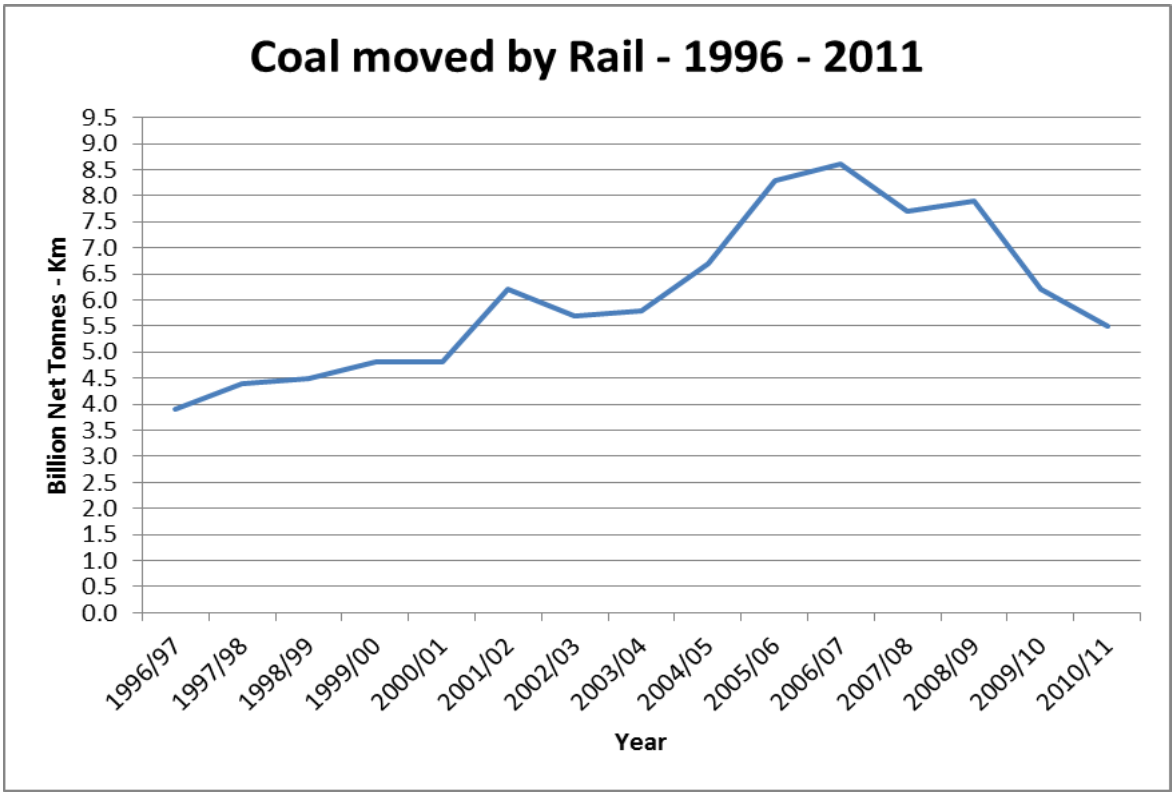
Year	Production	Consumption
1960	197	200
1970	147	151
1980	130	120
1990	93	108
1998	41	62

**Source: Shannon (2000)*

As aforementioned, coal production dramatically declined circa the release of the Beeching report. During the 1960s, the NCB unveiled a programme to construct new coal-fired electricity generating power stations. Requiring bulk loads of coal for their operation it was logical to use the railways as the preferred choice of transportation. BRB introduced a new pricing strategy to encourage longer trains. CEGB, who were to invest in these new power stations were asked to locate these away from collieries. CEGB built a new 2,000 megawatt power station at Didcot in 1970 which therefore had a coal transit of over 120 miles (Gourvish, 1986).

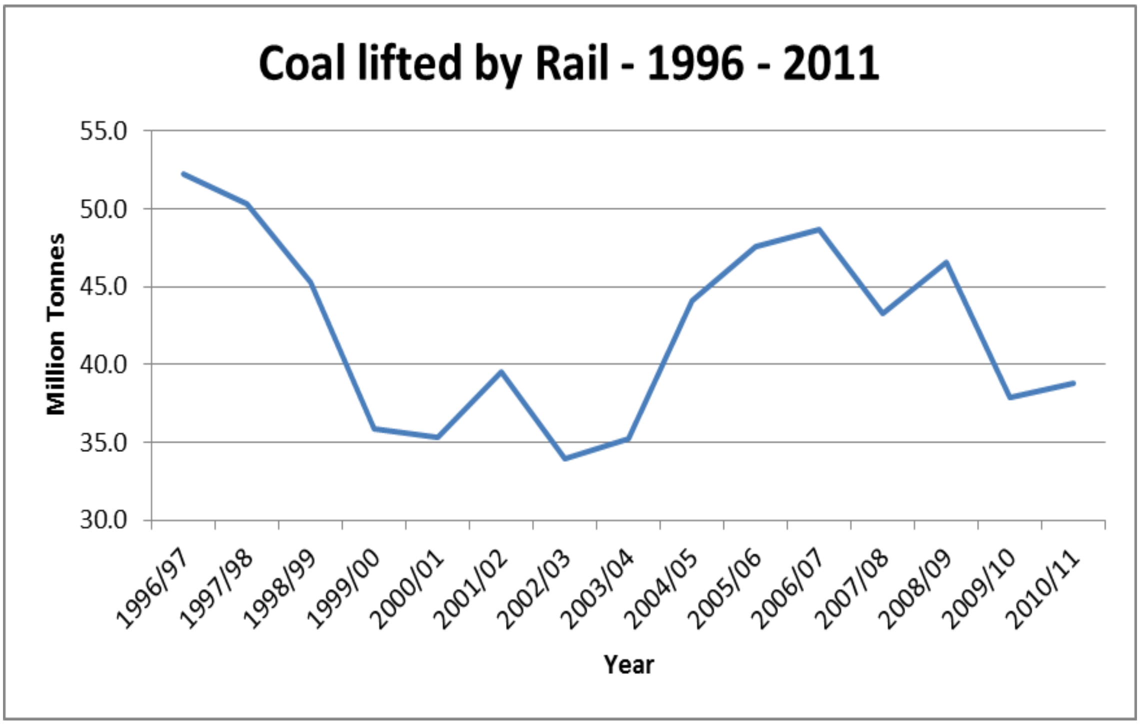
Significantly data obtained from the Department for Transport shows the amount of coal lifted decreased but the amount of coal moved increased. The results from Tables 5 and 6 support work previsouly Vanek and Smith (2004), emphasising that although coal production and usage has decreased, the amount moved on the railway has increased. This would contradict proposals by British Railways in the 1960s and the projected trunk routes scheme. Table 7 shows how general freight patterns have changed over the last 50 years regarding lifted and moved freight, highlighting that these changes are widespread across the whole industry on the rail network.

Table 5 – Coal moved by rail 1996 - 2011



*Source: DfT (2012)

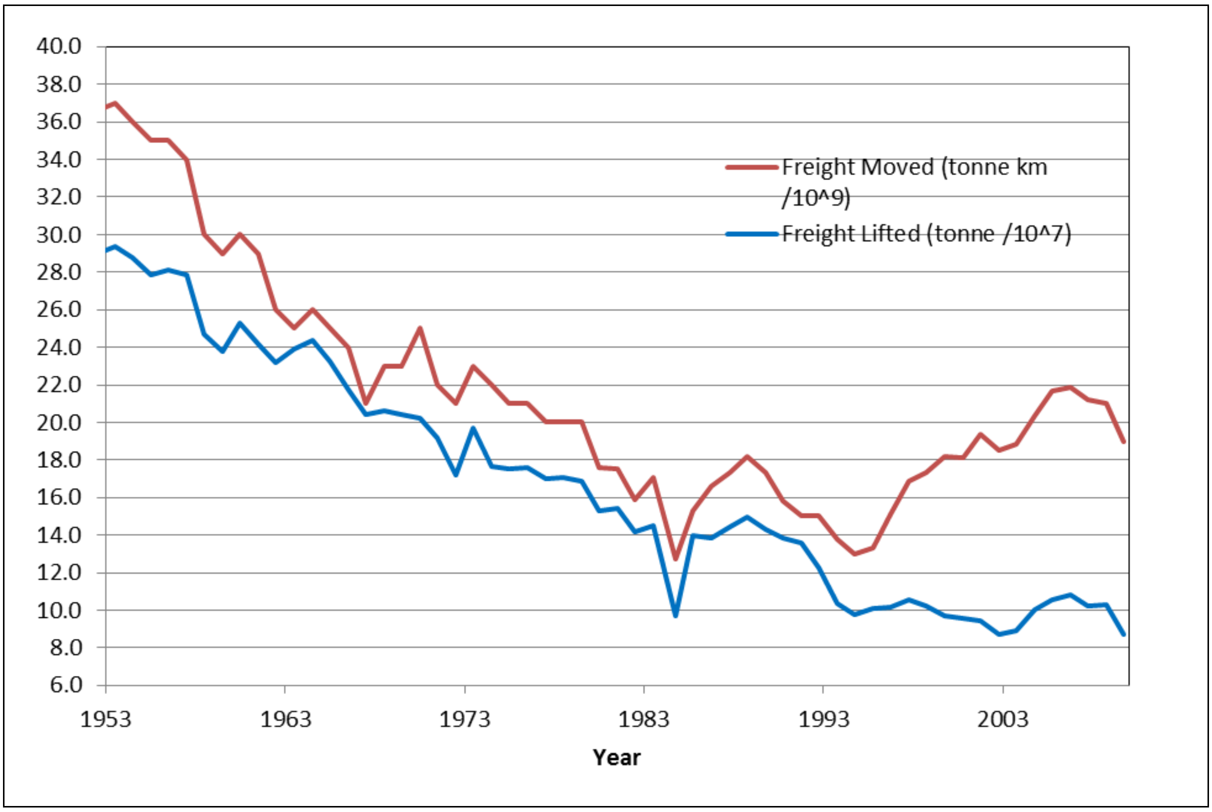
Table 6 – Coal lifted by rail 1996 - 2011



*Source: DfT (2012)

It is also clear from Table 7 below the impact of the miner's strike in 1984 and how that not only affected production of coal, but also the distribution of freight in general.

Table 7 – Total rail freight moved and lifted 1953 - 2010



*Source: DfT (2012)

The last ten years has seen a dramatic increase in the amount of coal moved, whilst the amount lifted continues a downward trend. Therefore the amount moved has increase based on where it is coming from and also where it is going to.

We can also analyse trends of traffic flow in the modern era by means of the Freightmaster timetable. The 2011 version is slightly different to the 1964 and 1984 maps, as internal (domestic) and external (imported) have been separated, possibly highlighting the fact that it is more common now for goods such as coal, to be imported as much as exported or transhipped around the UK.

It can be appreciated too that one of the main routes for domestic coal is between the power stations of Scotland, and the ports and power stations of the East Midlands. This contradicts the forecast earlier in 1984, concerning the removal of the link between the North and the South of the UK. Notice also for example how that the power station in Wales (Aberthaw) is served by the coal pits in South Wales, a good resource and utilisation of local terminals.

The traffic flows for imported coal are very similar to that of domestic; however the routes almost exclusively head to the port of Immingham, which is now the main provider of imported coal. The port of Liverpool and Ellesmere Port also serve the UK with imported coal. Whilst these maps provide route knowledge and details of locations for origin and destinations, they fail to provide sufficient detail regarding capacity and destination for transhipment planning. Furthermore although both the 1964 and 1984 maps from the BRB report of 1965 provide rough estimates of traffic flow through density of line thickness on the map, the 2011 maps fail to provide this. Therefore one can only speculate the amount of traffic on each route. It would be naïve to assume that longer distance routes are less frequent, based purely on the fact that they are longer journeys that therefore could incur higher costs. Similarly, one cannot identify based on the maps alone, the number of trains that depart and arrive at each destination. Put simply, one can again make an assumption that each “destination” should receive the same as trains as the “origin”.

