

The development of the railway network in Britain 1825-1911¹

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1. Introduction

This chapter describes the development of the British railway network during the nineteenth century and indicates some of its effects. It is intended to be a general introduction to the subject and takes advantage of new GIS (Geographical Information System) maps to chart the development of the railway network over time much more accurately and completely than has hitherto been possible. The GIS dataset stems from collaboration by researchers at the University of Cambridge and a Spanish team, led by Professor Jordi Marti-Henneberg, at the University of Lleida. Our GIS dataset derives ultimately from the late Michael Cobb's definitive work '[The Railways of Great Britain. A Historical Atlas](#)'. Our account of the development of the British railway system makes no pretence at originality, but the chapter does present some new findings on the economic impact of the railways that results from a project at the University of Cambridge in collaboration with Professor Dan Bogart at the University of California at Irvine.² Data on railway developments in Scotland are included but we do not discuss these in depth as they fell outside the geographical scope of the [research project](#) that underpins this chapter. Also, we focus on the period up to 1911, when the railway network grew close to its maximal extent, because this was the end date of our research project.

The organisation of the chapter is as follows. The next section describes the key characteristics of the British transport system before the coming of the railways in the nineteenth century. Section three discusses the long pre-history of railways and the technological developments that made them possible. Fourthly, we describe how the railway age began with the opening of the Stockport and Darlington Railway in 1825 and the Liverpool and Manchester Railway in 1830. Section five discusses the speculative 'manias' of railway investment which soon followed. Section six uses the new GIS dataset to describe the evolution of the British railway network after 1830. The next two sections explore the efficiency of the British railway system and its impact on British economy and society. Finally, conclusions are drawn.

2. Transport before railways

In all pre-industrial economies, poor transport links were a major obstacle to economic growth. The late seventeenth and eighteenth century saw major improvements to transport systems in England and Wales that accompanied and facilitated early industrialisation and regional specialisation. For reasons laid out by the famous political economist Adam Smith, transport by water was the only economic option for goods with a high weight to value ratio:

¹ This Atlas was made possible by a Higher Education Impact Fund grant awarded to Leigh Shaw-Taylor, *Cambridge e-Resources for teaching economic history and historical economic geography in secondary schools*.

² The research underlying this atlas chapter were made possible by three research grants: Economic and Social Research Council grant: *The Occupational Structure of Nineteenth Century Britain*: [Grant RES-000-23-1579](#). Leigh Shaw-Taylor was Principal Investigator and E.A. Wrigley was co-investigator; The Leverhulme Trust. *The Occupational Structure of England and Wales c.1379-c1729* (F/09/774/9): £505k. F/09 674/G. Leigh Shaw-Taylor was Principal Investigator and Professor Sir E.A. Wrigley and Professor R.M. Smith were co-investigators; The Leverhulme Trust, *Transport, Urbanization and Economic Development c.1670-1911*: Leigh Shaw-Taylor was PI. Professor Sir E.A Wrigley and Professor Dan Bogart (UC Irvine) were Co-Is

“As by means of water-carriage a more extensive market is opened to every sort of industry than what land carriage alone can afford, so it is upon the sea coast, and along the banks of navigable rivers that industry of every kind naturally begins to subdivide and improve itself, and it is frequently not till a very long time after those improvements extend themselves to the inland parts of the country. A broad wheeled wagon attended by two men, and drawn by eight horses, in about six weeks time carries and brings back between London and Edinburgh near four ton weight of goods. In about the same time a ship navigated by six or eight men, and sailing between the ports of London and Leith, frequently carries and brings back two hundred tonne weight of goods. Six or eight men, therefore, by the help of water carriage, can carry and bring back in the same time the same quantity of goods between London and Edinburgh, as fifty broad wheeled wagons attended by a hundred men and four hundred horses.”

Adam Smith, *Wealth of nations* (1776)

Coal had much the highest weight to value ratio of any major commodity. In the eighteenth century, moving coal ten miles by road would typically double the pit-head price. Unsurprisingly, coal was rarely used more than 10-15 miles from a coal-field or navigable waterway. Moving coal by water was radically cheaper than moving it overland, because water massively reduces friction. As we will see, the reduction of friction was a major factor in the development of the railways.

During the seventeenth and early eighteenth centuries the length of navigable rivers was considerably extended, while the second half of the eighteenth century saw the building of an extensive canal network in just a few decades. These improvements to inland waterways are explored at length in another chapter of this Atlas.³ Crucial though rivers and canals were to the transportation of heavy goods, coastal shipping was the dominant means of transportation for these goods and this continued well into the railway age.

Coal made up most of the ton-mileage and it rarely travelled far by road. Stage-waggons with broad wheels that were designed to cope with poor road surfaces (see Figure 1) rumbled along the country's roads on scheduled services and moved higher-value goods. The eighteenth century saw major improvements to main roads through the growth of turnpikes - roads on which tolls were charged. Toll receipts were used to improve road quality, which resulted in increased speeds, reduced costs and fewer accidents.

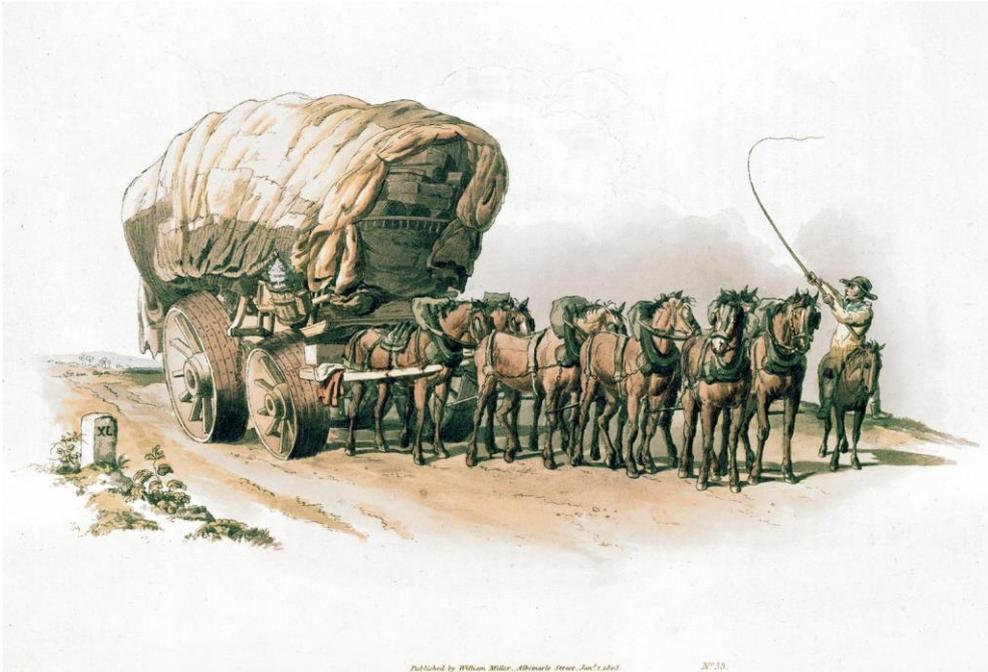
At the dawn of the railway age, the dominant form of passenger transport for those who could afford it was the scheduled stage coach - see Figure 2. These could whisk passengers around the country at an average speed of 8 miles an hour for 24 hours a day - a feat which astonished, and sometimes terrified, European visitors. However, stage coaches were far too expensive for most of the population. A hundred years earlier most main roads were unsuitable for wheeled traffic and those who could afford it travelled predominantly on horseback. They rarely achieved average speeds of more than three miles per hour and travel was generally restricted to daylight hours. The turnpike roads and the revolution they wrought are the subject of another chapter in this Atlas.⁴

In the hundred and fifty years preceding the early nineteenth century, the country's transport system improved out all recognition. This is shown in Figure 3. The left-hand panel presents an 'isochrone' map that shows how far a traveller on horseback could get from London c.1680 in a specified number of hours when travelling on the main roads mapped by John Ogilby. The right-hand panel shows isochrones from London c.1830 when travelling by stage coach.

³ Satchell, M., *Navigable waterways and the economy of England and Wales 1600-1835*

⁴ Bogart, D., *The turnpike roads of England and Wales*.

Figure 1: A stage-waggon



Print, aquatint, coloured, Plate 38 'Waggon' / W.H.Pyne. 'The Costume of Great Britain' engraved and written by W.H. Pyne, 1808. Science Museum Group Collection. © The Board of Trustees of the Science Museum. This image is released under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 Licence

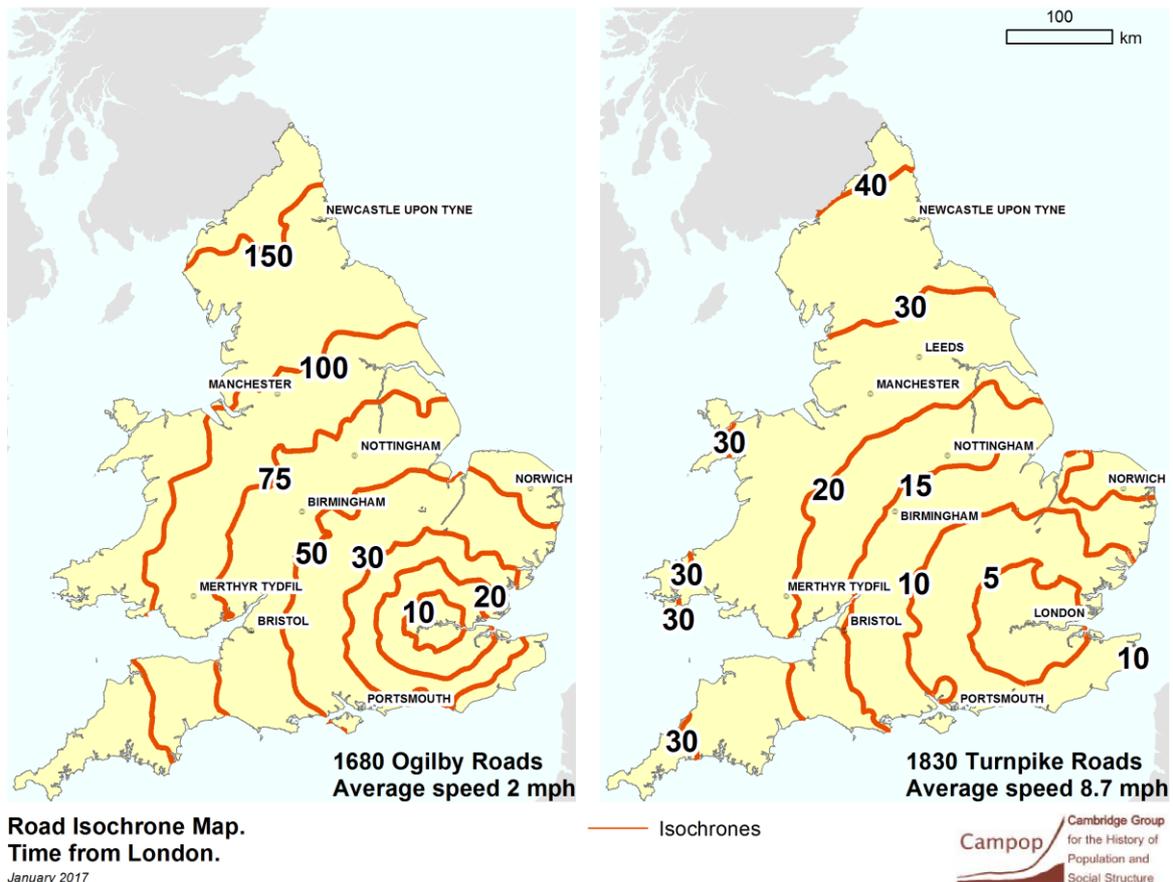
Figure 2: A stage coach



The 'Tally-Ho' London - Birmingham Stage Coach Passing Whittington College, Highgate, James Pollard, 1836. Tate Gallery, London. Image released under [Creative Commons CC-BY-NC-ND \(3.0 Unported\)](https://creativecommons.org/licenses/by-nc-nd/3.0/)

The improvements in English and Welsh transportation that have been described were the prelude to a more revolutionary development in transportation: the railways; this eventually brought safe and affordable travel to a large proportion of the working population at unprecedented speeds. In addition, and importantly, the railways supplied Britain's rapidly growing cities with food, coal and raw materials on a hitherto unimaginable scale and they enabled rich natural resources to be commercially exploited for the first time.

Figure 3: Road isochrone maps for England and Wales in 1680 & 1830



3. The genesis of steam powered railways

Usually, the opening of the Liverpool to Manchester Railway in 1830 is regarded as the start of the railway age and this still seems valid. However, it should be remembered that English and Welsh railway development was a long-drawn out process rather than a single event. The world's first fully-steam powered public railway that carried both passengers and freight took considerable time to evolve.

