

Long Run Trends in Energy Services:
The Price and Use of Road and Rail Transport in the UK (1250-2000)

Roger Fouquet and Peter J.G. Pearson
Centre for Energy Policy and Technology
Faculty of Life Sciences
Imperial College London

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Summary

This paper adds to the literature on the long run evolution of energy services. It presents an array of historical data on the cost and use of transport services. It measures the cost in pence per passenger/tonne kilometre-hour, to take account of the impact of technological innovations on speed of travel. These costs have fallen up to 750-fold over the last seven hundred years. The paper also explores the growth in the use of transport services over the last three hundred years. Freight service use is up to 1,000 times greater than it was in 1800; most of the increase happened in the nineteenth century. Passenger travel is around 350 times greater than it was three hundred years ago; most of the increase happened in the twentieth century. As might be expected, transport use has risen considerably relative to population and income over the last three hundred years. Two more striking changes were: the dramatic decline in the ability to provide transport services per unit of energy when steam-power replaced horses; and, correspondingly, that the modern transport system appears to be substantially less effective at providing transport services per unit of energy than were horses.

I. Introduction

William Nordhaus (1997) pointed to the importance of accounting for the influence of technological innovation in reducing the cost of lighting. In another paper (Fouquet and Pearson 2003b), we show the impressive long run decline in the cost of artificial lighting in the UK and the associated rise in the use of lighting services. In general, all forms of energy service have benefited from innovation. In this paper, we examine the extent to which transport service costs have fallen and consumption has risen.

Over the last few centuries increased speeds of travel have been the most obvious effect of technological developments on land transport service provision. We have attempted, therefore, to capture this improvement in the value of the services provided. In a similar way to the representation of the price of lighting services in costs per (million) lumen-hours (Nordhaus 1997), the price of travel is presented here in costs per kilometre-hour.

Building on past research (Fouquet and Pearson 1998, 2003a), we have recently begun delving into a variety of economic history sources¹ to provide further evidence on long run trends in energy use in road and rail transport, and on the costs and prices of the resulting transport services. These preliminary estimates of the average prices of carrying a tonne of barley, wood and stone in the Middle Ages (Rogers 1886) or of the speed of stage-coaches in the seventeenth century are rough (Jackman 1916) and approximate. They should, therefore, be treated with appropriate caution and are probably at best viewed as indicative of broad

¹ Due to space limitations, please contact the authors for the data sources associated with transport services. Sources of other historical energy data can be found in Fouquet and Pearson (1998, 2003a).

trends. Inevitably, there are gaps in the series. Some cannot be filled; others (although perhaps fewer than might be imagined) have been interpolated via bold assumptions; and some, including the costs of using road vehicles (rather than rail), are still missing, but should be addressed in the future. This paper is principally exploratory and descriptive, and is intended mainly to help identify key trends, issues and questions. Not least, the limitations in our knowledge and data suggest that care should be taken in drawing premature conclusions. While the evolution of transport services is of clear importance, it is influenced by a complex constellation of factors whose interactions should not be over-simplified.

The paper follows the chronology of developments in road and rail transport. Section II addresses pre-1700 freight transport services. The third section focuses on passenger travel in stage-coaches. Section IV discusses the great impact of railways. Section V examines the twentieth century. In the sixth section, we explore relationships between transport consumption and key variables, principally population, income and energy use. The final section concludes the paper.

II. Early Transport Services

In current terms (i.e. 2000 prices)², hiring a team to carry goods along a road to a nearby market or manor in the thirteenth century cost about 300 pence per tonne-kilometre travelled (See Figure 1). After the Black Death in 1347-48, when nearly half the population died, and with the broad exception of the latter part of the fourteenth century, for much of the next two hundred years, the cost of carriage fell, declining to about 100 pence per tonne-kilometre at the time of King Henry VIII's Reformation in 1534. It has been argued that selling-off church lands meant that many of the roads, once maintained by the clergy, went into disrepair over the next hundred years or so (Masschaele 1993). By the middle of the seventeenth century, the price of carriage rose back to 300 pence per tonne-kilometre.

These apparent variations in the state of the roads make estimation of the speed of travel difficult. Clearly, poorly maintained roads would have slowed movement, especially in the winter months. On the other hand, certain technological improvements would have accelerated the pace: the use of the harness (instead of a metal bar placed across the ox's chest and wind-pipe); the switch from oxen to horses; the use of (two-wheeled) carts for packhorses (carrying goods on their back); and, in the mid-seventeenth century, after the lifting of the 1618 ban (introduced to reduce damage to roads), the use of (four-wheeled) wagons. To try to take account of these two factors, separate indices of road quality and technological improvements have been created; they were then used together to determine variations in travel speed, 'anchored' between estimates of the speed of travel in the early fourteenth century and in the seventeenth century (Masschaele 1993). These 'anchor' estimates indicate that during these two periods the average speed of travel was about two kilometres per hour (See Figure 2). Interactions between the road quality and technological indices suggest that in the sixteenth century the speed of travel actually declined, as one road-maintenance institution disappeared, but then improved considerably from the seventeenth century, partly because of the introduction of the first turnpikes, new private institutions created to maintain and even improve the quality of roads, as well as the technological developments mentioned.