To understand how the system is used, and how it can be utilised the data must be extracted from the current statistics and timetables. Before modelling the transhipment for capacity utilisation, we can first analyse the trends over the past 50 by region, allowing for contrasts in the number of services, and changes to journey origins and destinations. Data will be obtained for general national statistics and results, and then broken down into regions to identify trends and comparisons.

Figure 7 - Map of Domestic Coal Traffic flows 2011

**Source: Rawlinson (2011)*

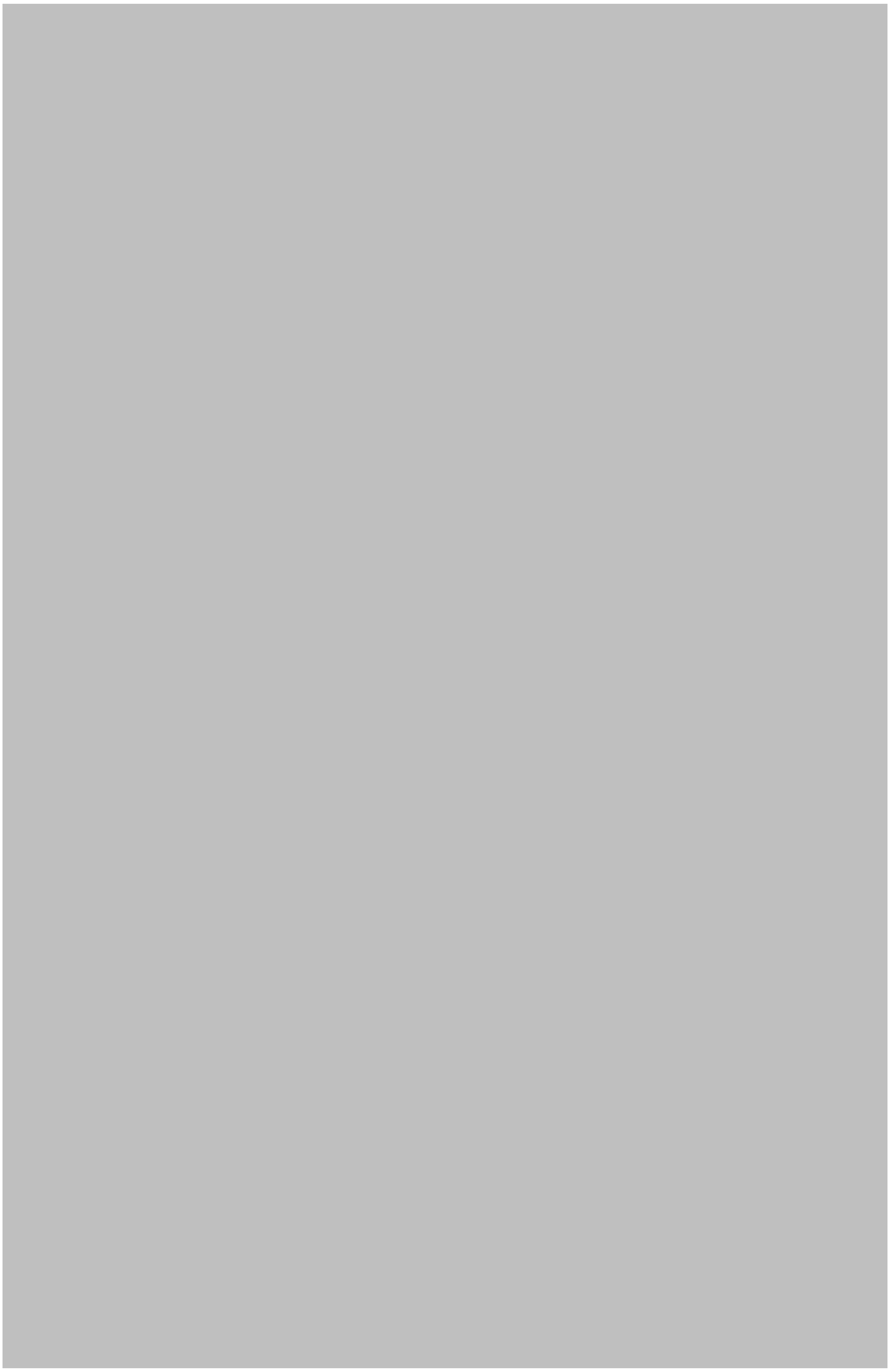


Figure 8 - Map of Imported Coal Traffic flows 2011

**Source: Rawlinson (2011)*

4 Coal by Rail Today

4.1 Timetables and Routes

4.1.1 Sourcing data

Data collected from the Freightmaster Timetable was entered into Excel (See Figure 9).

	A	B	C	D	E	F	G	H	I	J	K
1	H'code	Train	From	Region	Type of origin	To	Region	Type of destination	Traction	Type of train	Distance (km)
2	4C04	07:32:00	Stoke Gifford	South West	Yard/Sidings	Portbury	South West	Port	F.Liner 66	empty FHH coal hoppers	18.7
3	6F90	10:50:00	Portbury	South West	Port	Uskmouth p.s	Wales	Power Station	F.Liner 66	loaded FHH coal hoppers	41.5
4	4F57	17:54:00	Uskmouth p.s	Wales	Power Station	Stoke Gifford	South West	Yard/Sidings	F.Liner 66	empty FHH coal hoppers	42.2
5	4V32	23:21:00	Milford	Yorkshire	Yard/Sidings	Onllwyn	Wales	Coal mine	EWS 66	empty EWS coal hoppers	380.4
6	6C91	05:28:00	Cwbargoed	Wales	Coal mine	Aberthaw p.s	Wales	Power Station	EWS 66	loaded EWS coal hoppers	56.6
7	4C93	06:31:00	Aberthaw p.s	Wales	Power Station	Cwbargoed	Wales	Coal mine	EWS 66	empty EWS coal hoppers	56.6
8	6Z97	16:08:00	Killoch	Scotland	Coal mine	Port Talbot	Wales	Port	F.Liner 66	loaded FHH coal hoppers	666.9
9	6B68	09:24:00	Avonmouth	South West	Port	Aberthaw p.s	Wales	Power Station	EWS 66	loaded EWS coal hoppers	84.2
10	4C94	10:29:00	Aberthaw p.s	Wales	Power Station	Cwbargoed	Wales	Coal mine	EWS 66	empty EWS coal hoppers	56.6
11	4C95	14:24:00	Aberthaw p.s	Wales	Power Station	Cwbargoed	Wales	Coal mine	EWS 66	empty EWS coal hoppers	56.6
12	6V23	13:00:00	Cwbargoed	Wales	Coal mine	Aberthaw p.s	Wales	Power Station	EWS 66	loaded EWS coal hoppers	56.6
13	4Z98	14:53:00	Port Talbot	Wales	Port	Crewe Basford Hall	North West	Yard/Sidings	F.Liner 66	empty FHH coal hoppers	299
14	4C51	17:45:00	Aberthaw p.s	Wales	Power Station	East Usk	Wales	Yard/Sidings	EWS 66	empty EWS coal hoppers	49.2
15	6.E.09	15:55:00	Swansea Burrows	Wales	Yard/Sidings	Immingham	Yorkshire	Port	EWS 66	loaded EWS coal hoppers	454.5
16	6C94	17:47:00	Cwbargoed	Wales	Coal mine	Aberthaw p.s	Wales	Power Station	EWS 66	loaded EWS coal hoppers	56.6
17	4C93	06:24:00	Aberthaw p.s	Wales	Power Station	Cwbargoed	Wales	Coal mine	EWS 66	empty EWS coal hoppers	56.6
18	6C92	10:00:00	Cwbargoed	Wales	Coal mine	Aberthaw p.s	Wales	Power Station	EWS 66	loaded EWS coal hoppers	56.6
19	6F93	13:00:00	Cwbargoed	Wales	Coal mine	East Usk	Wales	Yard/Sidings	EWS 66	loaded EWS coal hoppers	53.4
20	6B66	05:50:00	Avonmouth	South West	Port	Aberthaw p.s	Wales	Power Station	EWS 66	loaded EWS coal hoppers	84.2
21	6M61	08:25:00	Portbury	South West	Port	Rugeley p.s	Midland	Power Station	F.Liner 66	loaded EWS coal hoppers	175.9
22	4F56	10:42:00	Uskmouth p.s	Wales	Power Station	Stoke Gifford	South West	Yard/Sidings	F.Liner 66	empty FHH coal hoppers	42.2
23	4C61	09:20:00	Aberthaw p.s	Wales	Power Station	Avonmouth	South West	Port	EWS 66	empty EWS coal hoppers	84.2
24	6B77	16:42:00	Avonmouth	South West	Port	Aberthaw p.s	Wales	Power Station	EWS 66	loaded EWS coal hoppers	84.2
25	4F56	10:42:00	Uskmouth p.s	Wales	Power Station	Stoke Gifford	South West	Yard/Sidings	F.Liner 66	empty FHH coal hoppers	42.2
26	6V46	00:01:00	Ripple Lane	South East	Yard/Sidings	Didcot p.s	South East	Power Station	EWS 66	loaded EWS coal hoppers	169.3
27	6M66	03:49:00	Immingham	Yorkshire	Port	Rugeley p.s	Midland	Power Station	F.Liner 66	loaded FHH coal hoppers	197.9
28	6M59	01:11:00	New Cumnock	Scotland	Coal mine	Ratcliffe p.s	Midland	Power Station	EWS 66	loaded EWS coal hoppers	429.5
29	6M49	12:41:00	Barrow Hill	Yorkshire	Yard/Sidings	Rugeley p.s	Midland	Power Station	F.Liner 66	loaded FHH coal hoppers	94.3
30	6E.03	14:15:00	Blackwell	Midland	Coal mine	Cottam p.s	Midland	Power Station	EWS 66	loaded EWS coal hoppers	168.3
31	6M86	10:30:00	Wolsingham	North East	Coal mine	Ratcliffe p.s	Midland	Power Station	Colas 66	empty coal hoppers	247.7

Figure 9 - Data from FreightMaster

Distances were calculated using the AA route planner, as the exact distances were difficult to obtain due to their obscure locations and infrequent routes. Furthermore, some of the locations were in the same city/area. For example Warrington has yards, power stations and ports in the town. Some journeys are made between these and these have been recorded as 0 km for consistency purposes, even though the distance would be more than zero. For that reason, combined with using the AA route planner, the distances obtained must be assumed to be an approximation and a margin of 10% each way should be considered for accuracy.

By analysing the timetable and quantifying the numbers into charts and graphs, the data could then be compared with information obtained from national statistics and earlier material and resources. For ease of reading, the data can also be converted into a pivot table, which would also provide more results. The timetable was be broken down by region, thus easier to compare distances, journey origins and also destinations. For simplicity, the regions have been named Scotland, Wales, the North East, the North West, Yorkshire, Midlands, the South East and the South West. Where possible, this was consistent throughout. The map of Great Britain below details the 8 areas aforementioned. as these groups are not defined regions there will be inevitable discrepancies regarding where certain locations should be categorised. For example, the Port of Immingham whilst in Humberside has been grouped in the

Yorkshire region. This has allowed for 8 independent groups to measure data, compared to dividing by the many unitary authorities and counties that current exist in the UK.