Railways (waggons on rails) have a much longer history than public railways. An excellent overview of the use of railways on the coal-fields before 1830 can be found in Michael Flinn's, *History of the British Coal Industry 1700-1830*, on which the next four paragraphs draw heavily.⁵ Wheeled tubs on wooden rails were used in mines in Germany, Alsace and Lorraine as early as early as the fifteenth century and tracks for wheeled vehicles were not

⁵ Flinn, M., *History of the British Coal Industry 1700-1830*, pp. 146-63.

unknown in the ancient world.⁶ Horse-drawn waggonways were in use on a number of English coalfields in the early seventeenth century, having been introduced into Britain by German miners in the Lake District in the sixteenth century. By the early eighteenth century, they were in general use on the great North-Eastern coal field, where they ran from the pit-head down to the staithes on the River Tyne; from here, coal was shipped down the east coast of England to the rapidly expanding city of London. These waggonways often involved considerable engineering work. For instance, Figure 4 shows the Causey Arch, the world's oldest surviving railway bridge, that was built in 1725-6; it has a span of 100 feet and is 80 feet above the valley floor. At the time of its construction it was the longest single-span bridge in Britain and it held this record for some 30 years.

Figure 4: The Causey Arch



Causey Arch, the world's oldest surviving railway bridge, near Stanley, County Durham, England. Photograph by John-Paul Stephenson, Create Commons Licence: https://commons.wikimedia.org/wiki/File:Causey_Arch.jpg

Over the eighteenth century, waggonways came into general use on all the major coal-fields, typically over distances of less than ten miles but occasionally more. Moving heavy loads of coal on waggonways had several advantages. First, the rails reduced friction and the heavy loads would move downhill as a result of gravity even on very gentle slopes, while the rails also served to keep the waggons on the waggonway. The waggons had brakes and the driver (or brakesman) would operate the brake continuously for much of the road, with the horse or horses following behind. The waggonways tended to be very carefully graded; this

⁶ Simmon, J., *Railways of Britain*, p.10

minimised the costs of pulling the empty waggons back up the hill and reduced the risk of accidents on the way down. In practice, the horses were primarily employed to pull empty waggons back up to the pit head while the reduction in friction meant that a single horse could pull a much larger load when required.

Nearly all these early waggonways were private lines built by local coal mine owners. They were part of an attempt to reduce the transportation costs of coal, which were formidable. As noted above, prior to the advent of public railways only water transportation was used to move coal over long distances. Hence, most of Britain's early railways were built over a short distance and they connected the coal pit to a river, canal or sea port. For example, an early waggonway was built at Broseley in Shropshire at the beginning of the seventeenth century to carry coal from the pit-head down to the River Severn so it could be loaded onto barges and conveyed to towns along the river.⁷

Whilst the vast majority of waggonways were built at coal mines, there were exceptions. Much of the stone for building Georgian Bath came from quarries located a few miles outside the town on Combe Down; this was transported along a waggon-way that the owner of the quarries, Ralph Allen, built in 1731. The print in Figure 5 below, shows the waggonway passing Allen's palatial residence.

From the 1750s, cast iron wheels began to replace wooden wheels; this further reduced friction and increased efficiency. Initially rails were made of wood and they had to be replaced relatively frequently. The first known use of cast iron rails was in 1767 at Coalbrookdale in Shropshire, where coal had first been smelted with coke by the iron master [Abraham Derby](#) in 1709; this is now a [world heritage site](#) with an excellent collection of industrial museums. Iron rails reduced friction still more so they allowed each horse to pull an even greater weight plus they were more durable than wooden rails. By the end of the eighteenth century, several hundred miles of horse-drawn waggon-ways existed primarily on the coal-fields.

Thus, the early railways were built with primitive technologies. Most modern readers would probably not recognise a horse-drawn waggon-way as a true railway. They had limited functions and only served the private purposes of their builders. All this changed in the nineteenth century due, in no small part, to the introduction of steam power into railways.

The first working steam-engine was built in 1712 by [Thomas Newcomen](#), a Devon ironmonger and blacksmith. Revolutionary as it was, this early steam engine was totally unsuited for running a locomotive for two reasons. First, the Newcomen engine was enormous, as can be seen from the picture in Figure 6, and it produced a mere 5 horsepower. For a modern comparison, a Ford Focus' engine generates about 100 hp. Clearly, Newcomen's behemoth was far too large and heavy to be mounted on a locomotive and it generated nowhere near enough power. The thermal efficiency of the engine (the percentage of the heat energy generated that was converted into mechanical energy) was a mere 0.5%. Low thermal efficiency meant the early steam engines burnt vast amounts of coal and were very expensive to run except at coal mines, where they could use small waste coal at close to zero cost. The second major limitation of the Newcomen engine was that, while it could operate a pump, it could not drive machinery because it did not generate rotary motion. As a result of these twin limitations, the vast majority of Newcomen engines were used to pump water out of coal mines. The major exception was the pumping of water out of tin and

⁷ Peter King, *The First Shropshire Railways* in G. Boyes (ed.), *Early Railways 4: Papers from the 4th International Early Railways Conference 2008* (Six Martlets, Sudbury, 2010), pp. 70–84.

Figure 5: Ralph Allen's Wagon-Way



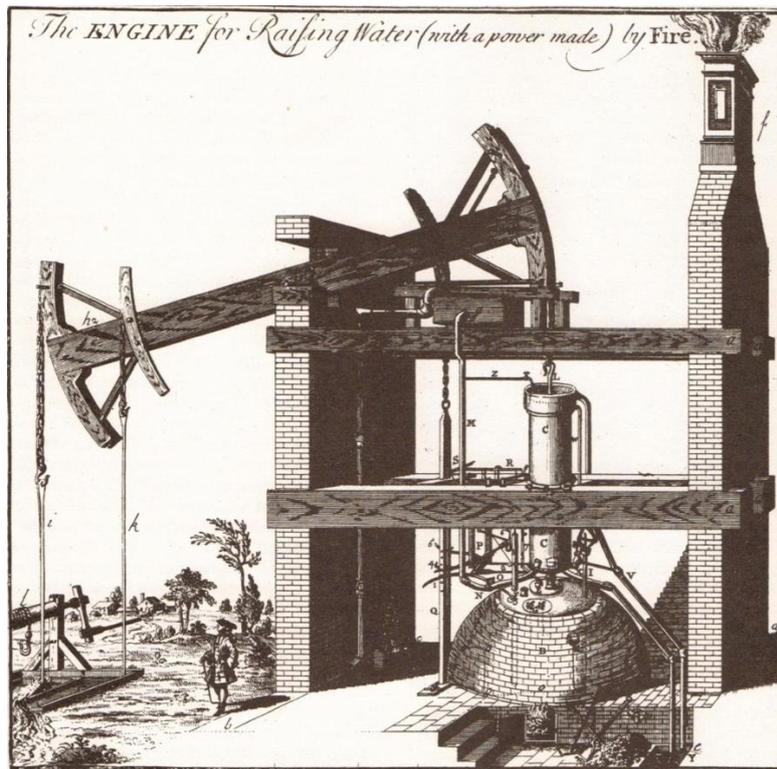
Coloured engraving of Prior Park, the seat of Ralph Allen Esq. and the Wagon-Way near Bath, 1730s. Prior Park had grounds landscaped after consultation with the poet Alexander Pope. Engraved by Ant. Walker. Printed by R Wlikinson, 58 Cornhill, London. An example of the earliest known railway print. Coloured engraving of Ralph Allen's Wagon-Way near Bath, early 18th century Science Museum Group Collection. © The Board of Trustees of the Science Museum. Creative Commons Licence: <http://collection.sciencemuseum.org.uk/objects/co65642/coloured-engraving-of-prior-park-the-seat-of-ralph-allen-esq-and-the-wagon-way-near-bath-print>

copper miles in Cornwall; for this, coal had to be shipped in from south Wales at considerable expense but once the mines were more than 200 feet deep no alternative existed to the steam engine.

Three key improvements made steam-powered trains technologically viable. First, the efficiency of steam engines was improved over time. Incremental improvements were made by a number of individuals so that by the late 1820s thermal efficiency had risen to around 17%.⁸ These engines generated 34 times more energy per unit of coal burned than the original Newcomen engine. James Watt's [separate condenser](#), developed in 1765, was the most important and best known of these improvements. Second, the development of the ingenious 'sun and planet gear', patented by James Watt in 1781, allowed steam engines to create the smooth and continuous rotary motion required for driving machinery. As will be apparent from the Figure 7, such steam engines were still far too large to be of any use in locomotives and only produced about 15 horsepower. Third, [Richard Trevithick](#), a Cornish mining engineer, developed the first high pressure steam engine. The Cornish dependence on expensive coal from south Wales to fuel steam engines created a particularly strong

⁸ Singer, C., Holmyard, E.J., Hall, A.R., Williams, T.I., *A History of Technology, Vol IV, The Industrial Revolution, 1750-1850* (1958).

Figure 6: Newcomen's steam engine



Framed print of Henry Beighton's Engraving of the Newcomen Engine at Griff, 1717, Henry Beighton, England, 1717-1725. This engraving (the original of which was discovered in Worcester College, Oxford, in 1925) is the oldest known illustration of a Newcomen engine. This image is released under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 Licence. Science Museum Group Collection. © The Board of Trustees of the Science Museum

Figure 7: the Boulton and Watt steam engine



The world's oldest surviving Boulton and Watt engine. Originally installed in Whitbread's Brewery, London, in 1785, now in the Sydney Powerhouse Museum. Photo: Leigh Shaw-Taylor

incentive to improve their efficiency. Unlike the Newcomen and the Boulton and Watt engines, which operated at atmospheric pressure, Trevithick's new steam engine was developed to operate at much higher pressures. With this innovation, radically smaller engines could produce far higher power with greater efficiency. Trevithick himself built the world's first steam powered locomotive, which was demonstrated at Merthyr Tydfil on the South Wales coalfield in 1804. It hauled ten tons of iron and 70 men ten miles from the Penydarren iron works at the stately speed of 2.75 miles an hour. However, the engine's weight broke some of cast iron rails and it was subsequently used for other purposes.

The world's first public passenger railway, the Oystermouth Railway, which ran from Swansea to Oystermouth, opened in 1807 and was operated by horses. Meanwhile, experiments continued on the coal field waggonways and by the second decade of the nineteenth century steam-powered locomotives were becoming sufficiently cost effective to replace horses.⁹ Trevithick, who died in poverty, was *the* key figure in the development of railways, but [George Stephenson](#) is a much better known as a pioneer of railway development. Stephenson was one of the first engineers to switch to wrought iron rails, which could take the weight of the new trains. He built the eight-mile line at Hetton Colliery in County Durham, which began operations in 1822 and has the distinction of being the world's first railway to make no use of animal power.

4. The beginning of the railway age

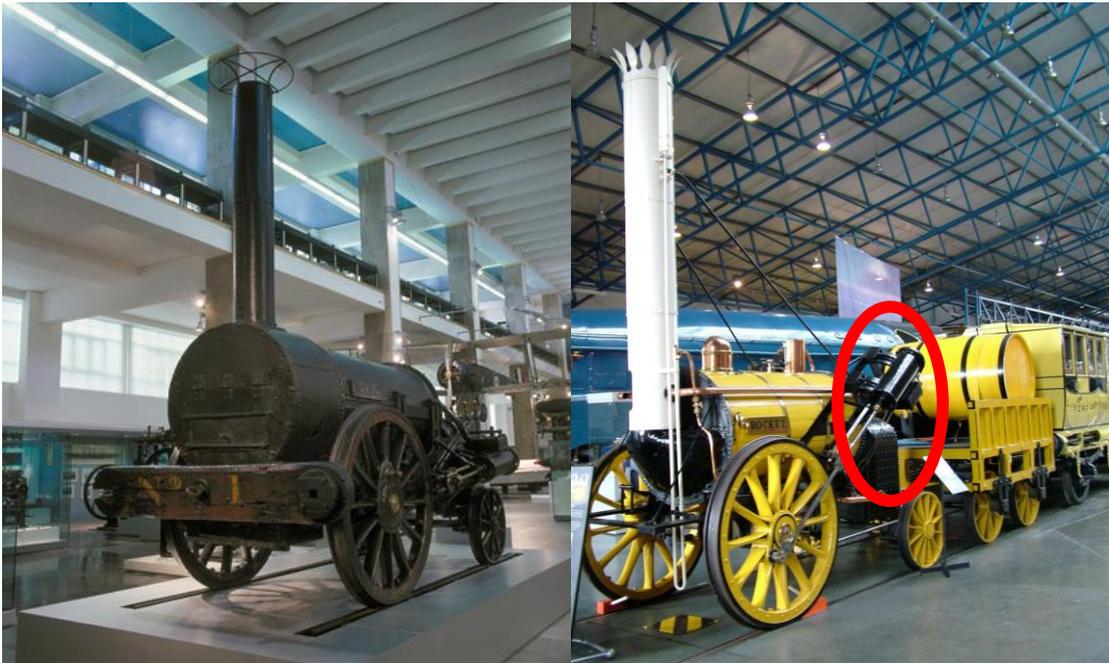
Stephenson became famous with the opening of the [Stockton and Darlington Railway](#) in 1825, which was run by a company of the same name. This railway was only 27 miles long but it provided proof of concept by being the world's first steam-powered public railway. Freight traffic (predominantly coal), hauled by Stephenson's engine 'Locomotion', was the main business of the railway while passenger coaches, run by competing private companies, were hauled by horses. The Stockton and Darlington Railway inspired the first wave of railway development and 25 new railways were authorised by Parliament over the next five years.