Clearly, the price per kilometre travelled should reflect these improvements from the perspective of the costs of supplying the service. Nevertheless, to the user, the same service

² All prices are quoted in year 2000 prices.

provided, at the same price, but in less travel time and hence at lower opportunity cost, is a superior service (other attributes being equal). An estimate of carriage per kilometre-hour is, therefore, presented (See Figure 3). This accentuates the cheapness of freight travel in the sixteenth century - falling to 40 pence per tonne kilometre-hour - and the dearness of travel before the Black Death and in the early seventeenth century – when at time it rose above 100 pence.

III. The Stage Coach Era

The first regular stage-coach journeys (from London to Chester in 1657) provide evidence of the cost of personal travel. There was clearly much variation in prices according to the number of passengers in the stage-coach, its comfort and whether the passenger was by the window or stuck in the middle. Yet, for two hundred years, average prices and speeds can be estimated, based on more than a dozen regular services between London and provincial towns, as well as between the burgeoning industrial towns of the midlands and Lancashire.

Up to 1750, the cost of travelling by stage-coach appears to have remained relatively constant, ranging from 50 to 60 pence per passenger-kilometre (See Figure 4). As competition for services grew, especially at the end of the eighteenth and the beginning of the nineteenth century, prices fell to 35 pence (Jackman 1966 p.343). But, over the next twenty years, prices doubled. It has been argued that this was associated with the realisation that railways would replace stage-coaches, and, consequently, proprietors only had a few years left to earn profit before disposing of their premises, coaches and horses (Hart 1960 p.149).

Modest improvements in travel speeds were achieved in the first century of stage-coaches and turnpikes, especially on routes near London. By 1750, stage-coaches were averaging speeds of 5 kilometres per hour. An important factor was that as ‘cruising’ speeds increased, fewer nights were spent in inns along the way (increasing average speeds, and reducing the overall cost of travel). For example, the London to Chester route, 290 kilometres long, took six days in 1657; in 1704, it took four days. By 1837, passengers could expect to reach Chester in 22 hours (Hart 1960). The second half of the eighteenth century and early nineteenth century were times of major road and technological improvements. By 1830, average speeds were around 15 kilometres per hour.

These developments had major implications for the cost of travelling a kilometre-hour (See Figure 5). The price peaked at over 20 pence per passenger kilometre-hour in the 1690s. But declining costs of journeys and faster times led to important reductions – down to 13 pence in 1750 and to 4 pence by 1800.

Evidence of stage-coach use reflects the dramatic growth in the use of transport services and in personal mobility from the seventeenth century (See Figure 6, which also includes estimates of private travel). In 1715 (not shown in the Figure), there were around seven million passenger-kilometres travelled on stage-coaches. By 1775, stage-coach services were providing over fifty million passenger-kilometres. Over the next fifty years, personal mobility had been revolutionised, with 1.6 billion passenger-kilometres from the use of stage-coaches, and nearly the same again in private travel. So, by 1815, horse-drawn travel generated more than three billion passenger kilometres per year. Interestingly, for the next twenty years afterwards, travel use appears to have stagnated, at a time of considerable economic growth and growing prosperity, but rising costs of transport services.

Despite a more than five-fold decrease in the price of carriage between the beginning and the end of the eighteenth century, from 70 pence to 12 pence per kilometre-hour (as shown in Figure 3), the growth in freight transport appears not to have been as dramatic. In 1715, there were about three million tonne-kilometres, increasing to forty million, sixty years later, and on to 225 million by 1815. This growth continued – by 1840, horses were providing nearly 400 million tonne-kilometres worth of carriage (See Figure 7).

IV. The Railway Mania

Intense capital investment, creating an extensive transport network, and faster technology enabled the railways to compete rapidly with horse-drawn transportation of goods and people. Initially, prices were higher using the newer form of transport technology. With declining costs and increasing speeds, by the 1840s, when the first data are available, railways were cheaper per kilometre-hour than horses (See Figure 5). Indeed, “the greater speed of railways than of coaches made travel a commodity available to people who would not otherwise have considered it as a possible item for expenditure...” (Hawke 1970 p.191).