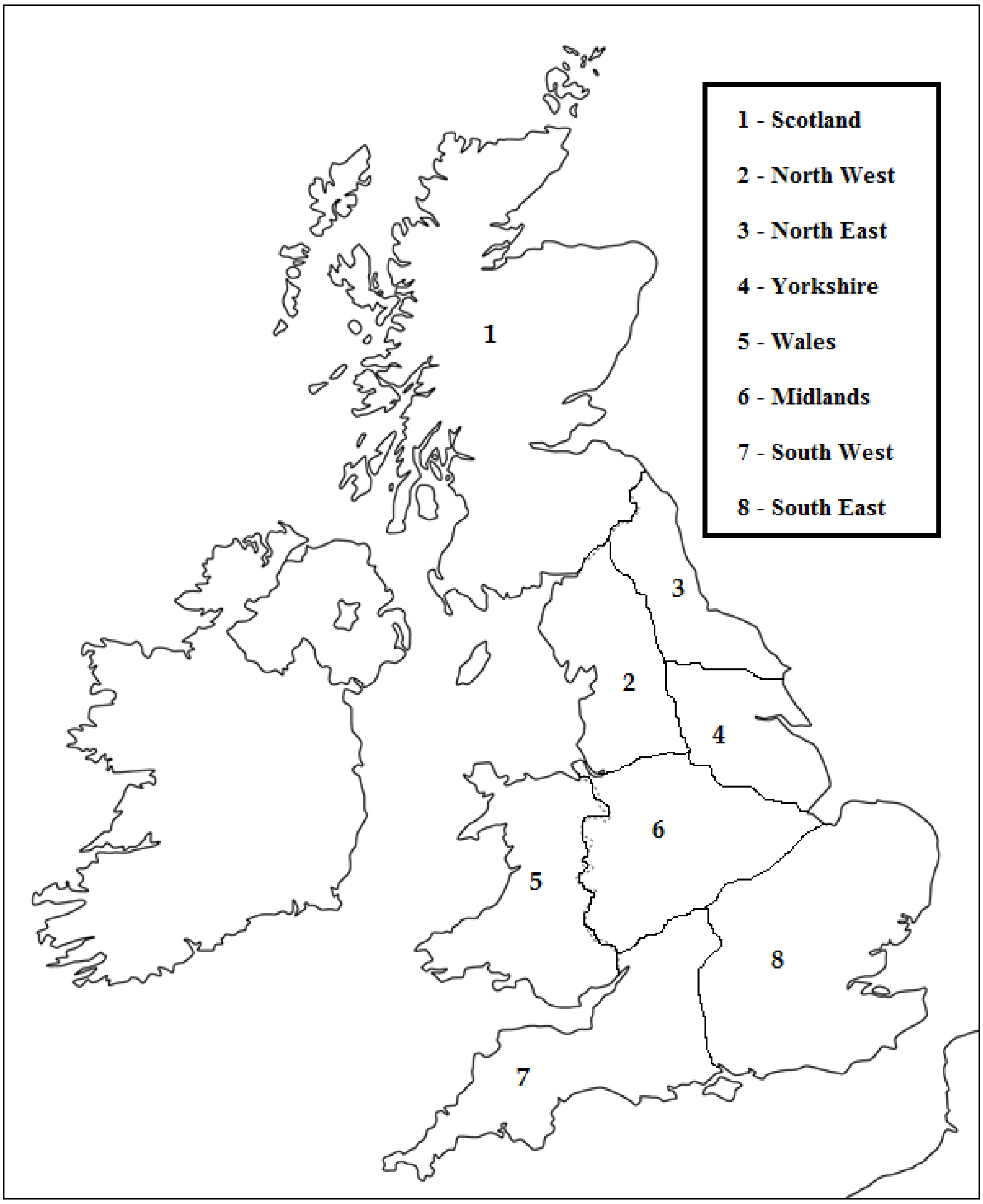


Figure 10 – Regional breakdown of Great Britain

It is also important to establish at this stage the method chosen to calculate the number of coal trains on any given week. Freight trains do not run as frequently or punctually as passenger ones, as demand is dependent on many external factors (Rawlinson, 2011). Therefore, as the timetable fluctuates every week, assumptions and averages had been used to calculate the predicted coal flows of traffic on a particular week as summarised in Table 5. Based on assumption the following are the codes and the number of assumed daily trains taken from the Freightmaster Timetable.

Table 8 – Number of Trains assumed Per Week

Headcode	Number of Trains per week	Assumption
Blank	5	Train run every day of working week
Q	3	Could be any of 1-5 days, so assume average 3
Mx	4	All days exclude one in the code (example: all days bar Monday
MTo	2	For example Monday and Tuesday only

These codes have therefore been used consistently throughout the data entry process, so as mentioned previously, some weeks may have more coal trains, and some weeks less, but none the less the results and statistics below give a good indication of the coal traffic presently on the UK rail network.

4.1.2 General UK statistics

After the data had been entered into Excel, the following charts presented the data. In total 1,179 coal trains ran approximately each week.

Table 9 reveals that 436 of the 1179 coal trains (37%) started at Ports. The influx of imported coal during the past few years is reflected in the data and results that were obtained. Furthermore only 15% of trains now started their journeys at coal mines, reflecting the demise of coal mining in the UK, whilst 33% of trains started at Power Stations, with the likely destinations to be both Ports and Coal mines, for either empty trains, or a small portion for export (to Ports). Interestingly 15% of trains started their journeys from Yards and Sidings.

Table 9 – Total number of Coal Trains – 2011

Origin	Coal mine	Port	Power Station	Yard/Sidings	Grand Total
Coal mine		21	144	13	178
Port		13	388	35	436
Power Station	92	232		60	384
Yard/Sidings	64	68	33	16	181
Grand Total	**156**	**334**	**565**	**124**	**1179**

Conversely, the data also presented destinations of all coal trains in the UK. Only 13% of coal trains went to coal mines compared to 15% originating from coal mines. However 10% of all coal trains ended at yards and sidings, and it could be assumed that some of these trains were loaded from coal mines but have not returned directly if there is not as much supply compared to ports. Fewer trains went to Ports (28%) then started the journeys at Ports (37%) reaffirming the trend that more coal is imported hence the increase in coal trains starting at ports. Fewer trains also went to Yards and Sidings (11%), however nearly half of the UK trains went to Power Stations (48%). The trains that went to Ports are likely to collect imported coal, as exported coal would be low due to fewer trains headed to coal mines. Likewise, 48% of trains headed to Power Stations, and so it is apparent that the lines on the maps can be misleading, as they do not differentiate journey routes by frequency. However the initial data confirmed the traffic flow of coal trains now established in the UK, the most frequent was between ports and power stations. Furthermore, 89% of total coal trains started at ports travelled to power stations. There were no services from coal mine to coal mine, port to coal mine and power station to power station all of which are fairly obvious as to why. However the fewest journeys occurred between coal mines and yards (7% of coal trains from coal mines) and also between coal mines to port (10%) and as they are loaded this would indicate that the coal was indented to be exported.

Table 10 – Loaded Coal Trains – 2011

Origin	Coal mine	Port	Power Station	Yard/Sidings	Grand Total
Coal mine		17	141	13	171
Port			388	31	419
Power Station	9				9
Yard/Sidings		4	33	4	41
Grand Total	**9**	**21**	**562**	**48**	**640**

Upon initial observation of Table 10 and Table 11 it is clear that most coal trains were loaded, and more specifically started at ports loaded and travelled to power stations for unloading. Of the 419 loaded coal trains that started at ports, 388 coal trains travelled to power stations, therefore 93% of coal trains that started at ports ended at power stations. Furthermore, 96% of coal trains that started from ports were loaded. There were 9 loaded coal trains that started loaded at power stations to go to coal mines. It is unclear why these trains were travelling to coal mines loaded, it could be assumed that they had picked up load from the port and filling up more from the coal mine and then continue onto a power station. Additionally only 4 trains started at yards and travelled to ports, perhaps these trains started a previously journey as loaded from coal mine to yard and the second train (journey) is yard to port. Of all the loaded coal trains in the UK, only 3% went to ports. The table below displays the unloaded train breakdown.

Table 11 – Unloaded Coal Trains – 2011

Origin	Coal mine	Port	Power Station	Yard/Sidings	Grand Total
Coal mine		4	3		7
Port		13		4	17
Power Station	83	232		60	375
Yard/Sidings	64	64		12	140
Grand Total	**147**	**313**	**3**	**76**	**539**

There were slightly more loaded trains on the network, than unloaded, and similarly the most frequent journey was between power stations and ports. These unloaded journeys would likely to be heading to the ports ready for the imported load of coal. Marshalling yards and sidings were used slightly more for unloaded coal trains than compared to loaded ones. The marshalling yards were one of the key outcomes of the Beeching legacy (Jones, 2012), and although many were ripped up during the last twenty years, without them, more empty trains would be running longer distances along the network, as they would have to return to their origin destination; wagon pooling and strategic wagon utilisation would be difficult on a national railway, compared with, for example if all the wagons on the network belong to the same company. Storing unloaded wagons would be more common as one can assume that loaded coal wagons take more priority as they head to the demanded location, i.e power stations. Some unloaded coal trains may not be required along that route for a few days and therefore could be stationed in a yard during this period. The table below breaks down the individual FOCs by both the loaded and unloaded trains.

Table 12 – Total number of Loaded and Unloaded Coal trains by Rail Operator – 2011

empty EWS coal hoppers	empty FHH coal hoppers	empty coal hoppers	empty GBRf coal hoppers	
260	**208**	**9**	**62**	
22%	*18%*	*1%*	*5%*	
loaded EWS coal hoppers	loaded FHH coal hoppers	loaded coal hoppers	loaded GBRf coal hoppers	Loaded Coal Box Wagon
293	**252**	**6**	**71**	**18**
25%	*21%*	*1%*	*6%*	*2%*
TOTAL	Total Loaded	Total Empty		
1179	**640**	**539**		
	54%	*46%*		

Whilst data regarding individual FOCs bears no impact on the results required within the project, the data showed that, as a percentage, all operations run more or equal numbers of loaded trains compared to empty. EWS had the most coal services, and accounted for 47% of all coal operators' services. The data was also used to analyse activity with each region as to how much traffic arrives and departs. The data showed that Yorkshire had the most trains that departed (41.6%) and the most trains that arrived (36.7%), therefore making it the largest and most important region for coal movements in the UK with a combined total of 39%. This is due to the region possessing three of the largest power stations of Drax, Eggborough and Ferrybridge, as well as the port of Immingham for collection of imported coal. On the opposite end of the scale, the South East accounted for the least amount of coal traffic in the UK. Scotland had the second largest combined share of coal traffic with approximately 20% and third was the North West with 17%. From the data we can see how the coal movements, based on the data and regions, accurately are represented on the maps shown earlier.

Table 13 – Origin and Destination Traffic by Region (%) - 2011

Origin	Origin %	Destination %	Average traffic combined %
Midlands	8.7%	14.8%	11.7%
North East	7.5%	4.8%	6.2%
North West	16.5%	17.6%	17.0%
Scotland	19.5%	20.4%	19.9%
South East	0.4%	0.4%	0.4%
South West	1.2%	0.8%	1.0%
Wales	4.6%	4.5%	4.5%
Yorkshire	41.6%	36.7%	39.1%
	100.0%	100.0%	100.0%

The pivot table (Figure 11) on the next page showed that 8 locations received nearly 50% of the total coal traffic; therefore 13% of coal locations received nearly 50% of the total incoming coal traffic. Of these, the port of Immingham received the most at 13.7%. The next 7 locations were all power stations, therefore showing the importance of coal traffic to these destinations. The top 9 locations where coal journeys started accounted for nearly 50% of the total number of departing coal trains. The data therefore showed that nearly 50% of coal traffic started at only 14% of coal locations Most of these origins are ports, which therefore supports the assumption that most of the coal traffic in the UK started at ports and travelled to power stations, a significant change to the way coal was moved 50 years ago, from coal mines to power stations.