One of these was the [Liverpool to Manchester Railway](#), which opened with great fanfare in 1825. This was the world's first public railway to use steam-powered locomotives to haul both passenger and freight trains. Escaping the hybrid qualities of the Stockton and Darlington, it is generally seen as ushering in the railway age. Stephenson's Rocket (see Figure 8) was selected for use on the railway after outperforming all other engines at the [Rainhill trials](#) in 1825. The Rocket was the only locomotive to complete all the trials, averaging 12 miles per hour with a thirteen-ton load and reaching a top speed of 30 m.p.h. Thousands of people including the prime minister, the Duke of Wellington, turned out for the opening ceremony on 25th September 1825. Unfortunately, the festivities were marred by the death of William Huskisson, President of the Board of Trade and MP for Liverpool, who was run over by the Rocket and died shortly afterwards.

The new railway provided Manchester with much improved access to the sea so raw materials could be imported for its burgeoning cotton industry (primarily raw cotton shipped to Liverpool from the slave plantations of the American south) and manufactured goods (primarily cotton cloth) could be exported. While the railway was built mainly with freight

⁹ Flinn, M., *History of the British Coal Industry 1700-1830*, p. 155.

Figure 8: Stephenson's Rocket



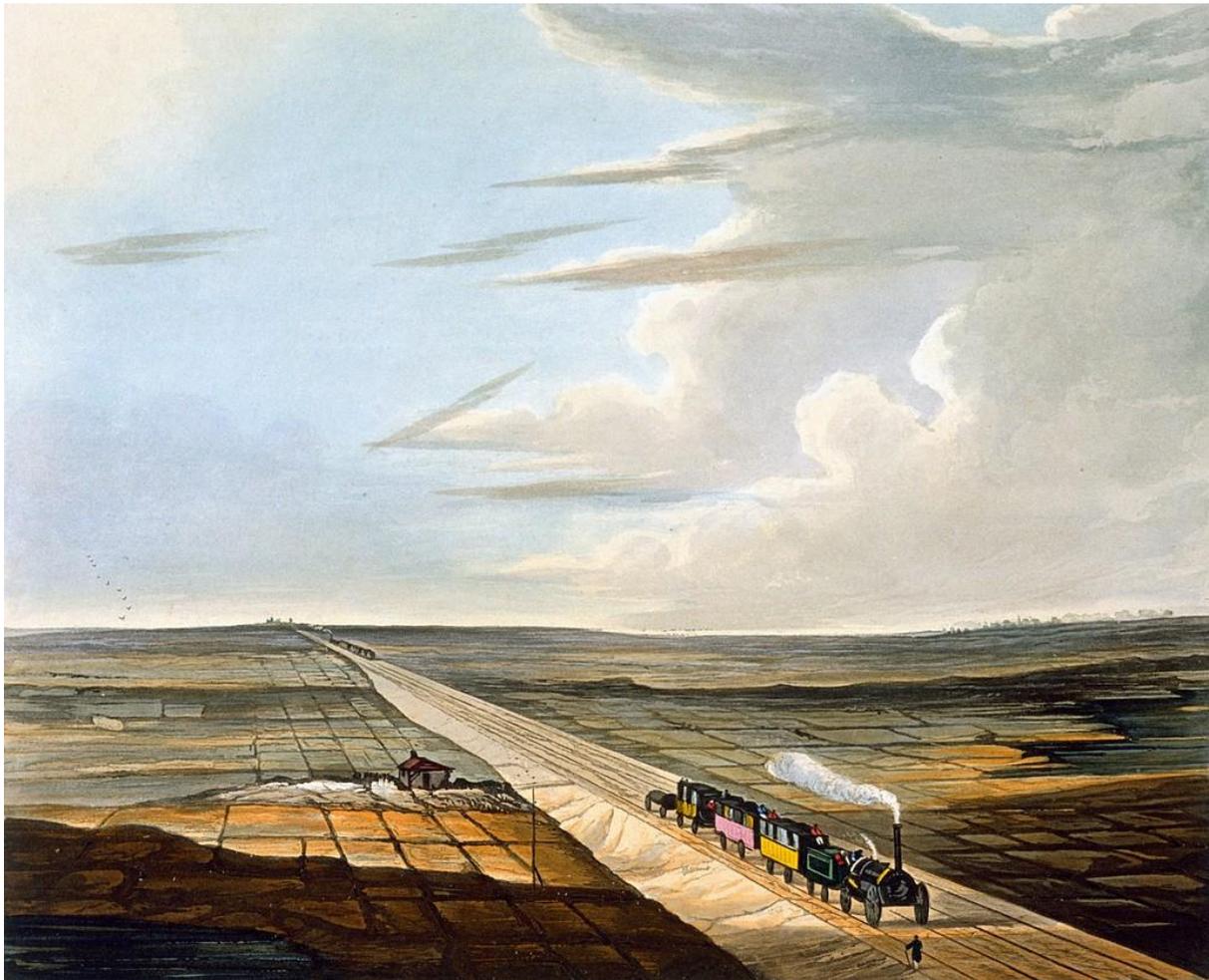
On the left is the original Rocket at the Science Museum in London. On the right is a replica at the National Rail Museum in York. Note how small the steam-engine cylinder (inside the red oval) is compared with the massive cylinders of the early engines pictured above. Photo: Leigh Shaw-Taylor.

in mind, passenger revenues made up 65% of its income in the first year of operation and exceeded 50% thereafter.¹⁰ The Liverpool and Manchester Railway, operated at 17 miles per hour, which enabled Liverpool merchants and Manchester manufacturers to conduct business by making return journeys in the same day. The Liverpool and Manchester Railway also marks the beginning of railway companies as large and complex public organizations.

The picture in Figure 9 shows the Rocket crossing Chat Moss in 1831. Chat Moss was an extensive peat bog between Liverpool and Manchester and building a railway across it involved some formidable engineering challenges.

¹⁰ Gourvish, T.R., 'Railways 1830-1870: the formative years', in Freeman, M.J., and Aldcroft, D.H., (eds.) *Transport in Victorian Britain* (1988), p.57.

Figure 9: The Rocket crossing Chat Moss in 1831



View of the Railway across Chat Moss, 1831. [Henry Pyall](#) - T.T. Bury (revised edition 1833), *Coloured Views on the Liverpool and Manchester Railway*. London: Ackermann & Co; plate 5

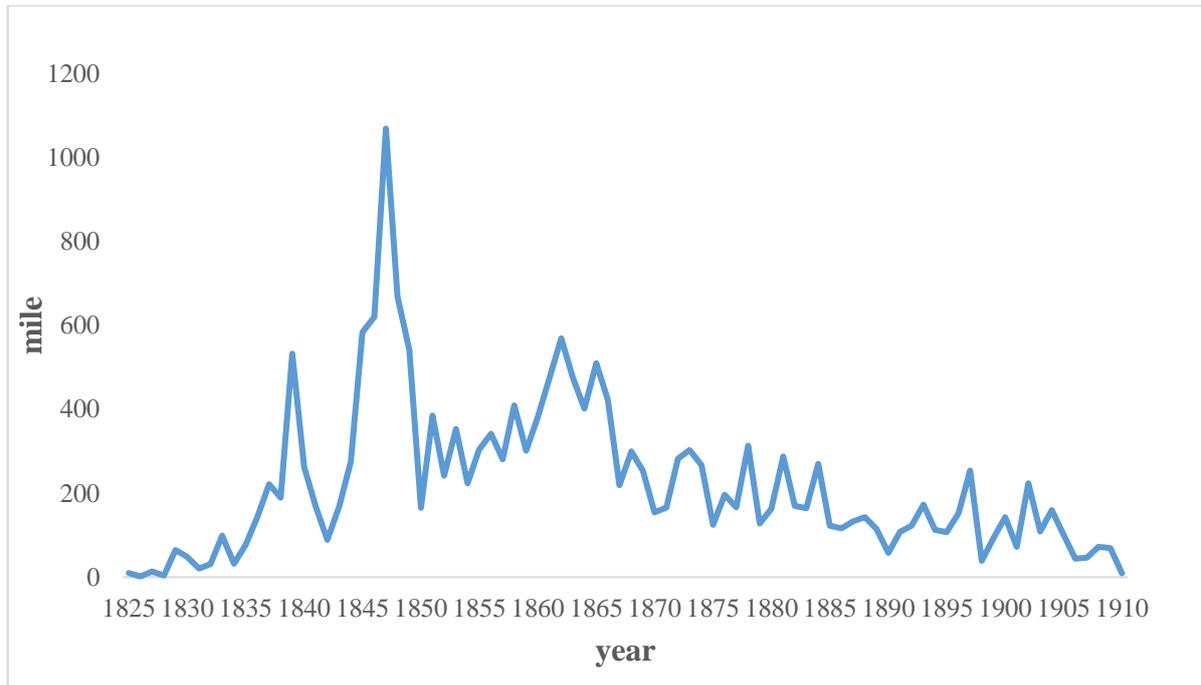
5. The railway ‘manias’

Following the Liverpool and Manchester Railway, there was a forty-year period of railway construction on a massive scale - as can be seen in Figure 10, which shows the year-by-year net additions to railway mileage in Britain. At the end of 1830, there were just over 125 miles of railway lines in Britain yet, by the end of 1871, this figure had jumped to more than 13,000 miles.¹¹ Railway expansion did not proceed at an even pace over this time. In contrast, there were three separate periods of intensive and speculative railway promotion, investment and construction; known as the ‘railway manias’ these periods occurred in the late-1830s, the mid-1840s and the early-1860s.¹²

¹¹ Cobb, M., *The railways of Great Britain*.

¹² Simmons, J. and Biddle, G., (eds.) *Oxford companion to British Railway History*, p. 311

Figure 10: The annual growth of railway mileage in Britain, 1825-1911.



The promotional boom of railways during the manias is reflected in Parliamentary activity. For example, during 1836 and 1837 railway companies were authorized by Parliament to raise nearly 35 million pounds to construct 1,500 miles of proposed railway lines.¹³ Also, during the three Parliamentary sessions that occurred between 1845 and 1847, 330 Railway Acts were passed to establish new railway companies or extend existing railway lines. The raising of nearly 170 million pounds¹⁴ of capital was authorized for the construction of these railways in England and Wales and it has been estimated that, at the height of the mid-1840s mania, individual capitalists invested more than twice as much into the construction of railways as the state spent on the military.¹⁵ However, as will be explained later, due to the collapse of the financial bubble, a third of the authorized mileage was not built.

One reason for the railway manias was the lack of government regulation or intervention. Anyone with sufficient financial means, or the capacity to borrow sufficient funds, could form a railway company, raise capital, and put forward an application for a railway Bill to Parliament that would propose railway routes and enable land to be acquired.¹⁶ Virtually no real checks existed on the financial viability of a proposed railway line. The economic policy of *laissez faire* left the design and construction of railways almost entirely to private enterprise. Unlike subsequent developments in other European countries, such as Belgium and France, there was no central planning or coordination of railway expansion in Britain. Armed with a competitive spirit and attracted by potential financial returns, railway promoters and capitalists were left alone to fiercely compete for the control of land and routes; sometimes this involved not only the immediate construction of railways but also the fencing out of potential future competitors. Railway investors engaged in frenzied speculation. One passage encapsulates the spirit of a railway mania, "It would have been unthinkable to pause, consider, and calculate. Immediate action was called for, without any

¹³ Ibid.

¹⁴ Simmons, J., *The railway in England and Wales 1830-1914*, p. 42

¹⁵ Odlyzko, A., *Collective hallucinations and inefficient market*, p. 4

¹⁶ Reed, M. C., *Investment in Railways*

nice scruples or refinement of thoughts. Very much indeed was at stake, to be settled in the shortest possible time, against the clock.”¹⁷

The manias were also fuelled by favourable economic conditions and the easy availability of investment capital. The British industrial revolution created an affluent and sizable middle class who were keen to enlarge their wealth through investment. The success of the railway industry in the 1830s made it an obvious investment choice. The impressive profits of the railway companies in the 1830s enabled them to pay out high dividends, which explains much of the overly optimistic speculation that occurred in the 1840s. Furthermore, capital formation in the railway industry during this mania relied on derivative-like assets, which amplified potential risks and eventually contributed to the bursting of the speculative bubble. When an application for a railway Bill was approved by Parliament, investors only needed to make a partial payment, normally 10%, for their allotted shares. It was only after the company was successfully incorporated, that future calls could be made on shareholders to invest the outstanding capital.¹⁸ It has been argued that this funding mechanism boosted speculation and led to overly optimistic railway investment.¹⁹ Individual investors could subscribe for more shares than they could actually fund. This led to more railway lines being built than would have otherwise occurred. Furthermore, when more capital was called for by a railway company and its investors were unable to pay the obligatory sum they had committed to, the collapse of its share price became almost inevitable.²⁰ This dynamic can be seen in the financial index of railway stocks at the time, which, in just five years, declined from its zenith of 1,984 on August 8, 1845 to its nadir of 673 on April 19, 1850.²¹

With investors being unable to pay the capital they had committed to, many proposed railway schemes were not realized. For example, over a third of the mileage authorized by Parliament between 1844 and 1847 was not built.²² Even so, the railway manias did create a tangible entity: a much expanded railway network. The scale of railway growth during the manias can be seen in Figure 10. In a single year, 1839, more than 530 miles of railway track were added to the existing network whilst in 1847 1,100 miles were added followed by another 570 miles in 1862.