Railway prices continued to fall – from around 1.3 pence per kilometre-hour and seven pence per tonne-kilometre in the early 1840s to one penny and five pence by 1850, to below 0.35 pence and just above one penny in 1900 (See Figure 8). Thus, taking account of time-savings, passengers could travel for one fortieth (2.5%) and one tenth (10%) of what it would have cost two hundred and one hundred years earlier. Freight cost one seventieth (less than 2%) of what it would have cost two hundred years earlier, and one twelfth (8%) of what it would have cost one hundred years earlier.

Inevitably, the use of transport services multiplied. By 1850, there were already one billion passenger-kilometres and one billion tonne-kilometres. By 1900 passenger-kilometres increased to 18 billion passenger-kilometres (See Figure 6). Railway freight was already larger than horse-drawn carriage had ever been. It rose to 30 billion tonne-kilometres in 1900 (See Figure 7). It should be noted that, at the beginning of the twentieth century, although horse-power was responsible for less than one-tenth of freight transport, it still provided more than one-third of all passenger journeys, through horse-drawn buses, trams, hackney carriages (i.e. taxis) and private carriages, as well as horse-back riding.

V. The Twentieth Century

Throughout the twentieth century, apart from in the nineteen thirties, railway prices per kilometre remained relatively constant and average speeds rose. Prices per passenger kilometre-hour fell nearly three-fold from around 0.35 pence in 1900 to about 0.16 pence in 1950, and have fallen a little since then, currently at 0.1 pence³ (See Figure 8). After the impressive fall in the nineteenth century, freight prices were the same in 1900 as in 1950, at one penny per kilometre-hour (Also Figure 8). After 1950, however, they dropped five-fold, down to 0.2 pence per tonne kilometre-hour by the end of the century.

³ This (0.1 pence) estimate appears remarkably low. In 2000, the average price per kilometre by train was below 10 pence per kilometre (See Figure 4). It is calculated by dividing national railway receipts (£3.5bn) by national railway passenger- kilometres (£47bn) using Department of Transport (2003). This figure is low because two-thirds of rail travellers in Britain are in the South-East, many having bought pre-paid rail cards, with an average cost per journey of around £3 (thus, costing them about 5 pence per kilometre). The speed data are based on a weighted average of speeds between major cities in the Britain and slower suburban trains (See Figure 2). While the Inter-City trains average 120 kilometres per hour, the suburban trains in the South-East only travel at about 50 kilometres per hour.

Despite these dramatic declines in the costs of these transport services, railway passenger-kilometres have only doubled, to 38 billion, since 1900 (See Figure 9). Another ten billion passenger-kilometres are provided by urban underground services. Freight tonne-kilometres increased from 30 in 1900 to 36 billion in 1950, and halved by 2000 (See Figure 10).

Underlying the modest rises in personal mobility and declines in goods-haulage from trains is the massive substitution of total transport services back to roads, as well as the use of waterways (including coastal services) and pipelines. As Figure 10 shows, by 2000 roads were responsible for 120 million tonne-kilometres of carriage; waterways 60 and pipelines ten billion. In 2000, transport companies provided a total of 250 billion tonne-kilometres of goods transport service. Excluding the important role played historically by waterways, freight transport is one thousand times greater than two hundred years ago, and twelve times greater than one hundred years ago.

Road transportation is even more prominent as the main source of transportation for people (See Figure 9). The total amount of transport service is around 720 billion passenger-kilometres. Of this, around 600 billion passenger-kilometres (83% of the total) are the result of car, van and truck use; another 50 billion (about 7%) are from public road transportation (i.e. buses and coaches). Personal travel has increased more than 350 times in the last two hundred years and 35 times in the last one hundred years.

VI. Transport Services in the Context of Economic Development

Comparing the growth in transport services with population, economic activity and well-being, and energy use may provide a useful perspective for understanding future growth. In terms of per capita consumption, according to these estimates the average person travelled by stage-coach around 60 kilometres per year in 1715 (of course, only a small minority of the population actually travelled by stage-coach). By 1800, the estimate had doubled. By 1900, average travel (taking account of all road and rail) was 700 kilometres per year. By 2000, excluding air and sea journeys, the average person travels 18 times more, or 12,000 kilometres per year.

Figure 11 indicates the kilometres travelled per £(2000) of GDP and is, therefore, a measure of travel intensity. Freight was only 0.3 kilogram-kilometres (i.e. 0.0003 tonne-kilometres in Figure 11, thus, not visible) per pound at the beginning of the eighteenth century. By 1800, it had increased to 8 kilogram-kilometres, and then soared to 220 by 1900. It peaked in 1979 at 340, before falling back to 240 (i.e. 0.24 tonne-kilometres) today. That is, eight hundred times greater per than three hundred years ago and forty times greater than in 1800.