Furthermore using the data from Figure 10 the 80-20 rule can be applied to determine whether this law can be applied to the coal traffic in the UK. The data showed that 20% of coal train destinations accounted for 67% of all traffic, which does however re-affirm the significance and importance of the larger coal locations in context to all the coal locations in the UK.

w Labels	Immingham	Drax p.s	Fiddlers Ferry	Cottam p.s	Longannet p.s	Hunterston	Eggborough p.s
Immingham		49		29			50
Fiddlers Ferry						5	
Liverpool Bulk Term			59				
Longannet p.s						35	
Hunterston			5	7	35		
Drax p.s	17						
Eggborough p.s	36						
Tyne Dock		21					
Milford	5						
Ratcliffe p.s							
Scunthorpe	17						
Killoch			8	3			
York	4					3	
New Cumnock		5		15			
Cottam p.s	18						
Ferrybridge p.s	15						
Daw Mill							
Ravenstruther		8			15		
Cwbargoed							
Ellesmere Port			20				
Aberthaw p.s							
Redcar							
Maltby	10	4					
North Blyth		4		4			
Liverpool							
Doncaster Decoy	7						
Leith South					13		
Leeds Hunslet	6						
Leeds						5	
Walton Sidings							
Garston							
Wolsingham							
Avonmouth							
Barrow Hill	4						
Tyne Yard		3					
Greenburn	3						
Ironbridge p.s							
Sudforth Lane	4						
Lynemouth							
Hatfield Mine		3		3			
Uskmouth p.s							
Doncaster	3						
Cockenzie p.s						5	
Millerhill							
Barnetby Sidings	5						
Worksop							
Ripple Lane							
Rugeley p.s							
Portbury							
Swansea Burrows	4						
Crewe Basford Hall							
Earles Sidings							
West Burton p.s	3						
Potland Burn		3					
Margam							
Carlisle Yard							
Carlisle							
Blackwell				2			
Leith Docks							
Stoke Gifford							
Port Talbot							
Warrington							
Grand Total	**161**	**100**	**92**	**63**	**63**	**53**	**50**
Running Total	161	261	353	416	479	532	582
Grand Total %	13.7	8.5	7.8	5.3	5.3	4.5	4.2
Running Total %	13.7	22.1	29.9	35.3	40.6	45.1	49.4

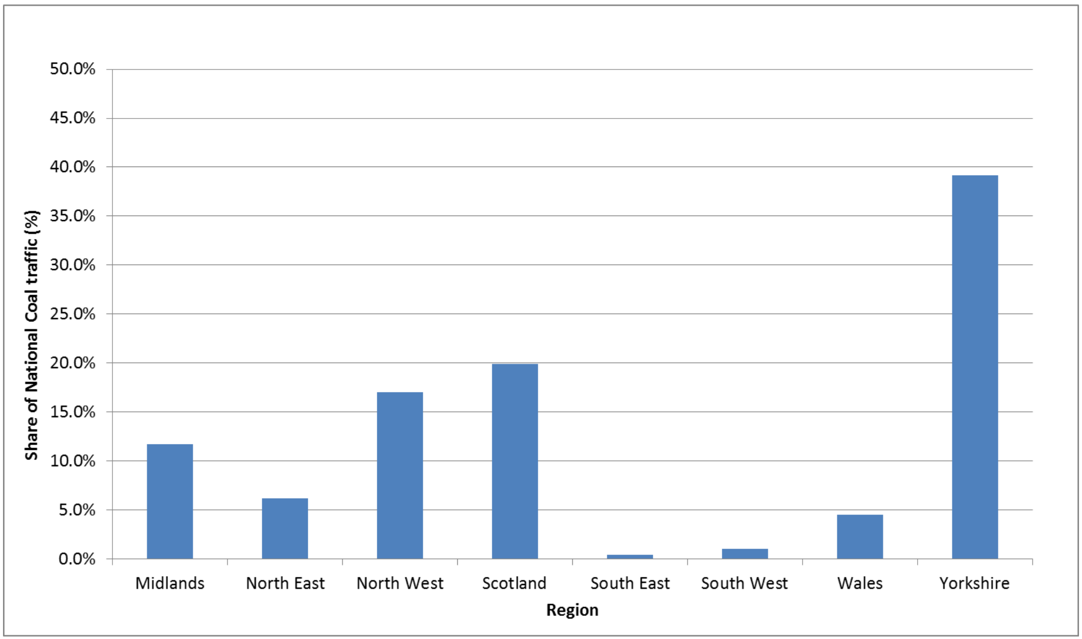
Figure 11 – Top 8 Destinations by number of coal trains - 2011

Table 14 – Pivot Table for Coal Traffic – 2011

Train origins	Midland – Coal mine	Midland – Power Station	Midland – Yard/Sidings	Midland Total	North East – Coal mine	North East – Port	North East – Yard/Sidings	North East Total	North West – Port	North West – Power Station	North West – Yard/Sidings	North West Total	Scotland – Coal mine	Scotland – Port	Scotland – Power Station	Scotland – Yard/Sidings	Scotland Total	South East – Power Station	South East Total	South West – Port	South West – Yard/Sidings	South West Total	Wales – Coal mine	Wales – Port	Wales – Power Station	Wales – Yard/Sidings	Wales Total	Yorkshire – Coal mine	Yorkshire – Port	Yorkshire – Power Station	Yorkshire – Yard/Sidings	Yorkshire Total	Grand Total
Midland																																	
Coal mine		26		26																													26
Power Station	15		3	18	3	4		7			11	11												1			1		21		14	35	72
Yard/ Sidings	2			2									3				3																5
Midland Total	**17**	**26**	**3**	**46**	**3**	**4**		**7**			**11**	**11**	**3**				**3**							**1**			**1**		**21**		**14**	**35**	**103**
North East																																	
Coal mine		6		6																										6		6	12
Port		4		4		2	5	7							7		7													51		51	69
Yard/ Sidings						5		5																						3		3	8
North East Total		**10**		**10**		**7**	**5**	**12**							**7**		**7**													**60**		**60**	**89**
North West																																	
Port		13		13					10	79		89																					102
Power Station									52		8	60	8	5			13																73
Yard/ Sidings									13		4	17												2			2						19
North West Total		**13**		**13**					**75**	**79**	**12**	**166**	**8**	**5**			**13**							**2**			**2**						**194**
Scotland																																	
Coal mine		29	3	32			5	5		8		8			15		15							1			1		3	27		30	91
Port		7		7						5		5			36	5	41																53
Power Station						7		7					21	40			61																68
Yard/ Sidings															18		18																18
Scotland Total		**36**	**3**	**39**		**7**	**5**	**12**		**13**		**13**	**21**	**40**	**69**	**5**	**135**							**1**			**1**		**3**	**27**		**30**	**230**
South East																																	
Yard/ Sidings																		5	5														5
South East Total																		**5**	**5**														**5**
South West																																	
Port		3		3																					10		10						13
Yard/ Sidings																					1	1											1
South West Total		**3**		**3**																	**1**	**1**			**10**		**10**						**14**
Wales																																	
Coal mine																									15	5	20						20
Port						1		1			1	1				2	2																4
Power Station																				3	6	9	14			3	17						26
Yard/ Sidings																													4			4	4
Wales Total						**1**		**1**			**1**	**1**				**2**	**2**			**3**	**6**	**9**	**14**		**15**	**8**	**37**		**4**			**4**	**54**
Yorkshire																																	
Coal mine		5		5		3		3																					14	7		21	29
Port		45		45																										128	22	150	195
Power Station					3	14	3	20			5	5	24				24											4	85		7	96	145
Yard/ Sidings	6	7		13		2		2			11	11	48	8			56						2				2	3	34			37	121
Yorkshire Total	**6**	**57**		**63**	**3**	**19**	**3**	**25**			**16**	**16**	**72**	**8**			**80**						**2**				**2**	**7**	**133**	**135**	**29**	**304**	**490**
Grand Total	**23**	**145**	**6**	**174**	**6**	**38**	**13**	**57**	**75**	**92**	**40**	**207**	**104**	**53**	**76**	**7**	**240**	**5**	**5**	**3**	**7**	**10**	**16**	**4**	**25**	**8**	**53**	**7**	**161**	**222**	**43**	**433**	**1179**

The table below showed the share of coal traffic by region and as can be seen, Yorkshire had a share of nearly 40% of the total.

Table 15 - Average share of total coal traffic by region - 2011



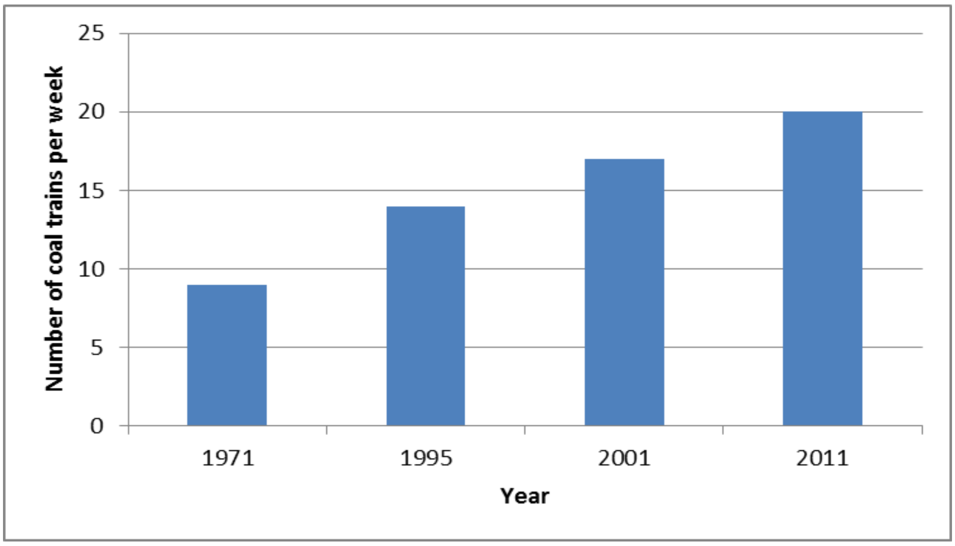
4.1.3 Scotland

Coal mines in Scotland produced coal sufficiently for power stations in the Midlands and Yorkshire, mainly to Cottam, Ratcliffe and Drax, in total 29. Eight of these services departed from Killoch coal mine, whereas 16 trains would leave a week in 1997 (Shannon, 2006). Coal from Ports usually served the Longannet Power Station. In total 52 trains left Hunterston Port compared to 21 that departed in 1997 (Shannon, 2006), higlhighting the increase in imported coal. From 2005 Leith Port, a traditional export location for Scottish coal became a loading point for imported coal (Shannon, 2006). This is reflected by the fact that no trains ran into Leith Port in 2011. Most traffic from Power Stations also served Scottish Ports and coal mines, allowing for a streamline system of moving coal back and forth along set routes. The continued use of Longannet power station means that coal traffic in Scotland is likely to maintain its service for the foreseeable future (Shannon, 2006). Scottish traffic hasn’t been sufficiently affected over the last 50 years. It seems that with the increase of power stations that had been built in the area, more traffic is moved around within the country and therefore only a few long distance journeys are required.

4.1.4 Wales

According to the 2011 timetable, 20 trains departed Aberthaw power station a week compared to 9 trains in 1971 (Shannon, 2006). One of these trains went to the port three times a week compared with none back in 1971. Significantly 9 coal trains a week travelled up to Scotland, the Midlands and Yorkshire from South Wales (Swansea and Margam to mention two). This therefore impedes capacity on both the East and West Coast Mainlines, and it would maybe be more beneficial to utilise the yards and sidings along the route, or potentially reconsider moving either the coal origin or destination. Perhaps it would be cheaper and more efficient to utilise closer coal mines and ports. The current operations in Wales have been significantly affected by the miners' strike of 1984/85 with 16 mines closing and 5 branchlines that served coal mines (Shannon, 2006). By the 1990s only 6 deep mines remained in South Wales. The table below compared the coal programme for Aberthaw over the last 40 years. In total, Wales has a coal traffic share 4.5 %, most of which is transported in and around Wales. In total 74% of all coal trains in Wales started at Aberthaw Power Station and Cwbargoed, both with a share of 34%. However, only Aberthaw Power Station received the most traffic, with a 45.3% share of all traffic that arrived into Wales. Therefore this highlights the importance and frequency of Aberthaw Power Station.

Table 16 – Aberthaw power station coal programme 1971-2011



4.1.5 North East

With no power stations in the North East, all the data showed that all traffic started at ports, coal mines and yards. Of the 89 services, 69 originated from ports and 19 of the coal trains were scheduled to ports in the North East. This showed that most coal train movements in the North East were now focused around ports, a stark contrast to the past, when the area was dominated by coal mines. Most of the coal locations from the 1970s have been all but removed. After the 1980s, significantly the miners' strike of 1984/85, many power stations ceased their rail operations (Shannon, 2006). In general there were few coal services starting in the North East, the majority of which were transported to Yorkshire to the power stations; in total 31 services to Drax power station, 21 to Scunthorpe and 8 to Ferrybridge power station. In total the data showed that 60% of all coal trains from the North East were scheduled for Yorkshire, presumably due to its close location. Less traffic arrived to the

North East than departed, again presumably due to the lack of power stations and coal mines. Most of the traffic arrived from Yorkshire, possibly for exportation but also as a temporary resting point in the sidings before an onward journey to Scotland.