6. The spread of railway lines from 1830 onwards

The length of the railways is not the only factor of interest. The impact of the railway network on Britain’s economy and society also depended on its capacity to forge connections between the nation’s inhabitants. Connectivity was enhanced not simply by an expansion in railway lines, but also by their location and by the places they linked together. Hitherto, a full picture of the development of the British railway network has not been created because the available maps have limited precision and detail and they are only available for a small number of years; as such, they cannot be easily related to other socio-economic variables. Now, thanks to Cobb’s definitive railway atlas, the new technology of GIS and the

¹⁷ Simmons, J., *The railway in England and Wales 1830-1914*, p. 48

¹⁸ Campbell, G. and Turner, J. D., *Dispelling the myth of naïve investor during the British railway mania, 1845-1846*, pp. 7-8.

¹⁹ Campbell, G. *Deriving the railway mania*, p. 3

²⁰ *Ibid.*

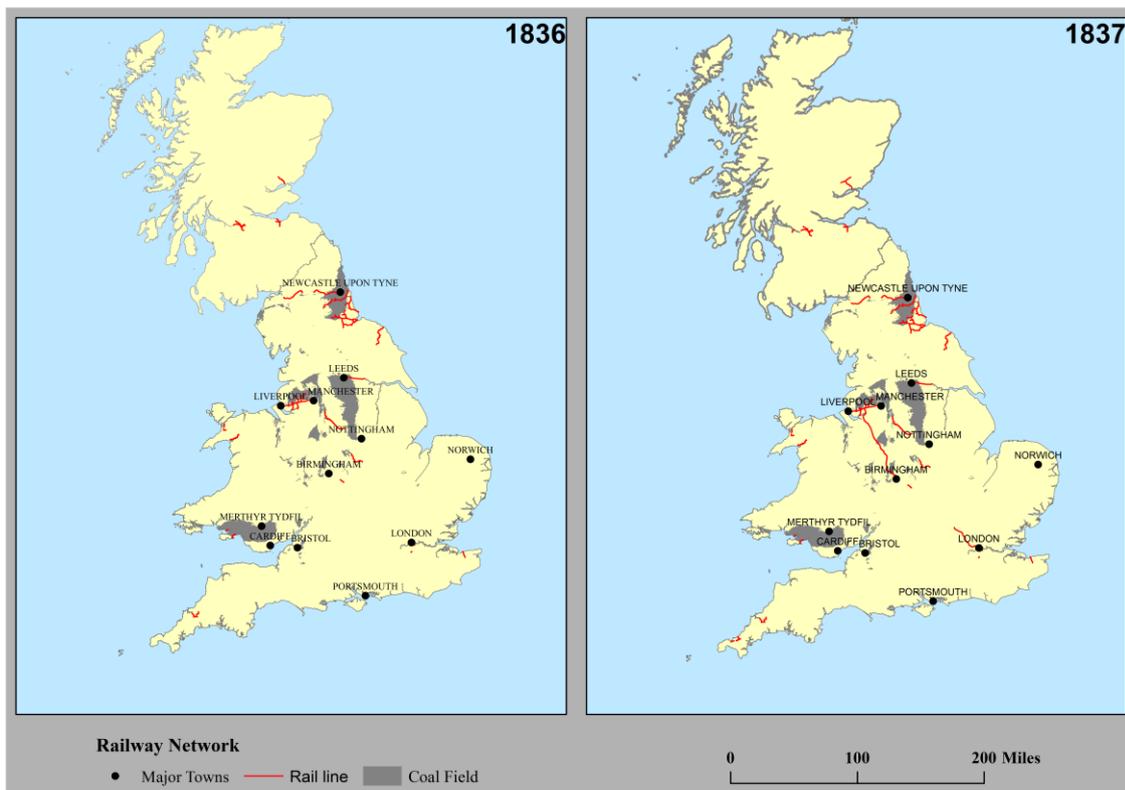
²¹ Campbell, G. and Turner, J. D., *Dispelling the myth of naïve investor during the British railway mania, 1845-1846*, p.7.

²² Simmons, J and Biddle, G., (eds) *Oxford companion to British railway history*, p. 311

digitisation of Cobb's atlas it is possible both to map the railway network for any given year and to relate it to other socio-economic variables (once digitised in a GIS framework). Cobb's atlas shows the locations of all railway lines and stations opened for the public carriage of passengers and/or goods between 1807 and 1994. In addition, for each line and station, historical details such as name, ownership and opening and closing dates are also documented. Private railway lines such as the early waggon-ways or the later industrial or mining side-lines are not included in Cobb's atlas. Other absent details include station capacity, the frequency of service and whether railway lines are single or double track. The maps which follow show the evolution and development of the railway network of England and Wales at dates that have been carefully selected to illustrate the key developments. All the dates refer to the end of the year. An animation of the development of Britain's railway system on a yearly basis can be found on our website at:

<https://www.campop.geog.cam.ac.uk/research/projects/transport/>.

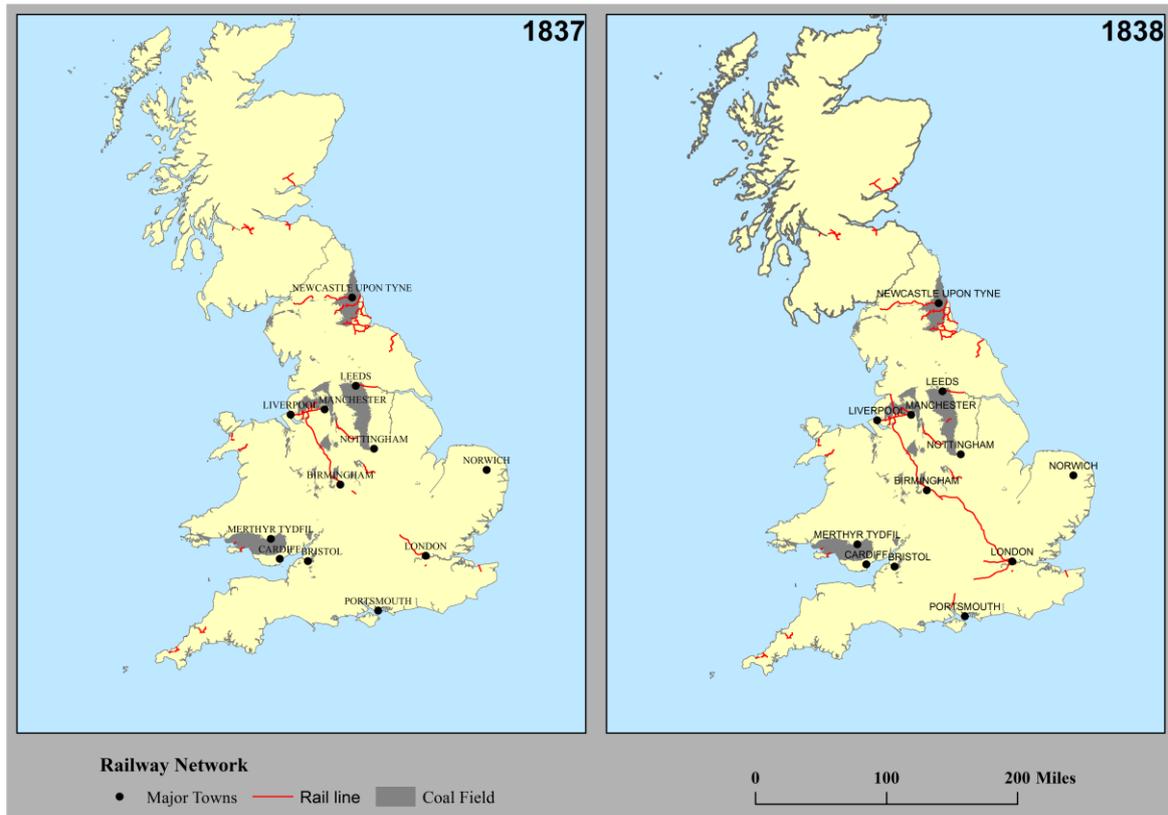
Map 1: The British railway network by the end of 1836 and 1837.



Map 1 compares the railway network between 1836 and 1837. It is clear that, six years after the opening of the Liverpool and Manchester Railway, the railways only provided relatively local services. Inter-regional travel by rail was not yet possible. Railways were present, but they were far from forming a network. The beginnings of an inter-regional rail network in England and Wales became apparent in 1837. By the end of that year, Birmingham was connected to Liverpool and Manchester through the Grand Junction Railway and the existing Liverpool and Manchester Railway. At the same time, the railway line being built by the London and Birmingham Railway Company started to reach out from London towards the northwest. It was intended to connect London with Birmingham and hence with Liverpool and Manchester. Engineering difficulty delayed the plan, though not for long. As Map 2 shows, the four major cities of Liverpool, Manchester, Birmingham and London became connected to each other by railways by the end of 1838. Map 3 presents railway development

from the end of 1839 to the end of 1840. Railways were now spreading out from London in other directions: towards the west (with the aim of connecting London to Bristol by the Great Western Railway) and towards the southwest (with the aim of connecting London to Southampton by the London and Southwest Railway).

Map 2: The British railway network by the end of 1837 and 1838.

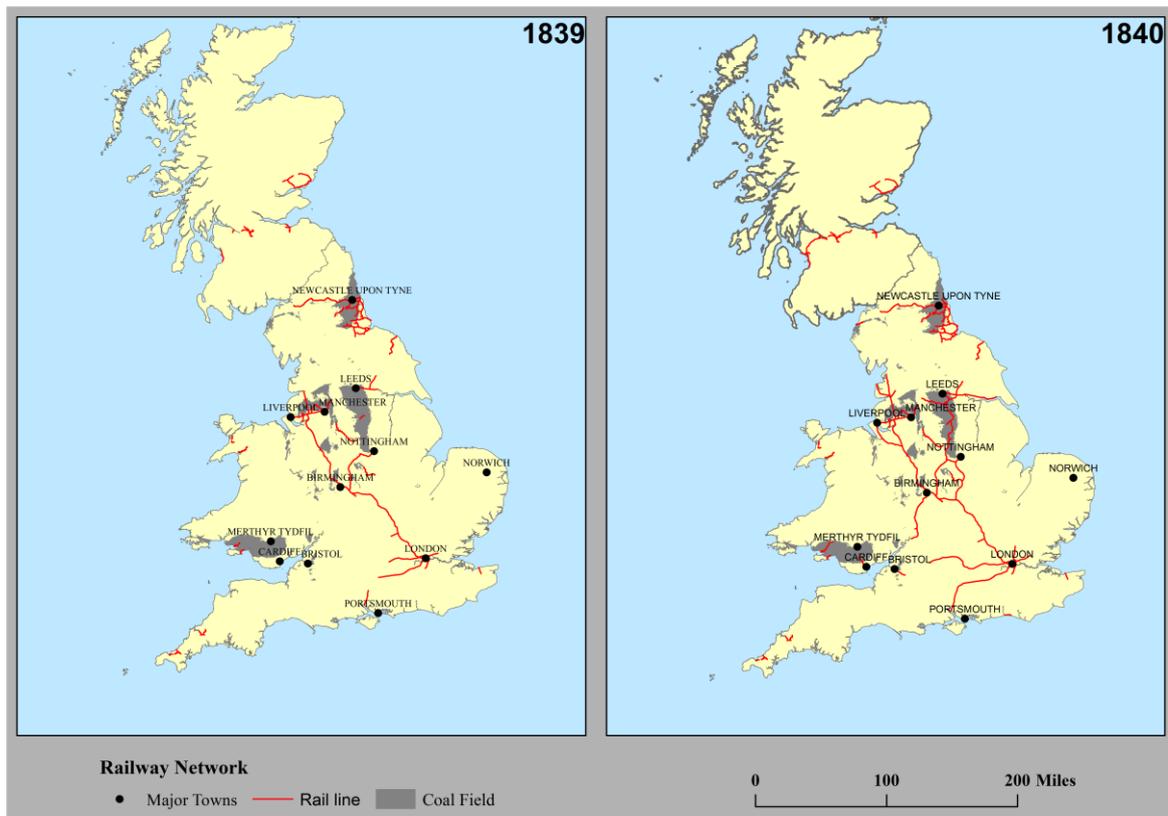


Map 3 shows another important railway development in 1840. By the end of 1839, the railway between London and Birmingham had reached out to Yorkshire in the northeast.²³ By the end of 1840, Leeds was connected to the network and, perhaps more importantly, the inland Yorkshire, Derbyshire and Nottinghamshire coalfield was ‘opened up’. Given the presence of railways, the output of this inland coalfield ceased to rely on short distance transportation modes like canals and waterways. With competition brought into a market that was hitherto monopolized by intra-regional supplies,²⁴ this coalfield powered more factories and warmed more households across a wider geographical area. Apart from these developments, a visible expansion of the railways can also be seen in the south: London became connected with another major city - Southampton - whilst Isambard Kingdom Brunel’s Great Western line that would link London with Bristol was not far from completion.