The expansion of personal travel came later. In the early eighteenth century, 0.07 passenger-kilometres were travelled for every pound. At the end of the century, it was 0.1. In 1900, the ratio had only doubled. The major increase took place in the twentieth century. It nearly quadrupled to 0.72 passenger-kilometres in 1950, and reached its maximum in 1992 at 1.00 and has fallen considerably; in 2000, it was 0.68 passenger-kilometres per pound spent.

Comparing the level of transport services consumed relative to the energy used for transportation provides the most striking information. In 1811, the first year for which data are available on horse population for transportation, 487,000 horses provided an estimated 3.68 Terajoules (based on the assumption that the average horse generates 700 watts (Smil

1994 p.86) working 10 hours per day for 300 days per year) – or equivalently, nearly 0.09 million tonnes of oil. In 1831, the first year that data are available on coal use for railway transportation, consumption was 0.16 million tonnes of oil. By 1850, 426,000 horses generated 0.08 million tonnes of oil equivalent. Coal use was 7.26 million tonnes of oil equivalent. The horses provided 3.1 billion passenger-kilometres and 0.4 billion tonne-kilometres. The railways provided 1.5 billion passenger-kilometres and 1.1 billion tonne-kilometres. So, the transport service provided were not very different but the fossil fuel-based transportation service used about one hundred times more energy than the animate energy-based transportation service⁴.

Figure 12 shows the dramatic decline in transport efficiency with the introduction of steam-engines, from 40,000 passenger-kilometres per tonne of oil equivalent in 1830 to 630 passenger-kilometres per tonne in 1850. In 1900, intensity is even slightly worse, at 568 passenger-kilometres. The introduction of the petroleum-based internal combustion engine helps intensity considerably, such that by 1950, one tonne of oil provided more than 2,800 passenger-kilometres. Over the next two decades the intensity soared back upwards, to reach 17,500 passenger-kilometres per tonne of oil equivalent by 1970, with the substitution of road for rail and the phasing out of coal in railway engines. Interestingly, it peaked in 1989 at 19,100, and (as oil prices were returning to lower levels than during the oil shocks) fell back to 18,600 passenger-kilometres in 2000. Freight transport has followed a similar, although less dramatic, inverse-U shaped path.

VII. Conclusion

This paper presented estimates of the cost and use of an energy service, transport, over the very long run. It illustrates, in particular, the impact of the adoption of new technologies. The shifts from horses to railways to cars have dramatically transformed the nature, cost and use of transport services.

While there are major data limitations, such as the lack of information on the cost of using cars (which are to be assembled) and the increasing ‘fuzziness’ of the data as we look back in time, it is possible to present broad trends. In particular, transport services cost around one seven-hundred-and-fiftieth (for freight) of what they did in the Middle Ages; one one-hundred-and-fiftieth (for passengers) of what they did before the ‘industrial revolution’; and one fortieth (for passengers) of what they did before the introduction of the steam-engine. Here, we have measured transport service prices by combining the cost per kilometre travelled and the speed of travel, estimating that in 2000, it cost (by train) 0.1 pence per passenger-kilometre-hour and 0.2 pence per tonne-kilometre-hour.

These declining costs are a major factor in the growth in transport use. It can be argued that while the nineteenth century was characterised by a dramatic rise in goods transport, the twentieth century experienced a dramatic rise in personal transport. These growth patterns remind us of the nature and evolution of our economies and societies since the ‘industrial revolution’ – we became a goods-transport-intensive then a people-transport-intensive society. It raises the question: what forms and modes of transportation will dramatically increase in the twenty-first century?

⁴ As with the limits associated with generating heat and motive power from biomass energy to fuel the industrial revolution (Wrigley 1988), it is very unlikely that animate-power could have expanded to meet the demands of the expanding transport system, even without consideration of the problems of waste disposal.

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Figure 1. The Price of Freight Transport (per Tonne-Kilometre), 1250-2000