Cheaper imported coal from Rotterdam might suggest why the North East ports are now the main location for coal traffic in this area. Only one out of the fourteen services to North East ports were loaded compared with one out of eighteen services that started at North East ports. More loaded coal trains' started at ports, which also reaffirm the fact that more coal is imported. In total the North East had a coal traffic share of 6.2%, 7.5% of all UK coal trains that started in the North East, and 4.8% of all UK coal trains for arrival in the North East.

4.1.6 North West

Most of the coal for the North West, in particular Fiddlers Ferry power station, originally came from the coal fields and pits of Yorkshire. However in 1989, Liverpool's Gladstone Dock received its first delivery of imported coal. Thereafter 7 trains a day would take trips of coal from Liverpool to Fiddlers Ferry. The table below summarises the difference in the coal programme for Fiddlers Ferry. As can be seen from the table, Liverpool Bulk Terminal had seen a huge increase in coal traffic from this port to Fiddlers Ferry. Interestingly, more services now to Fiddlers Ferry originated from Scotland (eight from Killoch coal mine and five from the port of Hunterston). So, whilst the distance had decreased due to the proximity of the ports (i.e. from Warrington to Liverpool) additional long distance journeys had increased the overall length of the average train services to Fiddlers Ferry. In total just over 8% of all coal traffic arrived into Fiddlers Ferry, making it one of the most important coal locations within the UK.

Table 17 - No. of Coal trains to Fiddlers Ferry 1995-2011

1995		1997		2011	
Milford	5	Liverpool Bulk Terminal	12	Liverpool Bulk Terminal	59
Liverpool Bulk Terminal	1	Walton Sidings	2	Ellesmere	20
Walron Sidings	1	Carlisle	1	Killcoh	8
Warrington Arpley	1			Hunterston	5
Ayr	1				
Total	9	Total	15	Total	92

Most of the traffic (86%) for coal that started in the North West stayed within this region. The data showed that imported coal from Liverpool to the power station at Fiddlers Ferry accounted for the majority of coal traffic. Additionally, traffic from Fiddlers Ferry also went to Liverpool Bulk terminal, however this was unloaded so it could be reloaded by imported coal and delivered again, creating an effective shuttle service. The data also showed the high usage of marshalling within the region, as services are traversed between Crewe, Warrington and Liverpool sidings. Less frequent were services from Yorkshire Power stations to Carlisle sidings and also imported coal to Ratcliffe and Ironbridge power stations in the Midlands, via the port of Liverpool. In total, the North West had a coal traffic share of 17%, almost evenly divided between trains that arrived and departed the North West.

4.1.7 Yorkshire

Once a landscape of coal mines and pits, Yorkshire now boasts three of the largest CEGB power stations in the UK: Ferrybridge, Drax and Eggborough. Together these three move around 300,000 tonnes of coal a week from a total of around 30 collieries (Shannon, 2006) which equates to nearly 10% of all coal traffic origins, and 16% of all coal destinations. In 1993, Drax would receive 46 services a week mainly from Gascoigne Wood, Eggborough received 14 trains and Ferrybridge received 11. None of these came from ports. In 2011, Yorkshire had a total of 195 trains departing from ports, and 161 trains arriving to ports.

The largest individual location for coal traffic was the port of Immingham. The data showed that in 2011 16.5% of all coal traffic started there and a further 13.7% of all coal traffic was to arrive at the port. Within the region of Yorkshire, nearly 40% of journeys departed from Immingham, and 37.2% of journeys arrived to Immingham. In total, exactly half of the journeys started either at the port of Immingham or at Drax power station. Furthermore just over 60% of journeys from Yorkshire to Yorkshire travelled to Immingham and Drax power station. 49 weekly services went from Immingham to Drax, yet only 17 went from Drax to Immingham. The data showed that the majority of train services from Drax actually went to Scotland, or to yards and sidings for temporary storage. Most of these sidings were in Yorkshire or the North East, possibly indicating that the services would continue up to Scotland unloaded to the ports and coal mines in that region.

Up until the 1980s Immingham was a key export location for British-mined coal, and the miners' strike of 1984/85 forced the terminal to switch its handling to become now the busiest port in the UK for coal. The decline of Yorkshire coalfields in the 1990s also contributed to the decision to shape the focus of Immingham. Most of the traffic from Yorkshire was delivered and transported within Yorkshire, followed by Scotland, the North West and the Midlands. Cottam (Midlands), Drax and Eggborough (both Yorkshire) received most from Yorkshire arrivals, in this case the port of Immingham that contained imported coal. In total, the coal traffic share for Yorkshire was 39.1%, the largest share of coal traffic in the UK.

4.1.8 Midlands

The data showed that power stations are the most frequent origin of coal trains in the Midlands, followed by coal mines. Cottam and Ratcliffe power station equated to 55.3% of all coal origins in the Midlands, and combined represented a 5% share of the whole UK. In total, these two power stations took 61.5% of all traffic coming into the Midlands, and 9% of all national coal traffic. Due its central location in the UK, most journeys from the Midlands were relatively small. In total 83% of traffic that arrived in the Midlands was destined for power stations, in particular Cottam and Ratcliffe power stations that received the most.

Most coal before the 1990s in the Midlands was excavated from coal pits in the region, however this changed with more services from Scotland, the North and Yorkshire (Shannon, 2006). In 1994 for example, Ratcliffe took coal mainly from Thoresby and Welbeck with 25 services a week. The smaller distance operations could allow more frequent coal runs, plus they would utilise the yards and sidings as journeys were shorter, eliminating the amount of empty wagons on the network. The data showed that at present, most journeys within the Midlands started at Daw Mill and ending at Ratcliffe. Some journeys continued to the North East to sidings, both loaded and empty, and furthermore to storage sidings at Crewe along the West Coast Main Line. Only one service travelled to Scotland, and only one to Wales, with no operations to the South East or West. Previously coal form the Midlands around Coventry would be used at Didcot power station in the South East, and travelled along the Great Western Main Line (Shannon, 2006).

In total, 71% of coal trains that arrived in the Midlands were scheduled for either Cottam or Ratcliffe power stations. Due to central location of the Midlands, most traffic coming in was loaded for power station, and therefore the Midlands had a higher percentage of traffic arriving then departing. Coal trains that departed the Midlands for the whole UK was 8.7% and 14.8% arrived in the Midland. In total, the coal traffic share for the Midlands was 11.7%.

4.1.9 South East

The smallest region for handling coal, Didcot is the only power station in the South East. Due to the pending closure of the power station, less coal is required and thus traffic has declined. The data showed that in the South East, only one train service went from a yard (Ripples Yard) to Didcot five times a week. It was also likely to be imported coal from London via one of the ports nearby. Imported coal has been used at Didcot for over 25 years, initially from Welsh ports such as Milford Haven, and more recently the ports at Avonmouth. In 1983, 18 services were transporting coal to Didcot, mainly from the Midlands. By 1997 the service was 6 (5 from Avonmouth). In total the coal traffic share for the South East was 0.4%, the smallest share in the UK. The main reason for this is the lack of coal mines, ports and power stations within this region. It could also be assumed that with over a third of the population of the UK now live in the South East (Office of National Statistics, 2011) there is less space on the rail network for extra traffic, and moreover less space in the surrounding areas to build and develop large power stations, yards and ports. Geographically it could be assumed that the lack of coal pits and mines in the areas was due to the type of terrain and lack of coal in the ground. It can therefore be concluded that these problems have contributed to the lack of coal traffic in the region.

4.1.10 South West

The ports of Avonmouth and Portbury (Bristol) served Aberthaw power station. The data showed that one service operated from the South West to Rugeley power station in the Midlands. The Portbury to Rugeley Power Station service ran three times a week, therefore all bar one service travelled less than 100km. Most traffic that arrived in the South West headed to yards and sidings. The data showed that three services went to Stoke Gifford (Bristol) however from these sidings only one service left the yards, onto Uskmouth power station. This therefore means that most of the traffic was for the South West or South Wales. As the data from the timetable is not from a working timetable, it could be assumed that the empty wagons were moved to the ports for imported coal, and thus not included in the data as this information was to available. The total coal traffic share for the South West was 1%, with slightly more trains departing from the region than arriving. In conjunction with the South East, and to therefore put into context the amount of coal traffic in these two regions, the data showed a combined coal traffic share of 1.4%. The coal share of Yorkshire was nearly twenty times this figure.

4.2 The Transhipment Model

4.2.1 Graphical networks and models

First, the transhipment model can be drawn out as a traffic flow chart to illustrate where coal trains are going and coming from. To clarify C = Coal mines, Po = Port, Pw = Power Station and Y = Yards. The data was taken from the pivot tables analysed in the previous chapter 4.1. Using this graphical network we can visualise the flows of movement.

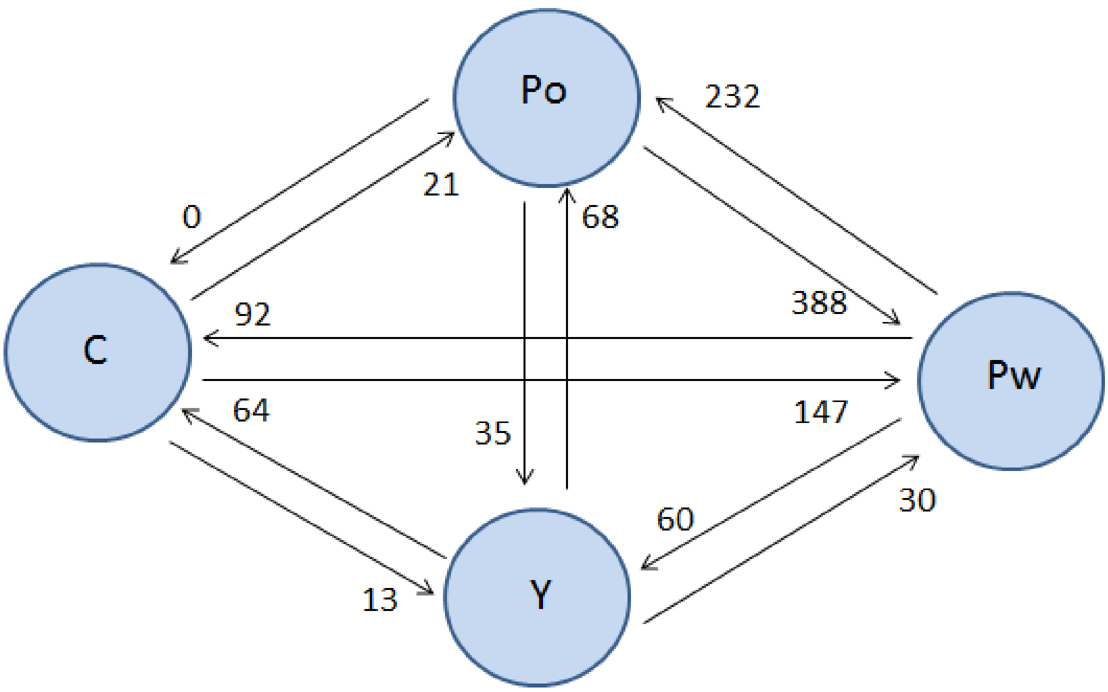


Figure 12 – Traffic flow of coal trains

The network flow of total coal traffic predominantly travels between power stations and ports. Whilst it seems that most trains directly travel from coal mine to power station, or power station to port, there seems to be a large portion of trains using yards and upon initial observation these trains start at ports or power stations and arrive at yards and sidings, where they may be stabled for a period of time before moving onto the coal mine or power station. This may help balance some of the loaded and unloaded trains on the network. For example, a direct train form port to power station counts as only one train, whereas if it goes via a yard this would be counted as two trains, as they have different head codes and different locomotives pulling them, on different days in the week. Likewise it is worth mentioning that some coal trains moved from port to port, or yard to yard which could obscure the data and results.