²³ Simmons, J., *The railway in England and Wales 1830-1914*, p. 25.

²⁴ Church, R., *The History of British coal industry (vol.3)*, pp. 42-5.

Map 3: The British railway network by the end of 1839 and 1840.



The three maps presented so far show the expansion of railways during the first mania. Moving away from being merely a collection of largely unconnected and fragmented lines in the 1830s that only served localized traffic, the mania created, within a few years, the skeleton of an emerging nationwide network. While it is easy to appreciate the importance of a nationwide network with long distance routes and wide geographical coverage, we should not dismiss the economic significance of some local railway lines that had not yet been connected to a wider network. A good example is the Taff Valley railway line that connected the Welsh coalfield with the port of Cardiff.²⁵

Even though the Taff Valley Railway was less than 30 miles long, it is difficult to exaggerate its impact. Before the arrival of railways, canals monopolised coal transportation in South Wales. The limited capacity and speed of canals placed a cap on the development of the South Wales coal industry. The construction of the Taff Valley Railway from Cardiff to Merthyr in 1840-41 effectively ended the canal companies' monopoly of coal transportation in the region.²⁶ In 1846, the re-building of Taff Valley Railway at a higher physical level reduced costs, speeded up processes and enhanced transportation capacity.²⁷ Then, in 1855, the Taff Valley Railway was extended to the Rhondda valley, which eventually made its coalfield the most important single source of steam coal (a grade of coal that is particularly suited to steam engines).²⁸ From 1856 to 1864, the decade after the Rhondda valley was linked with the Taff Valley Railway, output from its coalfield more than doubled - from

²⁵ Simmons, J., *The railway in England and Wales 1830-1914*, p. 31.

²⁶ Church, R., *The history of the British coal industry*, p. 40

²⁷ Ibid.

²⁸ Dauton, M., *Coal metropolis*, p. 5

205,200 tons to 520,022 tons; by 1869, coal production reached 1,250,000 tons²⁹ and, by the mid-1880s, it had risen to more than 5,500,000 tons.³⁰ Accompanying the exponential expansion of the coal mining industry, was a boom in population. Rhondda's population in 1831 was just over 1,500 and during the next 80 years it grew 100-fold to reach more than 150,000 in 1911.³¹

Cardiff's expanded and improved docks, in combination with the Taff Valley Railway, helped move South Wales to the forefront of the coal export trade, which further expanded coal mining in the region and greatly stimulated urbanization. Cardiff became the 'coal metropolis of the world'.³² Table 1³³ shows the shipments of coal from Cardiff in comparison with the other major Welsh coal ports. In 1840, before the arrival of railways, Cardiff lagged

Table 1. The shipment of coal from major Welsh port (tons)

	1840	1851	1874
Cardiff	166,109	750,003	3,780,000
Newport	489,654	603,159	1,066,000
Swansea	493,290	393,749	768,000
Llanelli	212,044	229,245	222,000

far behind Newport and Swansea in the shipment of coal. About a decade later in 1851, with the advent of the railway, Cardiff had surpassed the other Welsh ports. By the mid-1870's, nearly 4 million tons of coal were being shipped from Cardiff annually. The pace of Cardiff's urbanization was no less impressive. Figure 11 shows the population of Cardiff in comparison with Merthyr between 1821 and 1911. In 1840, before the arrival of the railway, Cardiff was much smaller than adjacent towns. For example, it was less than third the size of Merthyr, which was Wales' biggest town in 1831 with a population around 22,000. From the 1840's, Cardiff's population grew exponentially and by 1911 it exceeded 200,000.

During 1841 three notable improvements were made to Britain's railway network - as Map 4 shows. Firstly, London became connected to the major towns of Portsmouth and Bristol. Secondly, the North-East coal field was finally connected to the national network. Additionally, by the mid-1840s the South West of England and East Anglia were connected - as Map 5 illustrates.

²⁹ Lewis, E. D., *The Rhodda valleys*.

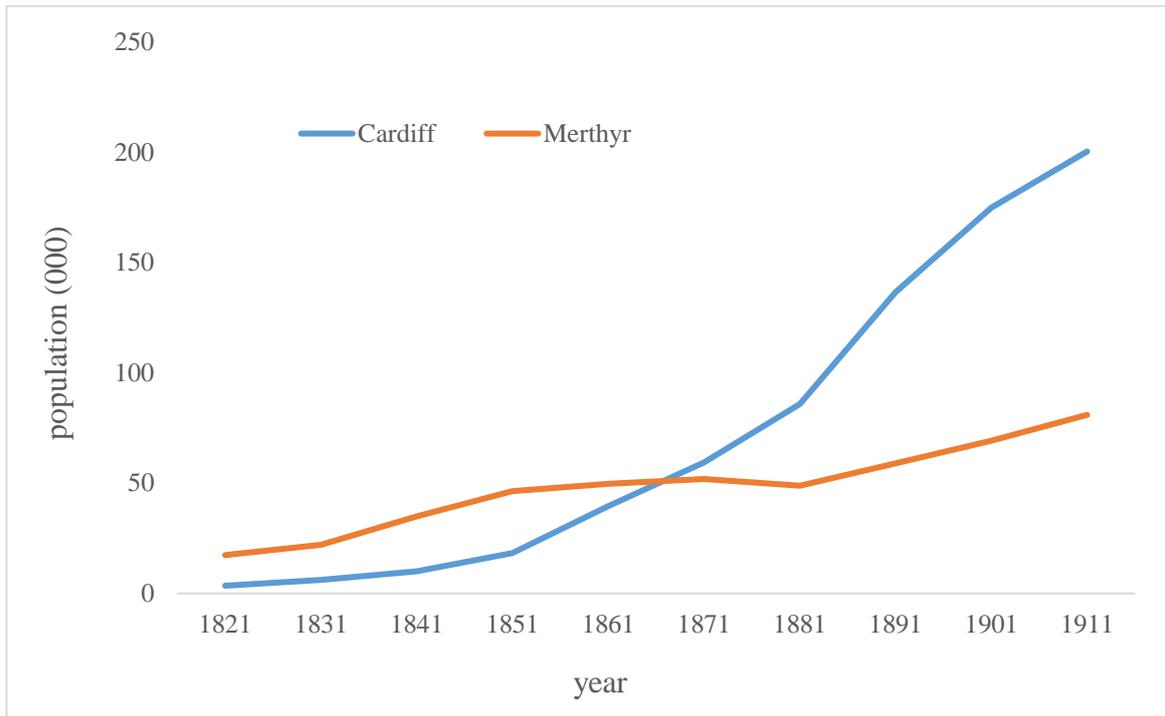
³⁰ *ibid*

³¹ *ibid*

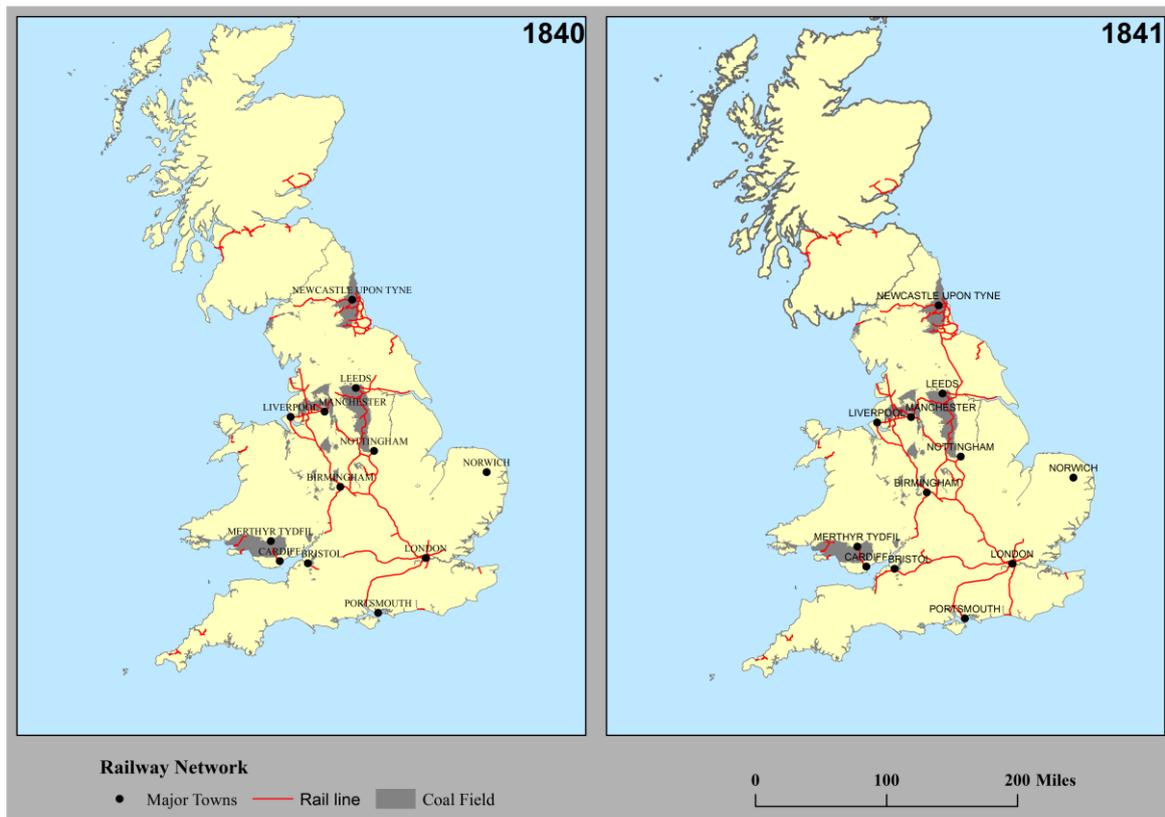
³² Dauton, M., *Coal metropolis*, pp. 18-36.

³³ Morris, J. H. and Williams, L. J., *The south wales coal industry*.

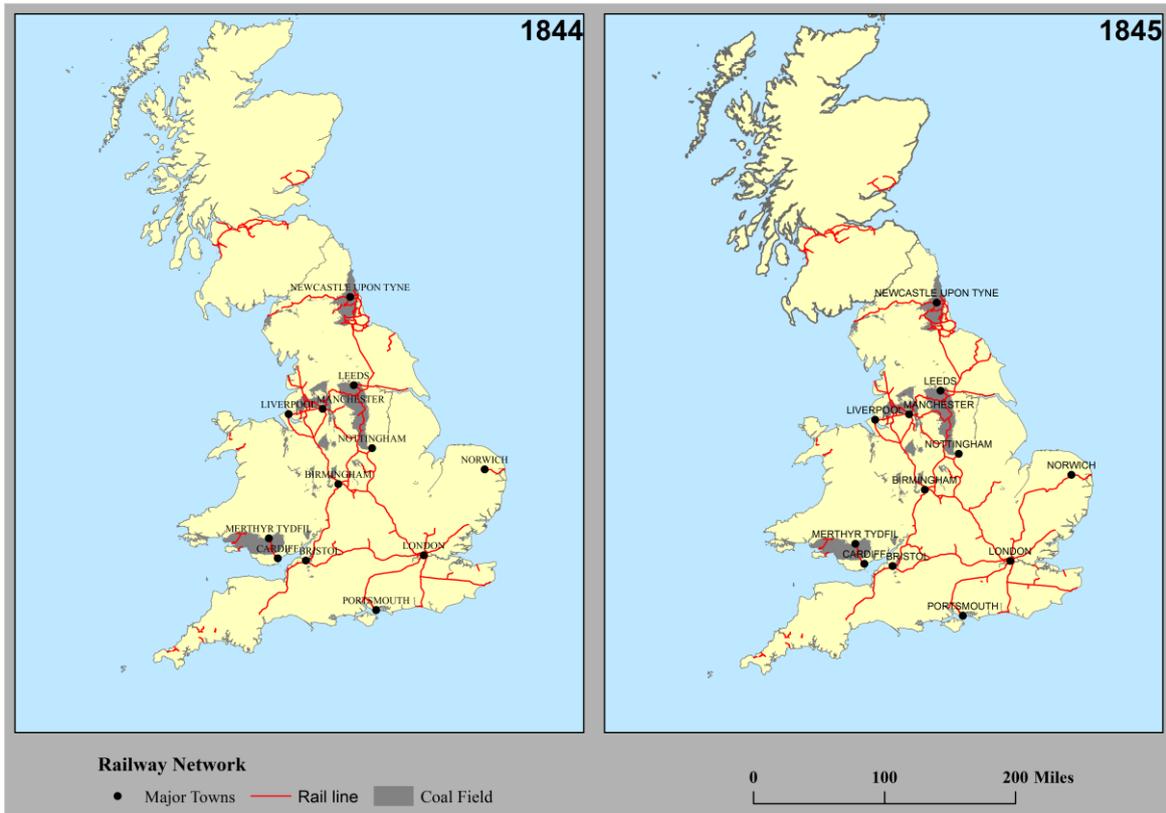
Figure 11: The population of Cardiff and Merthyr, 1821-1911