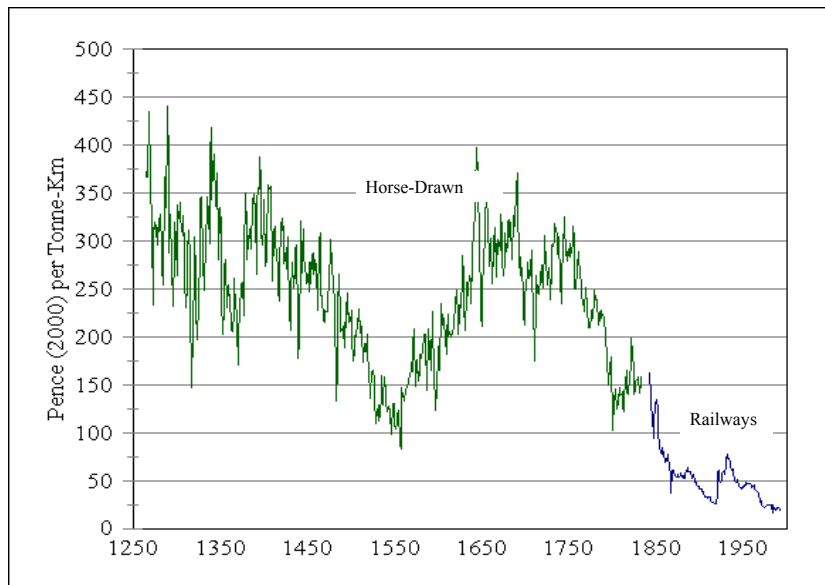


Figure 2. The Speed of Transport (Kilometres per Hour), 1650-2000

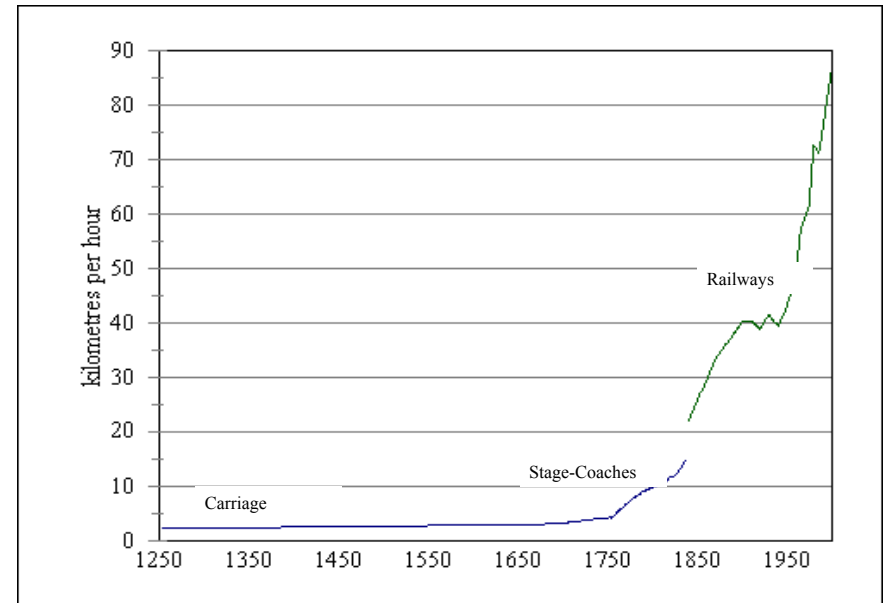


Figure 3. The Price of Freight Transport (per Tonne-Km-Hour), 1250-2000

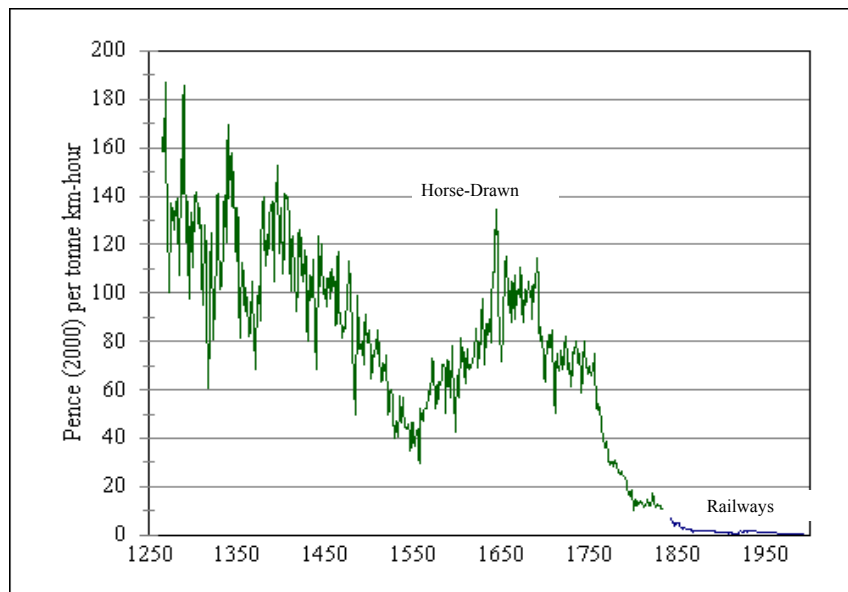