We can also see how complex moving coal is on the railway with this example taken from the Freightmaster book (Rawlinson, 2011) used to compile the data to demonstrate the imbalance in the operations:

Daw Mill (coal mine) to Ratcliffe (power station) – loaded (distance ~16km)

Ratcliffe (power station) to Milford (yard) – empty (distance ~123km)

Milford (yard) to Carlisle (yard) – empty (distance ~220km)

Carlisle (yard) to Margam (port) – empty (distance ~517km)

Margam (port) to Ayr (yard) – loaded (distance ~683km)

This coal train with 5 separate entries in the data would travel a combined distance of approximately 860km with an unloaded train. For this reason movements from yard to yard and port to port have been removed from the transhipment model as they do not contribute to the journey from supply to demand or visa-versa. In total this equates to 13 movements between ports and 16 movements between yards.

By using linear programming we can add the supply and demand constraints to find out the most effective way of moving coal. We can assume the amount of supply and demand of the locations, based how many trains currently serve the coal mines, ports and power stations (Rawlinson, 2011). Furthermore current coal train flows, i.e number of trains, were used within the model as it was assumed that these are the current required number of trains in comparison to the required supply and demand of the locations. So, if a power station receives X number of trains at the moment, it will still need that many when implementing the model.

The suppliers for the coal industry are the Ports and Coal mines, the power stations require demand and the yards can be categorised as the transhipment points. The discrepancy between supply and demand is due to some coal trains starting loaded at coal mines and going to ports to export coal, so they are not supplying the power stations in the UK.

Firstly we can use apply the traffic flow of coal trains (Figure 12) to loaded trains only. Therefore all trains will start loaded at the coal mines (listed C1 to C5) and will go direct to PW (power stations) or PO (Ports). Alternatively some coal trains will go to Y (yards) and then onto PW or PO. Note that the journey from C3 to Y1 does not go any further, a constraint with the data used.

The data obtained from the Freightmaster book does not detail the next action of a particular train so we cannot prove where this train would go next. Similarly there is an imbalance of supply and demand possible due to the unpredictability and ever-changing nature moving freight on the railway.

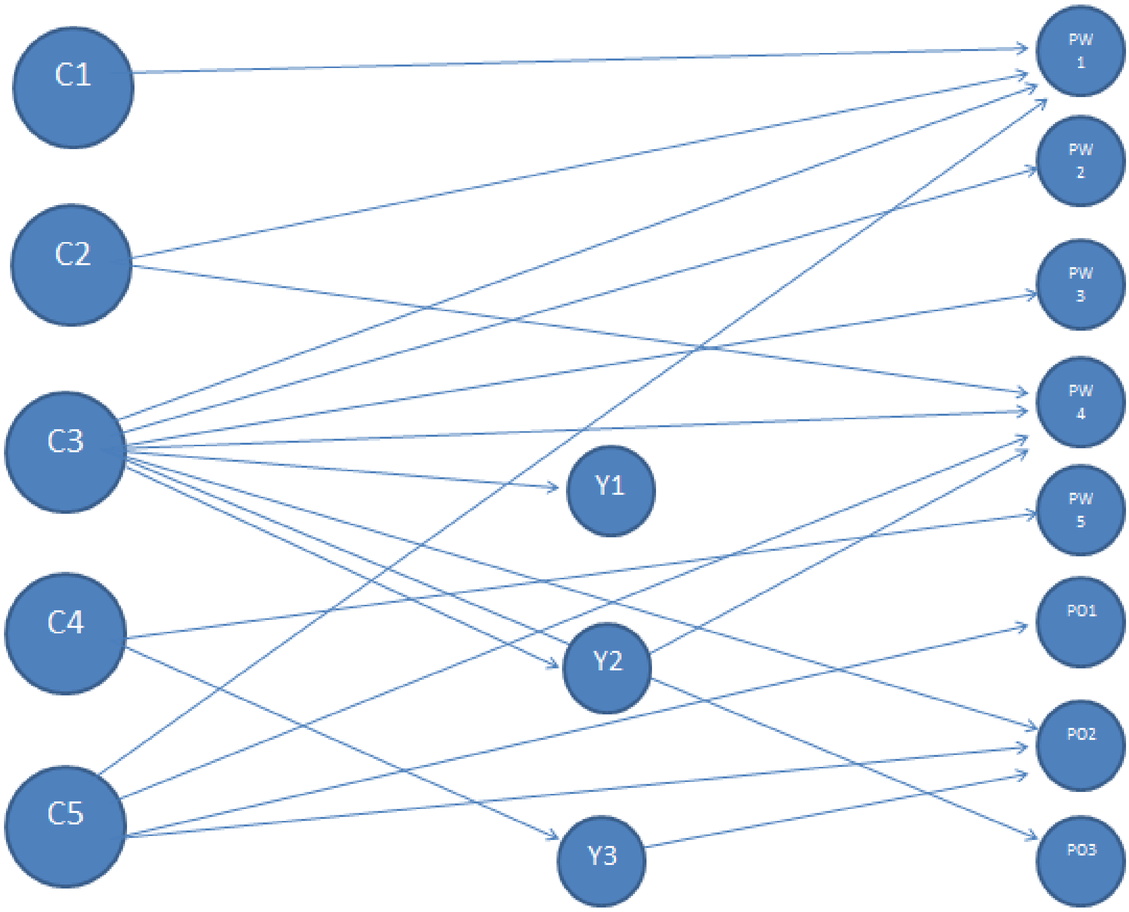


Figure 13 – Graphical Network of Loaded Trains

In the figure above, we can see how many different regions the loaded coal trains go to, as well as via the yards. The full legend list is displayed below:

C1	Midlands	Y1	Midlands	PW1	Midlands	PO1	North East
C2	North East	Y2	North East	PW2	North West	PO2	Yorkshire
C3	Scotland	Y3	Wales	PW3	Scotland	PO3	Wales
C4	Wales			PW4	Yorkshire		
C5	Yorkshire			PW5	Wales		

To understand how we can optimise capacity and determine the ideal locations for coal origins and destinations, the data from the timetable was used in a Transhipment Model based on the one designed by Barlow (Barlow, 1999). Below is a section of the distance matrix with the possible combinations plotted against each location to determine the relevant distances of all locations across the UK.

		Aberthaw p.s	Arpley Yard	Avonmouth	Ayr Falkland Yard	Barnetby Sidings	Barrow Hill	Blackwell	Carlisle	Carlisle Yard	Carstairs	Clitheroe	Cockenzie p.s	Cottam p.s	Crewe	Crewe Basford Hall	Cwbargoed	Daw Mill	Decoy Yard
Wales	Aberthaw p.s	0	325.4	84.2	676.7	415.7	336.8	188.8	512.7	512.7	633	325.4	682	351.8	289.9	289.9	56.6	232.7	362.6
North West	Arpley Yard	325.4	0.0	256.5	353.7	184.9	103.3	142.2	189.7	189.7	310.0	71.3	359.0	58.7	46.6	46.3	286.3	143.6	135.8
South West	Avonmouth	84.2	256.5	0.0	607.8	347.5	268.1	119.9	443.9	443.9	564.1	325.4	613.2	283.7	221.0	221.0	88.7	165.3	293.7
Scotland	Ayr Falkland Yard	676.7	353.7	607.8	0.0	442.9	429.5	493.6	166.7	166.7	78.1	331.5	152.1	306.4	397.5	397.5	637.5	494.7	394.1
Yorkshire	Barnetby Sidings	415.7	184.9	347.5	442.9	0.0	92.9	230.8	278.6	278.6	398.8	169.8	412.8	61.5	224.3	224.3	375.5	195.2	57.8
Yorkshire	Barrow Hill	336.8	103.3	268.1	429.5	92.9	0.0	152.2	265.1	265.1	385.3	147.6	399.1	50.4	99.8	99.8	297.1	116.7	40.4
Midland	Blackwell	188.8	142.2	119.9	493.6	230.8	152.2	0.0	329.4	329.4	449.5	210.8	498.7	168.3	106.4	106.4	149.0	49.9	178.3
North West	Carlisle	512.7	189.7	443.9	166.7	278.6	265.1	329.4	0.0	0.0	121.8	166.9	170.9	278.4	232.9	232.9	472.8	330.1	229.5
North West	Carlisle Yard	512.7	189.7	443.9	166.7	278.6	265.1	329.4	0.0	0.0	121.8	166.9	170.9	278.4	232.9	232.9	472.8	330.1	229.5
Scotland	Carstairs	633.0	310.0	564.1	78.1	398.8	385.3	449.5	121.8	121.8	0.0	287.1	68.6	398.6	353.1	353.1	593.2	450.5	349.7
North West	Clitheroe	325.4	71.3	325.4	331.5	169.8	147.6	210.8	166.9	166.9	287.1	0.0	336.7	36.4	114.1	114.1	354.1	211.3	120.9
Scotland	Cockenzie p.s	682.0	359.0	613.2	152.1	412.8	399.1	498.7	170.9	170.9	68.6	336.7	0.0	412.3	402.0	402.0	642.0	499.2	363.4
Midland	Cottam p.s	351.8	58.7	283.7	306.4	61.5	50.4	168.3	278.4	278.4	398.6	36.4	412.3	0.0	148.2	148.2	312.9	138.7	43.0
North West	Crewe	289.9	46.6	221.0	397.5	224.3	99.8	106.4	232.9	232.9	353.1	114.1	402.0	148.2	0.0	0.0	250.6	108.0	137.0
North West	Crewe Basford Hall	289.9	46.3	221.0	397.5	224.3	99.8	106.4	232.9	232.9	353.1	114.1	402.0	148.2	0.0	0.0	250.6	108.0	137.0
Wales	Cwbargoed	56.6	286.3	88.7	637.5	375.5	297.1	149.0	472.8	472.8	593.2	354.1	642.0	312.9	250.6	250.6	0.0	195.1	323.5
Midland	Daw Mill	232.7	143.6	165.3	494.7	195.2	116.7	49.9	330.1	330.1	450.5	211.3	499.2	138.7	108.0	108.0	195.1	0.0	147.7
Yorkshire	Decoy Yard	362.6	135.8	293.7	394.1	57.8	40.4	178.3	229.5	229.5	349.7	120.9	363.4	43.0	137.0	137.0	323.5	147.7	0.0

Figure 14 - Example of Distance Combinations

A transhipment model was created based on the data and the distances obtained from the AA route planning website. The solver add-on in Excel was used to determine which locations were supply or demand and based on the distance, how many trains should be allocated in that period. Additionally, number of trains that each location served was added so comparisons could be made.

The data obtained from the model only shows either trains coming in (demand) or trains departed (supply). So for example, even though a port will receive traffic both loaded and empty the model only recognised ports as a supplier of coal. Therefore trains that go loaded to the ports have not been taken into consideration as it would have been too complex and would obscure the results.

4.2.2 Results

Using linear programming with excel formula to assume routes for coal trains by distance and amount of required consumption or supply, the following results table was produced. It has been sorted by the number of trains required. To ensure that the model worked successfully, Yards and sidings had to be removed from the data as a destination. Whilst this means that they are not incorporated in train movements in the model, we can assume where trains made require the use of Yards if the distance between the two locations is very long. Put simply, a yard would not be a final destination of a coal train, merely a temporary stabling point.