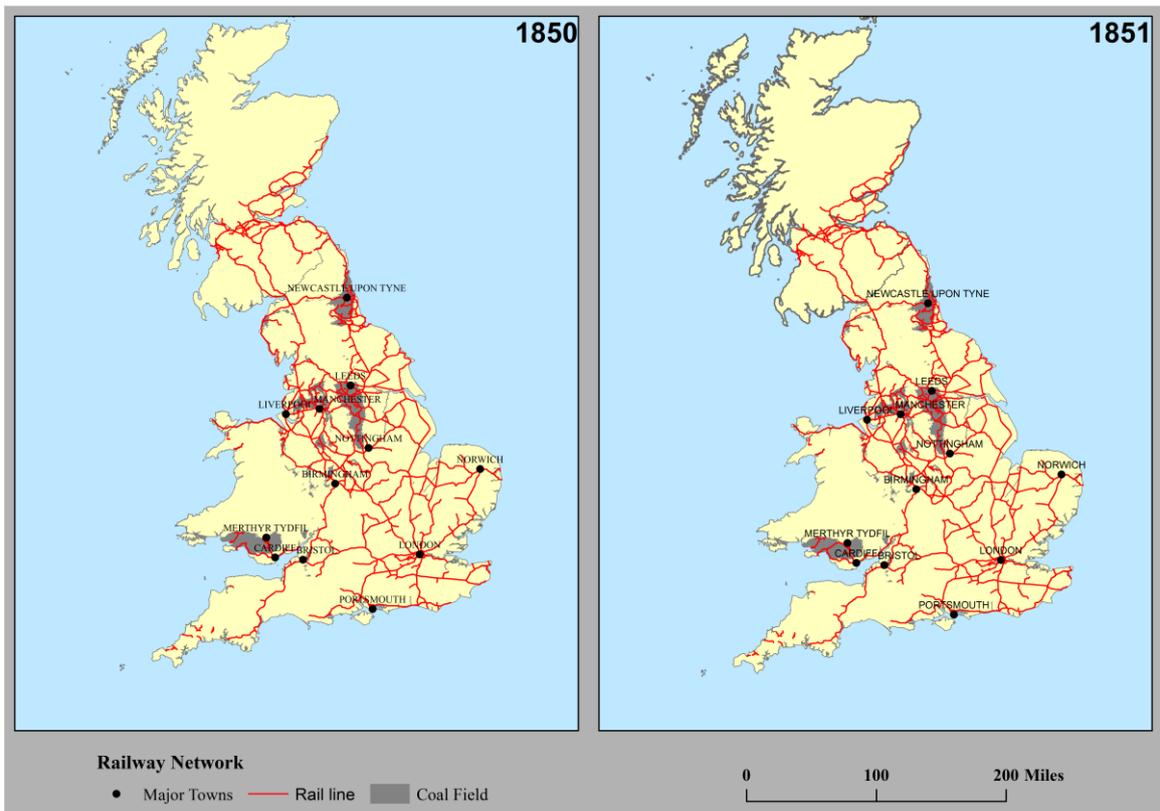
Map 4: The British railway network by the end of 1840 and 1841



Map 5: The British railway network by the end of 1844 and 1855



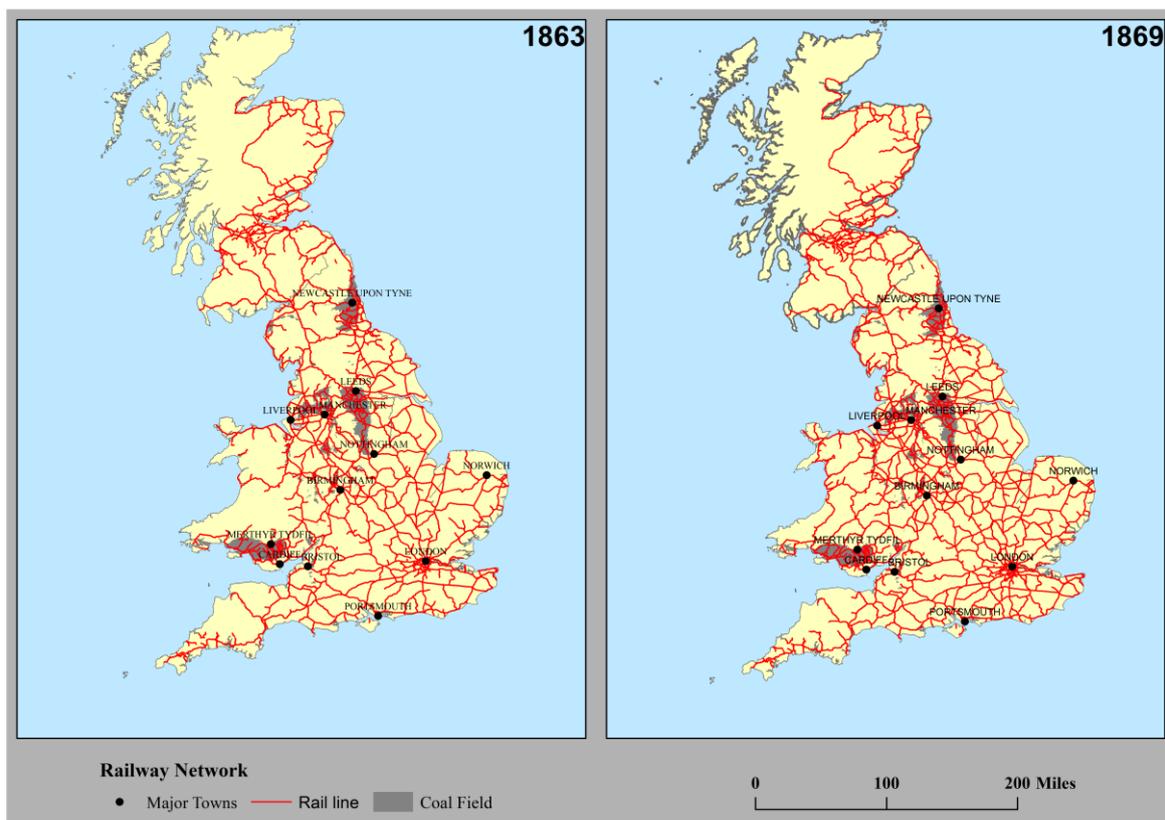
Map 6: The British railway network by the end of 1850 and 1851



The accelerated construction of railways during the second mania between 1845 and 1848 made the railway network much denser, particularly in England (see Map 6). If the railway network in the previous decades had resembled major arteries, veins now became apparent throughout the body. In 1844, there were just over 2000 miles of railway, but this more than doubled by 1848 and nearly trebled by 1851.

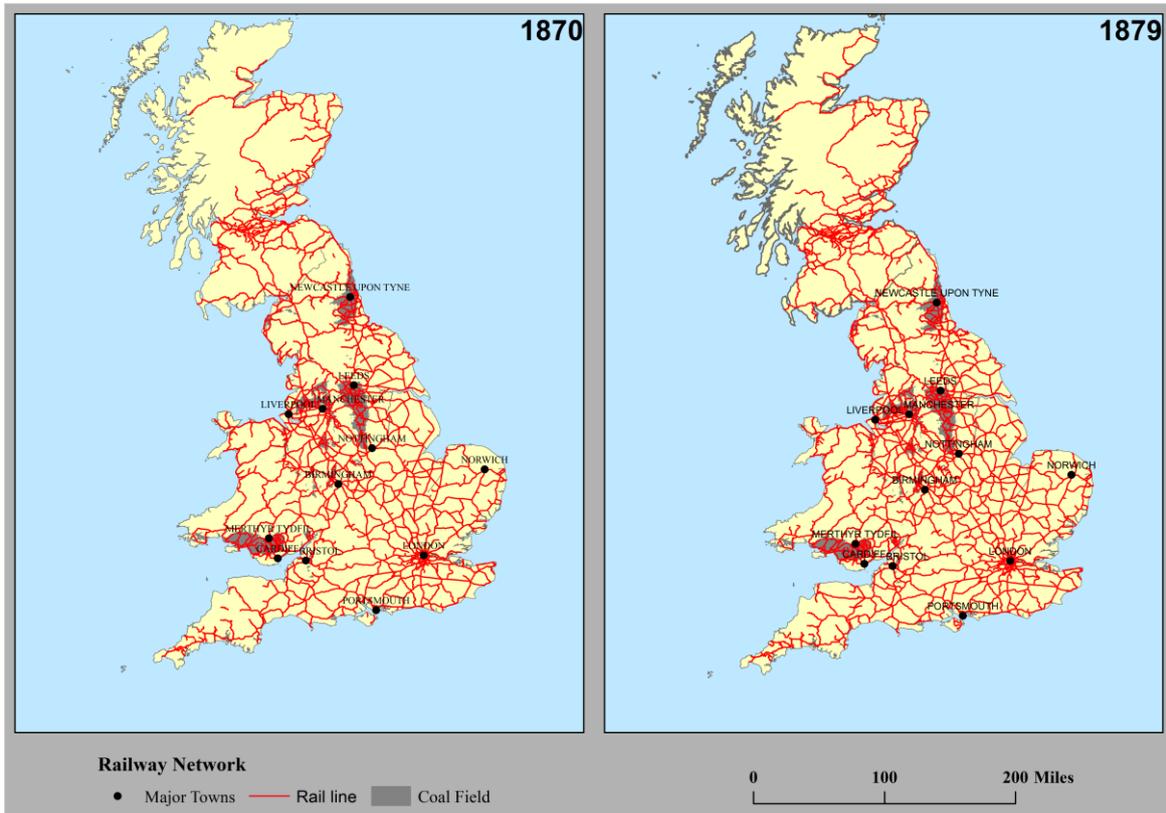
Whilst England started to have a much denser network at this time, railways were still largely absent from most of Wales. The density of the Welsh railway network did not increase significantly until the 1860s (see Map 7). By 1869, a considerable proportion of Wales had railway coverage and, at this time, the network of major trunk links in England and Wales reached its maturity. Afterwards, no major trunk lines were added to the railway network. Railway mileage continued to rise but the rate of increase fell.

Map 7: The British railway network by the end of 1863 and 1869

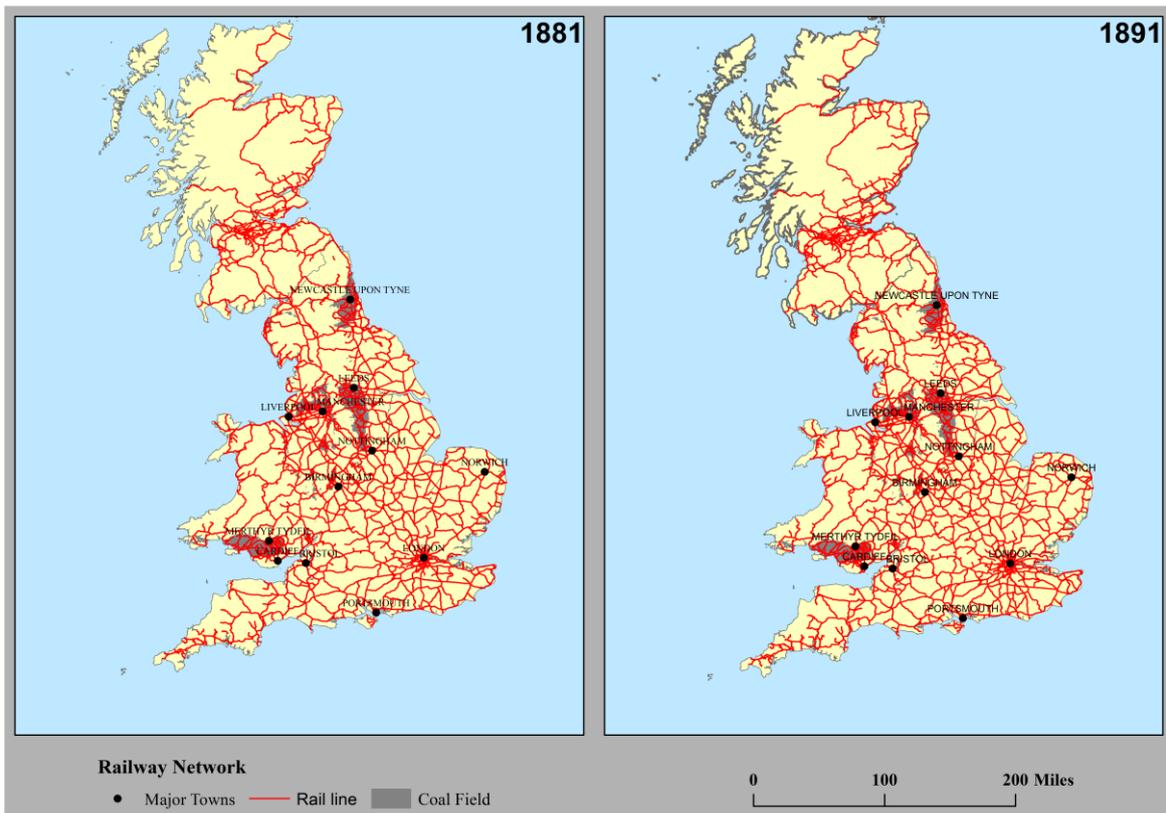


If the railways constructed up to 1869 mainly connected economically important areas such as population centres, ports, industrial concentrations and mineral-rich regions, then the railways built from the 1870s onwards mainly consisted of branch lines that filled gaps in the network. A comparison of the railway networks in the 1870s, 1880s, 1890s and early twentieth century (see Maps 8 to 10) reveal few major differences.