Figure 4. The Price of Passenger Transport (per Passenger-Kilometre), 1650-2000

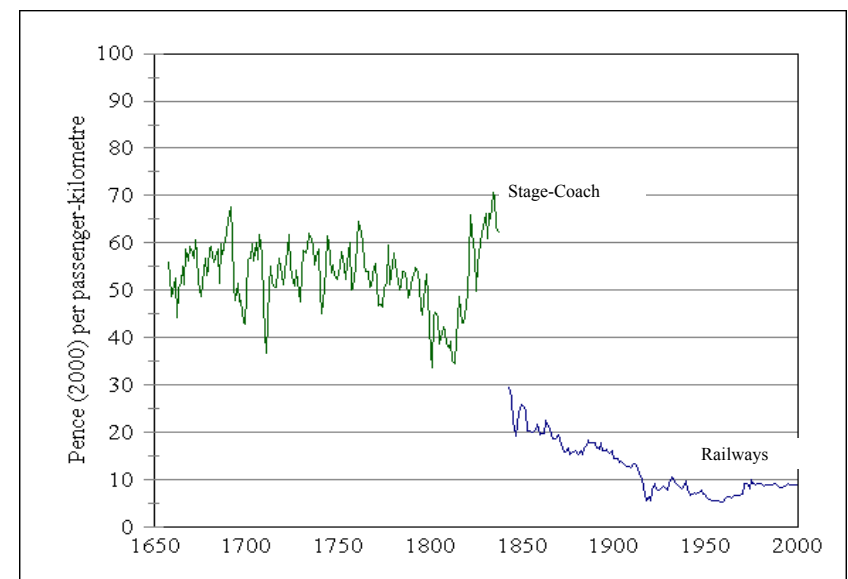


Figure 5. The Price of Passenger Transport (per Passenger-Km-Hour), 1650-2000

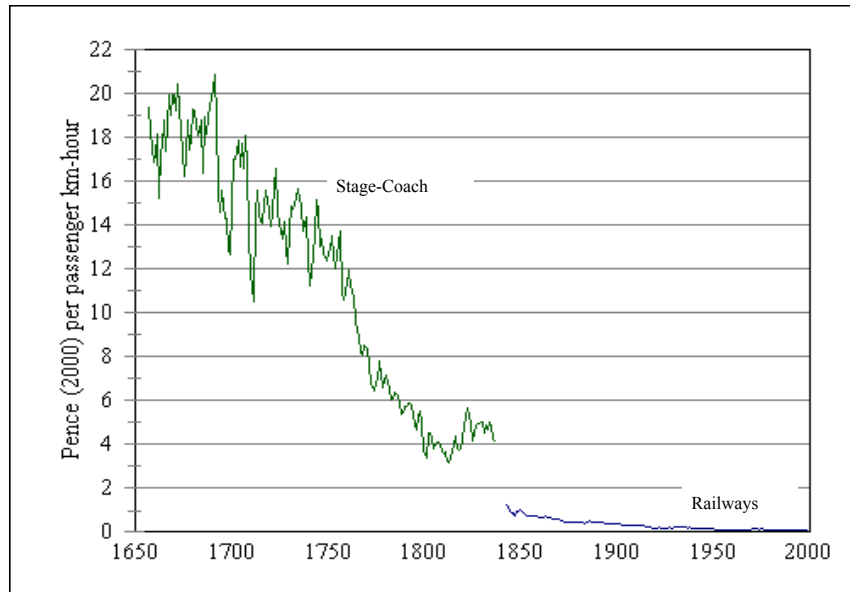


Figure 6. The Use of Passenger Transport (per Passenger-Kilometre), 1750-1900