Table 18 – Results from Transhipment Model

From		Region	To		Region	Distance	No of required trains
Maltby	*Coal mine*	*Yorkshire*	Drax p.s	*Power Station*	*Yorkshire*	116.7	76
Hunterston	*Port*	*Scotland*	Longannet p.s	*Power Station*	*Scotland*	104.9	63
Blackwell	*Coal mine*	*Midland*	Cottam p.s	*Power Station*	*Midland*	168.3	63
Worksop	*Yard/Sidings*	*Midland*	Blackwell	*Coal mine*	*Midland*	158.8	61
Immingham	*Port*	*Yorkshire*	Eggborough p.s	*Power Station*	*Yorkshire*	82.9	50
Immingham	*Port*	*Yorkshire*	Scunthorpe	*Power Station*	*Yorkshire*	35.9	48
Daw Mill	*Coal mine*	*Midland*	Ratcliffe p.s	*Power Station*	*Midland*	16.3	44
Immingham	*Port*	*Yorkshire*	Ferrybridge p.s	*Power Station*	*Yorkshire*	91.2	39
Liverpool Bulk Term	*Port*	*North West*	Fiddlers Ferry	*Power Station*	*North West*	25.3	35
Killoch	*Coal mine*	*Scotland*	Fiddlers Ferry	*Power Station*	*North West*	341.7	34
Ellesmere Port	*Port*	*North West*	Fiddlers Ferry	*Power Station*	*North West*	31.2	23
Doncaster Decoy	*Yard/Sidings*	*Yorkshire*	Daw Mill	*Coal mine*	*Midland*	147.7	23
Barrow Hill	*Yard/Sidings*	*Yorkshire*	Rugeley p.s	*Power Station*	*Midland*	94.3	19
Immingham	*Port*	*Yorkshire*	Drax p.s	*Power Station*	*Yorkshire*	80.5	17
Millerhill	*Yard/Sidings*	*Scotland*	Cockenzie p.s	*Power Station*	*Scotland*	15.4	15
Cwbargoed	*Coal mine*	*Wales*	Aberthaw p.s	*Power Station*	*Wales*	56.6	14
Liverpool	*Port*	*North West*	Ironbridge p.s	*Power Station*	*Midland*	120.9	10
Cockenzie p.s	*Power Station*	*Scotland*	Hunterston	*Port*	*Scotland*	158.4	10
Garston	*Port*	*North West*	Ellesmere Port	*Port*	*North West*	38.3	8
Leith Docks	*Port*	*Scotland*	Lynemouth	*Power Station*	*Scotland*	170.3	8
Immingham	*Port*	*Yorkshire*	West Burton p.s	*Power Station*	*Midland*	66.3	7
Crewe Basford Hall	*Yard/Sidings*	*North West*	Liverpool	*Port*	*North West*	76.4	7
Hatfield Mine	*Coal mine*	*Yorkshire*	Drax p.s	*Power Station*	*Yorkshire*	285.2	7
Avonmouth	*Port*	*South West*	Aberthaw p.s	*Power Station*	*Wales*	84.2	3
Portbury	*Port*	*South West*	Uskmouth p.s	*Power Station*	*Wales*	41.5	1

One weakness with the model was whilst the number of trains required could be based on actual train runs in reality, no prior information was used to determine how much each of the starting location could supply or demand. As the table above shows, the model proposed that Maltby Coal Mine should provide Drax with 76 trains per week, sufficiently more than the 17 trains it additionally recommends from the port of Immingham. Unfortunately we cannot prove from the model if indeed Maltby Coal Mine can supply 76 trains a week. What the table does show however is the potential to utilise local suppliers and demands to improve capacity on the network and potential redundancy of major rail marshalling yards and long distance coal trains. The model suggests that the greatest distance required is 341.7km for 34 trains form Killoch Coal Mine in Scotland to Fiddler's Ferry Power Station in the North West compared with the current longest distance of 682.4km between Margam and Ayr.

By analysing the data further we can see the general flow of the traffic and how this would be represented on the map of the UK. Most of the coal trains would start in the North West and Yorkshire and move to Yorkshire and the Midlands. This would alleviate some of the heavy traffic moving up and down the country. If we look at the results of the main power stations we can see that Drax would receive all the coal it required from Yorkshire, whilst Cottam power station would receive all the required coal from the coal mines in the Midlands. Power stations in Wales would be supplied by the ports of the south west and all of the power stations in Scotland would be supplied from ports and coal mines in Scotland. As a comparison, below is the train runs to Cottam power station to highlight the difference.

Table 19 – Train runs to Cottam Power Station

From	Region	Type of origin	To	Region	Type of destination	Distance (km)
Hunterston	Scotland	Port	Cottam p.s	Midland	Power Station	474.4
Hunterston	Scotland	Port	Cottam p.s	Midland	Power Station	474.4
Killoch	Scotland	Coal mine	Cottam p.s	Midland	Power Station	423.9
New Cumnock	Scotland	Coal mine	Cottam p.s	Midland	Power Station	257.2
New Cumnock	Scotland	Coal mine	Cottam p.s	Midland	Power Station	257.2
New Cumnock	Scotland	Coal mine	Cottam p.s	Midland	Power Station	257.2
New Cumnock	Scotland	Coal mine	Cottam p.s	Midland	Power Station	257.2
North Blyth	North East	Port	Cottam p.s	Midland	Power Station	257.2
Hatfield Mine	Yorkshire	Coal mine	Cottam p.s	Midland	Power Station	202
Blackwell	Midland	Coal mine	Cottam p.s	Midland	Power Station	168.3
Immingham	Yorkshire	Port	Cottam p.s	Midland	Power Station	76
Immingham	Yorkshire	Port	Cottam p.s	Midland	Power Station	76
Immingham	Yorkshire	Port	Cottam p.s	Midland	Power Station	76
Immingham	Yorkshire	Port	Cottam p.s	Midland	Power Station	76
Immingham	Yorkshire	Port	Cottam p.s	Midland	Power Station	76
Immingham	Yorkshire	Port	Cottam p.s	Midland	Power Station	76
Immingham	Yorkshire	Port	Cottam p.s	Midland	Power Station	76

As we can compare the actual train runs with the model, it is obvious from the proposed new routes and number of trains that there would be sufficient improvements on the network ift he mode was adopted. From the table above we can see how Cottam power station receives coal trains from Scotland, the North East, Yorkshire and the Midlands. The transhipment model proposed one service from Blackwell coal mine to run all 63 trains that are required. This also meant that coal from the port of Immingham would not be required. In total the model suggested that only 161 trains could be served by the port of Immingham, which equates to 24% of total coal trains. Presently 16.5% of total coal trains start at Immingham however this includes coal train runs to yards and sidings which have not be included in the transhipment model. In total 46% of coal trains would start at ports. The transhipment proposed that less trains were required on the UK network to run coal trains effectively to meet the required supply and demand of the ports, power stations and coal mines. Eliminating the yards and sidings would create more direct routes and also therefore more services at shorter distances.

There are however, some ambiguous results. The model suggested removing numerous current train runs as perhaps it considered these not effective due to the length of the journey or limited trains run. However some train runs were calculated that would need to be analysed. The model suggested that 8 trains would be required to run between the ports of Garston and Ellesmere Port. It is unclear why this would need to be implemented; especially a distance between of only just over 38km such a journey seems inadequate. This could be viewed as a way of moving loaded or unloaded trains between ports to connect up and create larger coal trains to run longer distances. Perhaps it is better to send one long train than two smaller ones. Similarly yards and sidings can be utilised and incorporate into the results by allocating various stops if capacity became an issue or on longer journeys.

5 Conclusions

5.1 Findings

The findings and results can be concluded into two parts: the conclusions from the data and the conclusions from the transhipment model.

Firstly the data, and the statistics proved that trains that moved to and from the ports carried the most traffic. In 2011, 37% of coal trains started at ports, and 28% of coal trains arrived at ports. The difference between the two explained how more imported is used in the UK compared during the last 50 years. Two important reasons are firstly, the increased amount of coal trains moving to and from ports, but also significantly that 96% of coal trains that started at ports were loaded and only 3% of coal trains that headed to ports are loaded. Additionally 93% of coal trains that started at ports, also headed to power stations. This implies that more trains arrived at the ports unloaded; they were then loaded up, and then departed back to the power stations. The data and results supported this statement and therefore concluded how the coal trains moved around the UK.

In total the results suggested that 54% of all coal trains were loaded, therefore more coal trains on the network carried goods. Overall, 13% of locations received 50% of all coal traffic; mostly power stations, and 50% of coal traffic started at 14% of all coal locations; mainly ports. Unfortunately this implied that there were key locations within the UK that consumed or required more services than others. Such statistics were used to justify the closure of many railway lines and routes in the 1960s under the “Beeching Report”. The proportion of traffic on the railway now is unbalanced around the country. Perhaps after analysing the results, it would be important to acknowledge the coal locations that contribute little to the movement of coal, and perhaps discuss if these locations are still significant today.

Further results showed that power stations generated the second highest amount of traffic, most that departed and also coal traffic that arrived. This reaffirms the assumptions that more trains shuttled between power stations and ports, rather than between power stations and coal mines. The data when calculated using the AA route planner roads distances and compared with the UK rail maps, demonstrated that ports and therefore subsequently journeys were longer than the 50 years ago. The strategic placing of new ports and power stations has meant that journeys can be made effectively within the regions; however, it has enabled longer distances from other regions.

Yorkshire had the largest share of coal traffic in the UK, both within the region and also traffic to other regions. When the distances were calculated between the coal locations, the distances have increased over the last year, and not the amount of coal transported around the UK. Due to Yorkshire’s location within the UK, it’s connections to the North, Midlands and

Europe and the amount of important ports and power station within the region, it can be concluded that to maximise coal operations this region is the most productive and utilised the locations the most effectively.

The transhipment model converted the data and results to determine the optimum levels of the coal traffic and how this would shape coal trains and traffic flow on the current UK railway network. For the model to work successfully yards and sidings were removed as destinations as realistically, they would not be the final loading or unloading place for the coal trains, and therefore not a true destination merely a temporary storage facility. The model proposed that the power stations in the UK could successfully be supplied by ports and coal mines within a realistic distance and within the same region. Ports would continue to provide most of the coal, in particular Immingham. However the model failed to acknowledge the productivity of the coal mines in the UK, so whilst the ports could supply the amount required it cannot be assumed that the coal mines would be able to satisfy the number of coal trains required. A more detailed look into the coal production of each coal mine would allow for the model to re-calculate the flow of trains based on supply. The model successfully proved that if coal mines and ports could supply the amount predicted, there is potentially a more effective method of strategically moving coal trains and it is possible to reduce the distance and length of journey of coal trains.

To conclude overall, the data and the model have supported the statement that coal traffic is moving more than compared to historic statistics due to the length of distance coal train are moving. The decline in coal mines and coal production in the UK has meant more imported coal is required to come to the shores of the UK. The routes that coal trains take have significantly changed too, over the last 50 years. The analysis of the maps from the 1960s, the 1980s and the 2000s proved this, combined with the demise of the coal mines in the North East and the increase of power stations and ports in Yorkshire. This impacted on where coal trains now start and where they are destined to. The creation of the power stations over the last 40 years reaffirms that coal is still required in the UK to power them, and whilst British coal has decreased in production, imported coal has been used as an effective replacement, and the railway system has adapted to enable robust traffic flows.

5.2 Recommendations

The findings of the work are useful for analysing the coal movements of the UK. There are some imperfections with the work detailed below, that could be improved to provide a much more accurate set of data and results. The knowledge attained from the model is important to understand how effective the coal traffic movement is in the UK.

Based on the data, particularly from the Freightliner timetable, it is evident which ports and power stations require the most traffic and also produce traffic for the UK and abroad. In line with new capacity enhancements, proposals could be considered for re-connecting some of the old private goods and freight lines, if this means separating the freight from the mainline, and thus improving and increasing coal services and improving passenger services and frequencies. Further studies into potential coal production of coal mines could help appreciate if the coal mines are indeed able to produce more coal and how much can be used towards supply the power station.

Yards and sidings are still importance to ease congestion on the mainline, but a review into which trains and in particular which yards are being used would help determine the ability to effectively manage the number of coal trains. Similarly, consideration could be made on how practical long distance coal trains are, and whether it would be possible to limit these by utilising local and regions coal mines, power stations and ports.