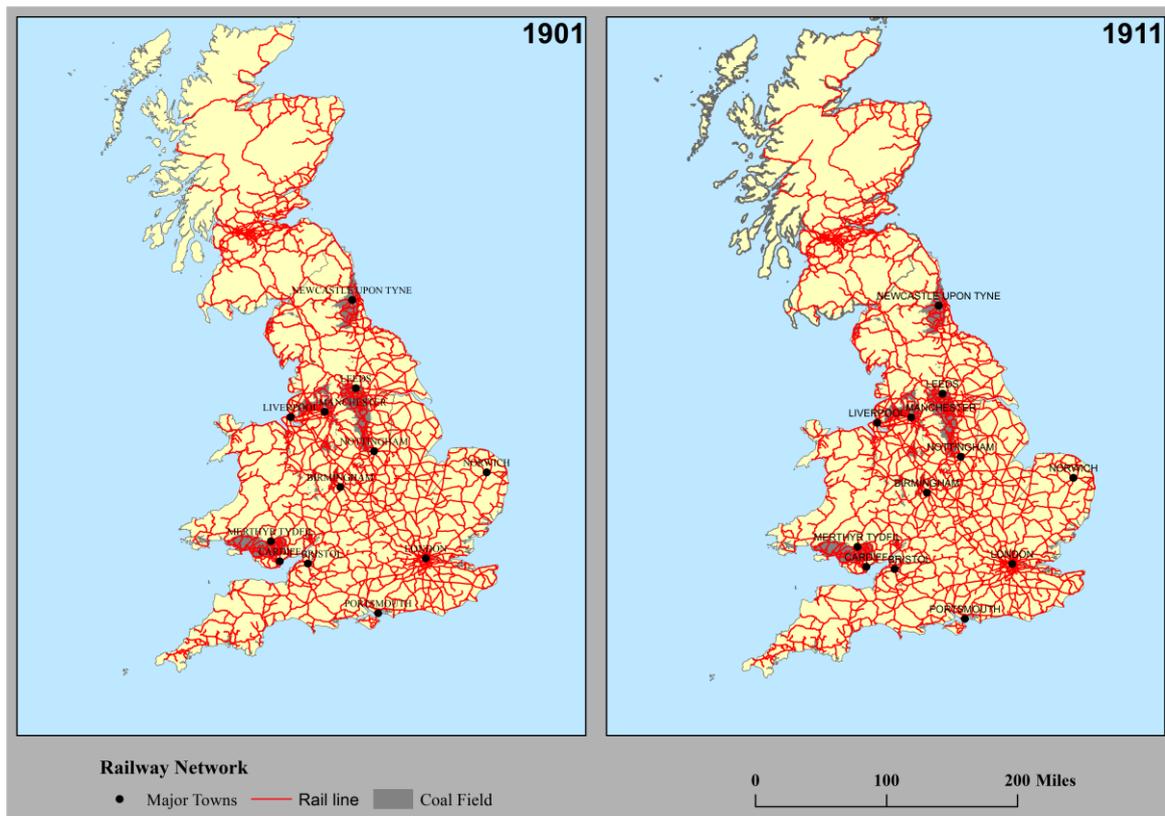
Map 8: The British railway network by the end of 1870 and 1879



Map 9: The British railway network by the end of 1881 and 1891



Map 10: The British railway network by the end of 1901 and 1911



7. The efficiency of the British railway network

As shown in the previous section, Britain's railway network became dense by the end of the 1860s after decades of construction that began with the opening of the Stockton and Darlington Railway in 1825. The high density of the railway network generated great social benefits through both passenger and freight transportation. However, this does not necessarily mean that the network was efficient. Efficiency increases as a network yields the same social benefits while incurring lower social costs. There have been suggestions that the efficiency of Britain's railway network left a lot to be desired³⁴.

Casson, in a recent study, attempts to quantify the efficiency of the British railway network and identify the factors that affected efficiency.³⁵ He finds that the inefficiency of the railway network in Britain was much larger than previous scholars have suggested. By constructing a counterfactual railway network, he suggests that the social benefits arising from Britain's actual railway network, which had 20,000 miles of track in 1914, could have been achieved by an efficiently designed network of only 13,000 miles. The huge difference between the actual network and the counterfactual, efficient network occurs for two reasons. First, main lines in the actual network that connected major cities were often duplicated due to inter-company competition. Second, some regional lines were wasteful because they were built to

³⁴ Turnock, D., *A historical geography of railways in Great Britain and Ireland*.

³⁵ Casson, M., *The world's first railway system*.

achieve a regional monopoly rather than to generate social benefits - this was another negative consequence of inter-company competition.

Casson argues that two underlying factors explain the inefficiency of the British railway network: 'excessive' competition between railway companies and regulatory failure by the British government.

Excessive competition is a form of market failure. The private railway companies failed to envision an integrated network at national level; instead, they saw each region and route as a territory to dominate. Hence, they sought to achieve regional monopolies by constructing wasteful lines that protected their territory from present or future competitors and by building railway hubs in sub-optimal locations that damaged the traffic interchange of rivals. Consequently, Casson argues the fierce competition between railway companies was 'excessive' because it did not create an efficient railway network in which resources had been optimally allocated. In contrast, significant social costs were generated.

In Casson's view, regulatory failure by the government bears equal, if not greater, responsibility for the inefficiency of Britain's railway network. Had the government intervened, some of the social costs arising from 'excessive competition' could have been avoided. During the mania between 1844 and 1847, concerns about the inefficiency of the proposed railway lines had been raised by various individuals and institutions. For example, when Brunel wrote to Charles Babbage in September 1844 he said, "There are railway projects fully equal to 100 million pounds of capital for next year, and all the world is mad. Some will no doubt have cause to be so before the winter is over".³⁶ The railway committee of the Board of Trade did recommend the introduction of greater state regulation and central planning. However, that recommendation failed to secure Parliamentary approval partly because Parliament had a strong ideological belief in the capacity of free markets and competition to produce optimal outcomes. As Klein suggests, most MPs failed to understand that unchecked competition in the construction of public infrastructure can easily lead to overcapitalization and inefficiency. In the case of Britain's railways, more lines and stations did not necessarily generate additional incremental benefits.³⁷ Casson also argues that Parliament in the middle of the nineteenth century was dominated by landowners who promoted local interests at the expense of the national interest. They saw their constituency as a self-contained community that competed with its neighbours for a fixed amount of resources. This mercantilist and locally-biased view encouraged 'excessive competition' and was opposed to government regulation and intervention in the national interest. In essence, the government's failure to develop a national railway policy reflects a situation in which, "Short-term local interests triumphed over long-term national interests."³⁸

8. The impact of Britain's railways

One obvious advantage of railways, speed, is indisputable. Figure 12 shows 'isochrones' of travelling time from London to other locations in England and Wales by stage coach in 1830 and by train in 1911. With an average speed of less than 9 mph by stagecoach on turnpike roads in 1830, travel from London took 15 hours to Birmingham, more than 20 hours to Manchester, and more than 30 hours to Newcastle. By contrast, with an average speed of 40 mph on the railways at the beginning of the twentieth century, the same journeys from

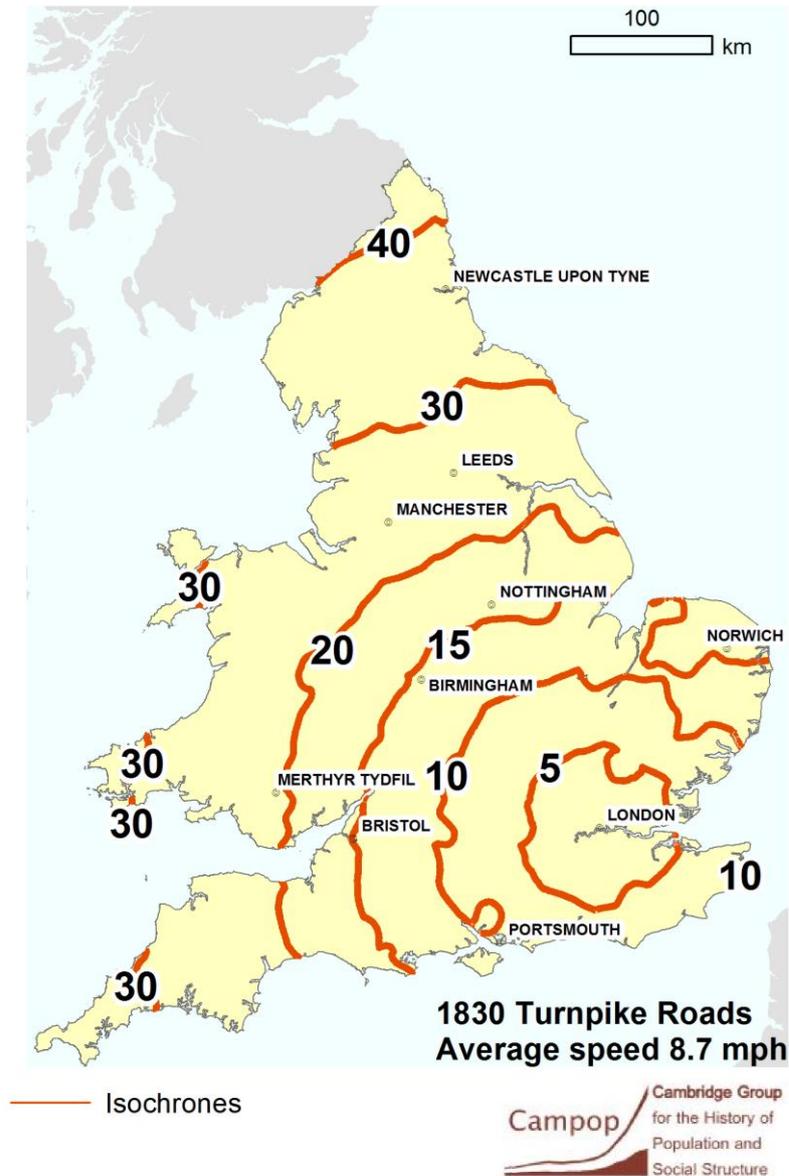
³⁶ Rolt, L. T. C., *Isambard Kingdom Brunel*, p. 234.

³⁷ Klein, M., *Network industries*.

³⁸ Casson, M., *The world's first railway system*, p. 327.

London took three, five and seven hours respectively. Railways meant people could travel faster than ever in Britain.

Figure 12: Isochrones of travelling time from London to other locations in 1830 & 1910



The other clear benefit that railways brought was a massive expansion in traffic volumes. Figures 13 and 14 show the number of passenger journeys and the volume of freight traffic by rail.³⁹ Passenger journeys increased from about 20 million in the early 1840s to nearly 1,300 million in 1911. Taking the size of Britain’s population into account, the number of journeys per head of population increased on an unprecedented scale. On average, there were 0.65 railway journey per head of population in 1841; 20 in 1881 and 32 in 1911.

³⁹ Mitchell, B. R., *British Historical Statistics*, pp. 545-7.