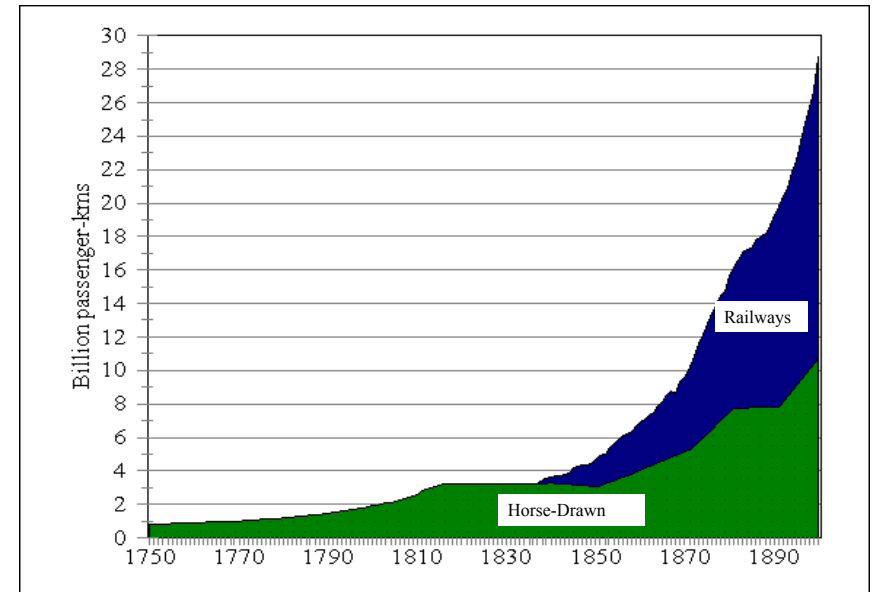


Figure 7. The Use of Freight Transport (per Freight-Kilometre), 1800-1900

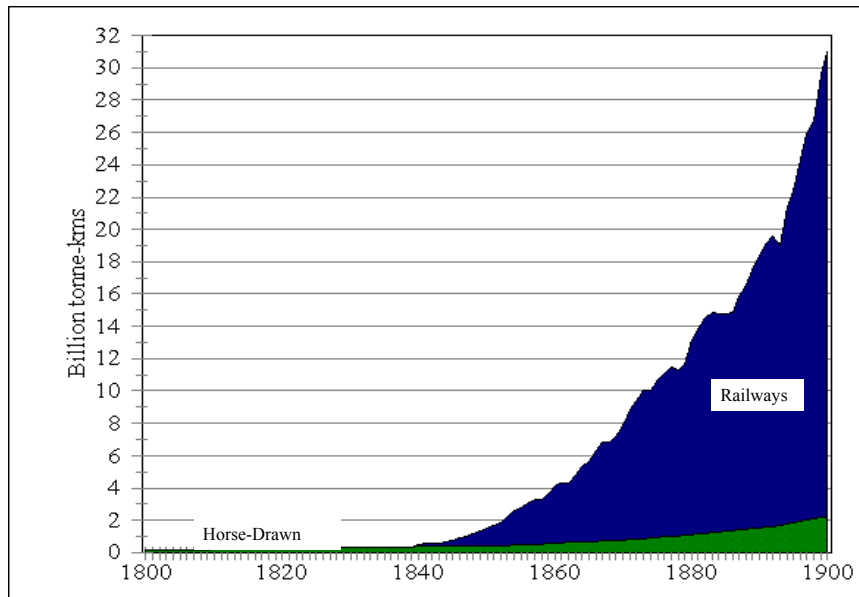


Figure 8. The Price of Passenger and Freight Transport (per Passenger- and Tonne-Kilometre-Hour), 1840-2000