5.3 Review of Approach

The approach to the project was such that historic trends could be analysed in conjunction with the modelling of the railway today. The transhipment model was an ideal model to make and use, due to the simplicity, although a tedious method to create. Some minor details and alterations to satisfy the project may indeed impede the results. Two significant problems that had to be overcome in not the most efficient way were the calculation of number of trains and also the distances of journeys. The number of train services was calculated from the timetables based on each train’s head code. The number of freight trains differs from passengers as the timetable is more flexible and not so rigid. Therefore the resource from which the data was retrieved specified that some trains might run one, two, three or zero times a week. This therefore made the data not as accurate as anticipated, something that would be challenging to change, and perhaps indicates why there is less literature on freight compared to passenger services. Whilst most of the train services did indeed run every day, some did not and so may upset the data and thus the results. Also importantly, it was difficult to attain the actual distances of the railway routes. These were not easily available to find compared to road distances, as some of the routes used private lines which were sometimes difficult to trace, even when using google earth as lines join up at junctions and mainlines. So it was difficult to trace the definitive route as there could be multiple ways to get from A to B. To overcome this, distances were taken from the AA route planner website, and therefore unfortunately based on the road distances rather than the railway, although most of the lines ran almost parallel so a 10% margin of error each way could be sufficient when analysing and comparing the data and the results.

5.4 Areas for Further Work / Research

Should the work be carried on or more research to be conducted, it would be an ideal start to obtain all coal mine production levels and potential or maximise loads that could be sent out on a weekly basis, to determine optimum numbers of coal trains. Moreover, further studies into ports and power stations would be beneficial. Significantly the investigation into yards, where trains come from and where they go, the duration within the sidings and weather trains combine or separate would help to understand how yards and sidings could be more effectively used on the network.

In addition it would be worth comparing this data and the results to other freight modes in the UK to identify trends. It was initially intended to mirror the work for coal by rail and also apply to the container industry in the UK. Additionally comparing the rest of Europe regarding moving coal and distances would provide more information on the changing nature of moving coal. However this would be an extremely large and ambitious project and to obtain accurate data could prove difficult.

6 Bibliography

Anghinolfi, D., Paolucci, M., Sacone, S. and Siri, S. (2011). 'Freight transportation in railway networks with automated terminals: A mathematical model and MIP heuristic approaches'. *European Journal of Operational Research*. vol. 214. no. 3. November. p. 588–594.

Ashwoth, W. (1986). *The History of the British Coal Industry 1946-1982: The Nationalised Industry*. Oxford: Clarendon Press.

Barlow, J.F. (1999). *Excel Models For Business and Operations Management*. New York: Wiley.

Barrie, D.S.M. (1980). *A Regional History of the Railways of Great Britain: Volume XII South Wales*. London: David & Charles.

Beurrier, A., Demota, P., Levine, P. and Pomerol, J.-C. (1990). 'Distribution of Empty Railcars by an Expert System: A Case Study with Comparison with OR Approaches'. *Journal of the Operational Research Society*. vol. 41. no. 6. pp. 527-537.

British Railways Board (1963). *The Reshaping of British Railways*. London: Her Majestry's Stationary Office.

British Railways Board (1965). *The Development of the major railway trunk routes*. London: British Railways Board.

British Transport Commission (1955). *Modernisation and re-equipment of British Railways*. London: British Transport Commission.

Brooks, R.J. and Tobias, A.M. (1996). 'Choosing the Best Model: Level of Detail, Complexity and Model Performance'. *Mathematical and Computer Modelling*. vol. 24. no. 4. May. pp. 1-14.

Callinicos, A. and Simons, M. (1985). *The Great Strike - The Miner's strike of 1984-85 and it's lessons*. London: Socialist Worker.

Cao, C., Gao, Z. and Li, K. (2012). 'Capacity allocation problem with random demands for the rail container carrier'. *European Journal of Operational Research*. vol. 217. pp. 214-221.

Cheng, Y. and Lin, W.-H. (2004). 'A Network-based Scheme for Allocating the Cost of Empty Railcar Movements in Railway Systems'. Taipei, Taiwan.

Coal Industry Advisory Board (1985). *Moving Coal: a study of transport systems*. Paris: IEA.

Crainic, T., Florian, M. and Leal, J.-E. (1990). 'A Model for the Strategic Planning of National Freight Transportation by Rail'. *Transportation Science*. vol. 24. no. 1. pp. 1-24.

Department for Transport (2006). *Focus on Ports*. Basingstoke: Palgrave Macmillan.

Department for Transport (2007). *Delivering a Sustainable Railway*. London: Department for Transport.

Department for Transport (2011). *Realising the potential for GB rail*. London: Department for Transport.

Freeman, M. and Aldcroft, D. (1985). *The Atlas of British Railway History*. London: Croom Helm.

Gourvish, T. (1986). *British Railways 1948-73*. Cambridge: Cambridge University Press.

Griffin, A.R. (1981). *The Nottinghamshire Coalfield 1881 - 1981: A Century of Porgress*. Ashbourne: Moorland Publishing Ltd.

Harris, N.G. and Schmid, F. (2003). *Planning Freight Railways*. London: A & N Harris.

Haywood, R. (1999). 'Land development implications of the British rail freight renaissance'. *Journal of Transport Geography*. vol. 7. pp. 263-275.

Haywood, R. (2007). 'Britain's national railway network: fit for purpose in the 21st century?'. *Journal of Transport Georgraphy*. vol. 15. pp. 198-216.

Heaton, J. (2011). 'Blyth Spirit'. *The Railway Magazine*. vol. 157. no. 1319. pp. 42-46.

Hoole, K. (1986). *A Regional History of the Railways of Great Britain: Volume IV The North East*. Devon: David & Charles.

Humm, R. (2013). 'How the 'Axe' fell: 50 years since Beeching'. *The Railway Magazine*. vol. 159. no. 1343. March. pp. 14-20.

Ison, S., Frost, M. and Watson, R. (2012). 'UK rail transport: a review of demand and supply'. *Institution of Civil Engineers*. vol. 165. no. TR3. pp. 225-234.

Jones, R. (2012). *Beeching the Inside Track*. Lincoln: Mortons Media Group.

Liu, S.Q. and Kozan, E. (2011). 'Optimising a coal rail network under capacity'. *Flex Serv Manufacturing Journal*. vol. 23. pp. 90-110.

Loft, C. (2006). *Government, the Railways and the Modernization of Britain*. London: Routledge.

Lowe, D. (2005). *International Freight Transport*. Oxford: Elsevier Butterworth-Heinemann.

Mamurekli, D. (2010). 'Environmental impacts of coal mining and coal utilization in the UK'. *Acta Montanistica Slovaca*. vol. 15. no. 2.

Marinov, M. and Viegas, J. (2011). 'A mesoscopic simulation modelling methodology for analyzing and evaluating freight train operations in a rail network'. *Simulation Modelling Practice and Theory*. vol. 19. pp. 516-539.

Modern Railways (1962). 'Midlands Carries Heaviest Freight'. *Modern Railways*. vol. 16. no. 168. pp. 146-149.

Monk-Steel, D. (2012). *Merry-Go-Round*. London: HMRS.

Morris, J.H. and Williams, L.J. (1958). *The South Wales Coal Industry 1841 - 1875*. Cardiff: University of Wales Press.

Mu, S. and Dessouky, M. (2011). 'Scheduling freight trains traveling on complex networks'. *Transportation Research Part B: Methodological*. vol. 45. no. 7. August. pp. 1103-1123.

Narisetty, A.K., Richard, J.-P.P., Ramcharan, D., Murphy, D., Minks, G. and Fuller, J. (2008). 'An Optimization Model for Empty Freight Car Assignment at Union Pacific Railroad'. *Interfaces*. vol. 38. no. 2. pp. 89-102.

Nash, C., Coulthard, S. and Matthews, B. (2004). 'Rail track chrages in Great Britain - the issue of charging for capacity'. *Transport Policy*. vol. 11. pp. 315-327.

Network Rail (2007). *Freight Route Utilisation Strategies*. London: Network Rail.

Rawlinson, M. (2011). *Freightmaster: The National Railfreight Timetable*. 201163rd edition. Swindon: Freightmaster Publishing.

Shang, Z. and Kokossis, A. (2004). 'A transhipment model for the optimisation of steam levels of total site utility system for multiperiod operation'. *Computers & Chemical Engineering*. vol. 28. no. 9. August. p. 1673–1688.

Shannon, P. (1998). 'Rail, Road & Sea: The Container Story'. *The Railway Magazine*. vol. 144. no. 1169. pp. 56-60.

Shannon, P. (2000). 'The British Freight Scene in Focus No 4 = Coal Blackgold'. *The Railway Magazine*. pp. 24-30.

Shannon, P. (2000). 'The British Freight Scene in Focus Part II (North West Midlands Wales and the South)'. *The Railway Magazine*. pp. 24-27.

Shannon, P. (2006). 'All Change Freight: East Midlands Coal'. *The Railway Magazine*.

Shannon, P. (2006). 'Freightliner - Ten Years in the private sector'. *The Railway Magazine*.

Shannon, P. (2006). *Rail Freight Since 1968 Coal*. Kettering: Silver Link Publishing Ltd.

Shannon, P. (2007). 'Port to Power Station'. *The Railway Magazine*.

Shannon, P. (2011). 'West Midlands Freight - Then and Now'. *The Railway Magazine*. vol. 157. no. 1319. pp. 14-19.

Sharma, D.K. and Jana, R.K. (2009). 'A hybrid genetic algorithm model for transshipment management decisions'. *International Journal of Production Economics*. vol. 122. no. 2. December. pp. 703-713.

Sherali, H.D. and Lunday, B.J. (2011). 'Equitable apportionment of railcars within a pooling agreement for shipping automobiles'. *Transport Research Part E*. vol. 47. pp. 263-283.

Sherali, H. and Suharko, A. (1998). 'A tactical Decision Support System for Empty Railcar Mangement'. *Transportation Science*. vol. 32. no. 4. pp. 306-329.

Spieckermann, S. and Voss, S. (1995). 'A case study in empty railcar distribution'. *European Journal of Operational Research*. vol. 87. pp. 586-598.

The Railway Magazine (1965). 'Merry-Go-Round'. *The Railway Magazine*. vol. 15. no. 3. March. p. 172.

The Railway Magazine (2012). 'Britain's Freight Only Routes'. *The Railway Magazine*. March. pp. 16-21.

Turnock, D. (1998). *An Historical Georgraphy of Railways in Great Britain*. Aldershot: Ashgate.

Vanek, F.M. and Smith, R.I. (2004). 'Prospects for Rail Freight from Peripheral Regions: The Case of North-East Scotland and Grampian Country Foods'. *International Journal of Logistics: Research and Applications*. vol. 7. no. 1. March. pp. 59-70.

Vis, I.F.A. and de Koster, R. (2003). 'Transshipment of containers at a container terminal: An overview'. *European Journal of Operational Research*. vol. 147. pp. 1-16.

Whittaker, J.R. (1975). *Containerization*. 2nd edition. London: Hemisphere.

Wiles, P.G. and van Brunt, B. (2001). 'Optimal location of transshipment depots'. *Transportation Research Part A: Policy and Practice*. vol. 35. no. 8. September. p. 745–771.

Woodburn, A. (2003). 'A logistical perspective on the potential for modal shift of freight from road to rail in Great Britain'. *International Journal of Transport Management*. vol. 1. pp. 237-245.

Woodburn, A. (2007). 'Appropriate indicators of rail freight activity and market share: A review of UK practice and recommendations for change'. *Transport Policy*. vol. 14. pp. 59-69.

Woodburn, A. (2008). 'Intermodal Rail Freight in Britain: A Terminal Problem?'. *Planning Practice & Research*. vol. 23. no. 3. pp. 441-460.

Woodburn, A. (2011). 'An Investigation of Container Train Service Provision and Load Factors in Great Britain'. *EJTIR*. vol. 11. no. 2. pp. 147-165.

Woodburn, A. (2012). 'Intermodal rail freight activity in Britain: Where has the growth come from?'. *Research in Transportation Business & Management*. vol. 5. pp. 16-26.

http://www.legislation.gov.uk/ukpga/1993/43/contents - for the Railway Act 1993 by Her Majesty's Stationary Office (Accessed 28 Feb 13)

www.ons.gov.uk/ons/rel/regional.../portrait-of-the-south-east.pdf - for the statistics on population of the South East of the United Kingdom (Accessed 22 June 13)