Figure 13: The number of railway passenger journeys in Britain, 1838-1911

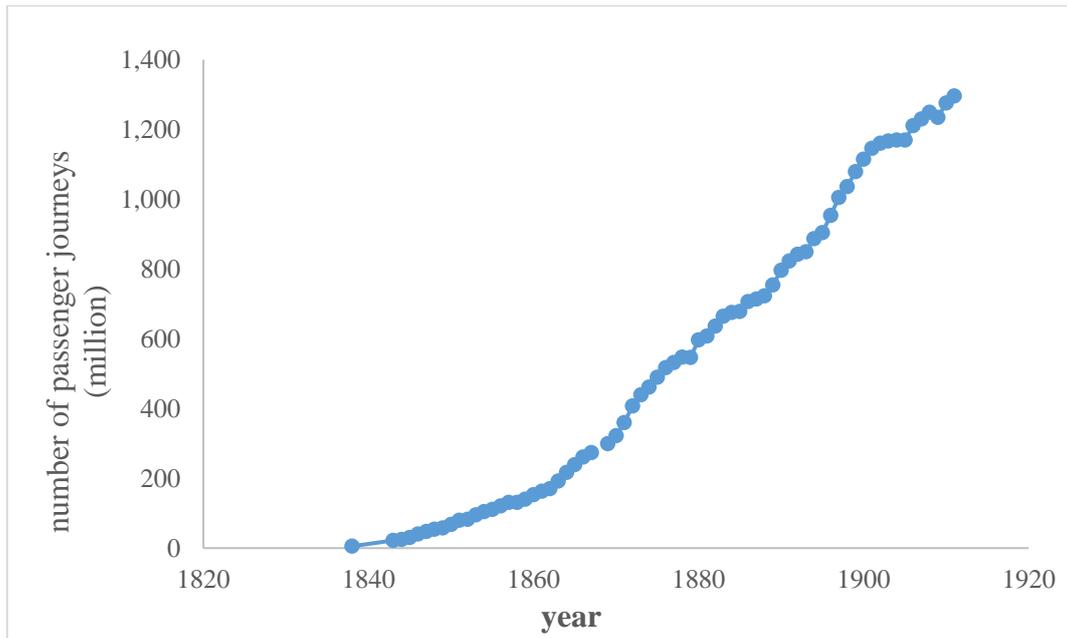
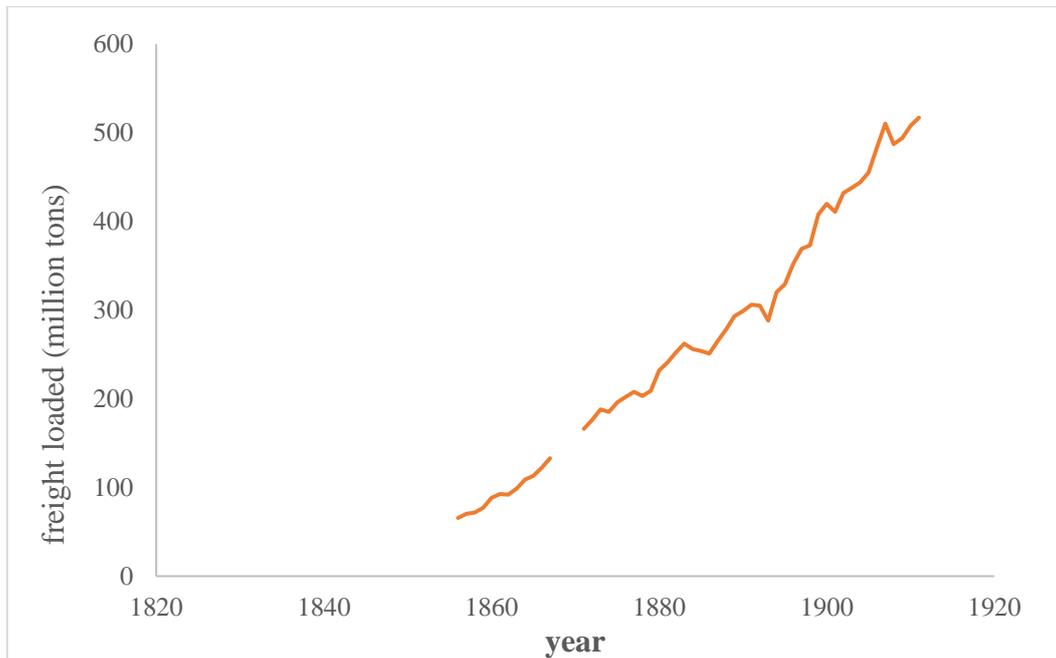


Figure 14: The volume of railway freight traffic in Britain, 1856-1911



The frequency of passenger journeys by rail indicates that the working population was massively on the move for the first time. After the passing of Gladstone's Railway Act in 1844, which made the provision of third-class accommodation on at least one train per day obligatory at a cost of no more than a penny per mile, third-class passenger traffic took off.⁴⁰ The expansion of third-class passenger traffic was further boosted by the Midland Railway's

⁴⁰ Bagwell, P. S., *The transport revolution from 1770*, p. 109.

decision in 1874 to abolish the second-class and greatly improve the comfort of third-class accommodation. Other railway companies soon followed the suit. By 1890, the difference in the standard of first and third class accommodation had narrowed substantially.⁴¹ While the number of first-class journeys remained at roughly the same level of 20 million throughout the whole period between 1851 and 1911 and the number of second-class journey declined from c. 30 million to c. 10 million, the number of third-class journeys increased continuously from c.40 million to more than 1,200 million.⁴² Hence, the expansion of passenger journeys during this period can be almost entirely attributed to the dramatic increase in third-class travel. The three classes contributed an equal share of the railway companies' revenue from passenger traffic in 1852. But, by 1912, third-class tickets made up nearly 80% of the companies' revenue from passenger traffic.⁴³

Turning to freight traffic, canals had been the most common inland mode of transport for bulky goods before the coming of railways. However, railways quickly destroyed the canals' monopoly. By 1911, railways conveyed c. 520 million tons of goods while canals only carried c. 40 million tons.⁴⁴

Before the 1960s, a consensus existed amongst historians that railways had brought significant benefits to British society by fostering economic growth, stimulating population increase and facilitating urbanization. However, this consensus was often based on isolated observations. No attempt was made to comprehensively measure the impact of railways. However, the 1960s saw a breakthrough in railway research that was helped by new econometric methods and the power of computers. Fogel, as well as Fishlow, pioneered the use of quantitative studies to assess the effect of railways on economic growth.⁴⁵

These influential works have greatly enhanced our understanding of the overall economic impact of railways and they have influenced many subsequent research studies. This type of research has even created a separate academic discipline - cliometrics: the analysis of historical data with statistical and econometric methods. However, it should be pointed out that different assumptions, statistical models and data, lead different cliometric studies to reach very diverse conclusions about the impact of railways. To date, no definitive conclusion about the impact of railways on the British economy has been reached.

The 'social saving' approach has been frequently used; it employs counterfactual analytical techniques. It measures the difference between the actual cost of the transportation services provided by railways and the hypothetical cost of the same services using the next best alternative means of transportation in the absence of railways.⁴⁶ Fogel, in the context of the America's agricultural sector at the end of the nineteenth century, estimated that the social saving from railways contributed no more than 2.7 per cent of GDP. This estimate was small when compared to previous expectations. Fogel argued that, in the hypothetical absence of railways, extra investment in waterways and canals would have mitigated much of the potential losses in land values and agricultural product transactions.

⁴¹ Ibid.

⁴² *P.P.* 1852-3, XCVII, pp. 298-321; *P.P.* 1914-16, LX, p. 680.

⁴³ Bagwell, P. S., *The transport revolution from 1770*, p. 110.

⁴⁴ Ibid, p. 161.

⁴⁵ Fogel, R., *Railroads and American economic growth*; Fishlow, A., *American railroads and the transformation of the ante-bellum economy*.

⁴⁶ Gourvish, T.R., 'Railways 1830-1870: the formative years', in Freeman, M.J., and Aldcroft, D.H., (eds.) *Transport in Victorian Britain*, p.79.

Hawke undertook a similar exercise for England and Wales.⁴⁷ He arrived at a more positive account of the benefits that railways brought to the British economy. He estimated that the social saving from the railways contributed 6-11 per cent to the national income of England and Wales in 1865. Based on this estimate, Hawke concluded that, “The innovation of railways within England and Wales did have a considerable impact on the growth of that economy”.⁴⁸ The larger part of the saving in Hawke’s estimate came from passenger rather than freight traffic. The variation between 6 and 11 per cent depended on the different assumptions that could be made about the best alternatives to the different classes of railway passenger traffic. As noted by many other scholars, one of the shortcomings of the ‘social saving’ approach is its high sensitivity to the assumptions being made. For instance, if one assumes the best alternatives to first-class, second-class and third-class rail travel were the posting coach, inside coach travel and outside coach travel respectively, then the social saving on passenger traffic would account for more than 7 per cent of national income in England and Wales. However, if one assumes the alternative for first class rail travel was inside coach travel and the alternative for the other classes was outside travel, then the social saving on passenger traffic would only account for 2 per cent of national income in England and Wales.⁴⁹ Hawke’s estimation of social savings from freight traffic is not free from problems and criticisms either. The best alternatives to railways for freight traffic are coastal shipping, particularly for long haul coal transport, and canals. But evidence on the cost of coastal shipping and canal transport are very limited. For example, taking canals, Hawke can only rely on the flimsy evidence from two atypical canals - the Leeds and Liverpool and the Kennet and Avon. Both experienced great construction and operational difficulties.⁵⁰ Hence the cost of these canals is likely to have been much higher than other canals and railway transport. Hawke estimated that these two canals cost c. 2.3d per ton-mile as compared to the 1.2d per ton-mile for railway freight traffic.⁵¹ Had more data been at Hawke’s disposal, the social saving from railway freight traffic could have varied considerably.

The lack of reliable and systematic empirical evidence is not the only problem for ‘social saving’ calculations. More fundamentally, the methodology has several flaws. Firstly, it is assumed that there was an inelastic demand for transport. This implies that, in the absence of railways, higher cost transport modes would not have affected the volume of passenger and freight traffic. Clearly, it is highly implausible to assume that the demand for transportation would have been unresponsive to price changes. Hence, the economic value of expanded passenger and freight traffic is not captured in social saving estimations. Secondly, in many scenarios, a traffic decrease without railways is not the issue because the traffic may not have happened at all. A recent paper by Leunig considers the cost of stagecoaches, railway fares and passenger’s incomes; he argues that without railways the best alternative to third class passenger rail travel in the nineteenth century was walking.⁵² If that was the case, many passenger journeys, especially those over a long distance, simply would not have taken place. Thirdly, the social saving approach is conducted in a partial equilibrium framework. It only focuses on a particular industry. Within this framework the industry of concern, in this case railways, is treated as an isolated entity in the economy and spillover externalities to other sections of the economy are ignored. For example, the so-called effect of ‘backward linkage’ from railways has long been acknowledged by historians; this effect suggests railway

⁴⁷ Hawke, G., *Railways and economic growth in England and Wales, 1840-1870*.

⁴⁸ *Ibid.*, p. 410.

⁴⁹ *Ibid.*, pp. 43, 48-9, 62, 88-9, 188.

⁵⁰ Gourvish, T.R., ‘Railways 1830-1870: the formative years’, in Freeman, M.J., and Aldcroft, D.H., (eds.) *Transport in Victorian Britain*, p.81.

⁵¹ *Ibid.*

⁵² Leunig, T., ‘Time is money: a re-assessment of the passenger social savings from Victorian British railways’.

construction created considerable demand for iron and steel which, in turn, spurred the development of this key industry in the nineteenth century.⁵³ Perhaps more importantly, the railway industry's novel labour, capital and management structures may well have influenced other industries in the pursuit of greater productivity during the nineteenth century.⁵⁴ It is difficult to quantify such effects as even Hawke himself has admitted, "The difficulty with such external economies is simply that they must be identified and measured".⁵⁵ None of these effects on the wider economy is captured in the social saving approach. Last, but not least, the counterfactual alternative to railways in the social saving approach only takes into account the price factor so it neglects natural plausibility. The implicit assumption behind this framework is that even though conveying the same number of passengers and freight by canals or stagecoaches would be more expensive, it could have been done. But in reality, this is unrealistic. Take, for example, passenger traffic; there were more than 300 million passenger journeys by railways in 1870. To convey the same number of passengers by stagecoach, the quantity of horses needed would have absorbed a big proportion of the nations' land and caused massive agricultural disruption. Although railways freed the British economy from such a yoke their beneficial effect in this respect is not captured by the social saving approach.

9. Conclusions

Following innovative transportation improvements through turnpikes, inland waterways and coastal shipping, Britain pioneered the more revolutionary development of railways between 1825 and 1911. The railway network grew through bursts of activity rather than steady incremental expansion and unregulated private enterprise played the leading role. Although no consensus has materialised amongst scholars, Britain's railways most probably delivered significant economic and social benefits. As we have seen, railways transformed both passenger and freight transportation, and they appear to have boosted urbanisation and population growth while making the British economy more integrated and international. Nevertheless, it is unlikely that the returns to investment were optimal; inefficiencies due to *laissez faire* economic policies and a reluctance to engage in national state planning and industry regulation appear to have capped the benefits gained at an artificially low level. The pursuit of local, sectional interests did not, it seems, fully maximize the national interest. Even so, Britain's railways did help to make the industrial revolution a permanent phenomenon that significantly improved living standards in the long-run both at home and abroad.

⁵³ Mitchell, B. R., 'The coming of the railway and United Kingdom economic growth'.

⁵⁴ Simmons, J., *The railway in England and Wales 1830-1914*, pp. 12-15.

⁵⁵ Hawke, G. and Higgins, J. P. P., 'Transport and social overhead capital', in Floud and McCloskey (eds.), *The economic history of Britain since 1700* (vol. I), p. 240