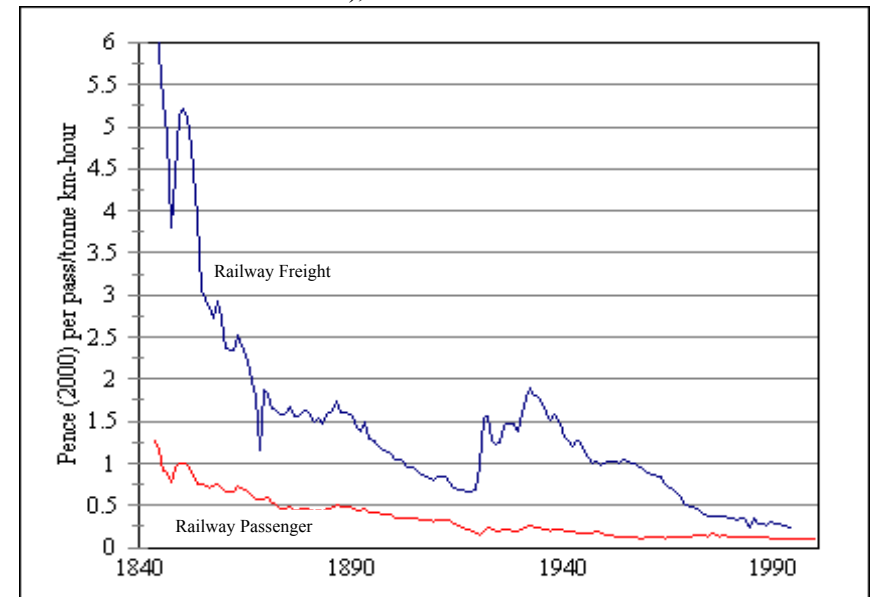


Figure 9. The Use of Passenger Transport (per Passenger-Kilometre), 1850-2000

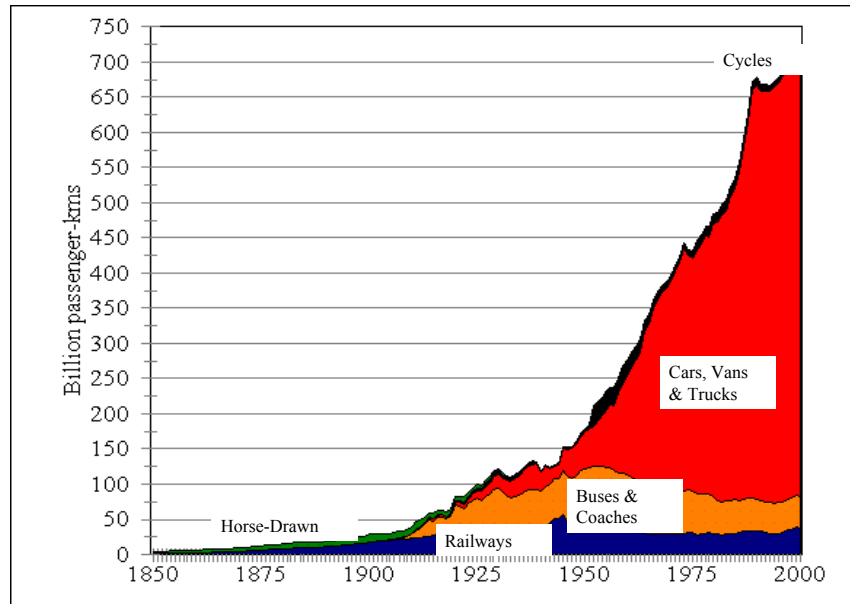


Figure 10. The Use of Freight Transport (per Tonne-Kilometre), 1850-2000

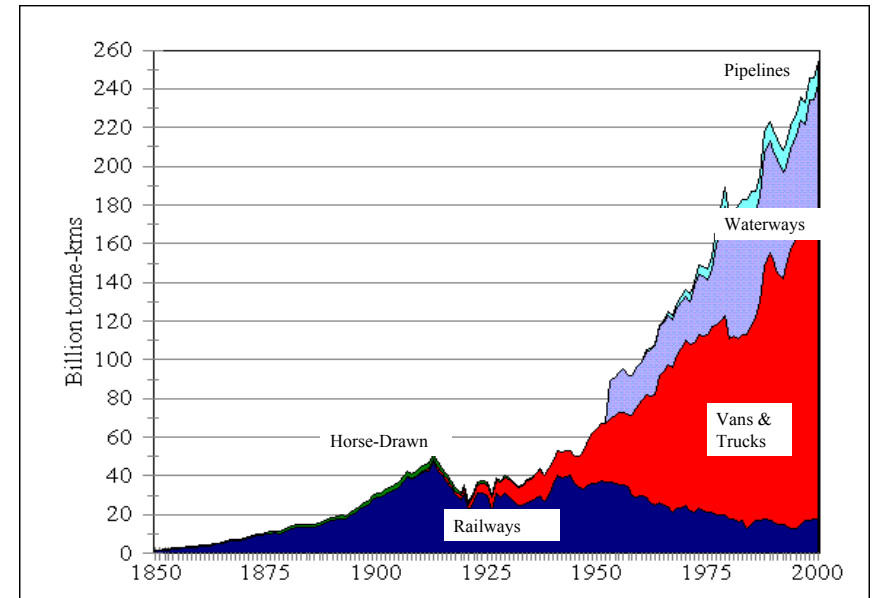


Figure 11. The Use of Freight and Passenger Transport per Tonne and Passenger-Kilometre per thousand £(2000)GDP, 1700-2000

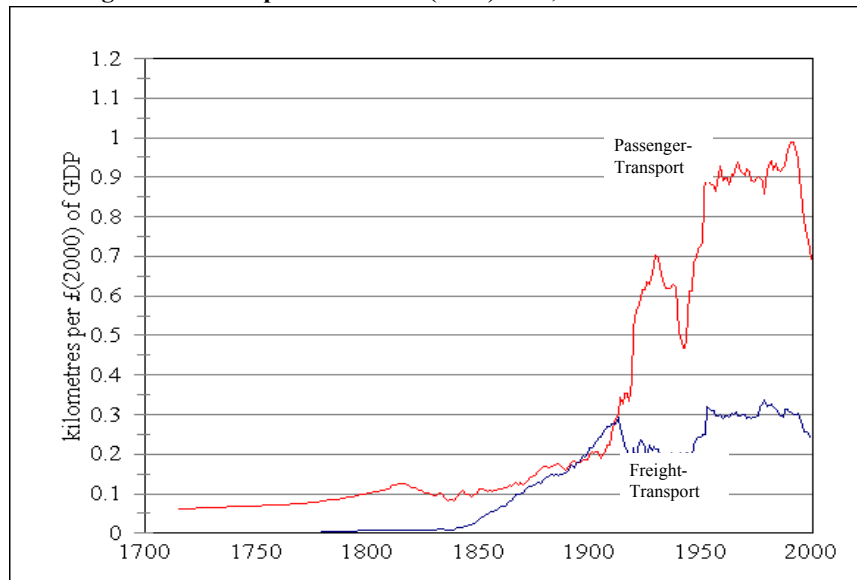


Figure 12. The Use of Freight and Passenger Transport Services (per Tonne- and Passenger-Kilometre per tonne of oil equivalent, 1800-2000

