Surface transport history in the UK: analysis and projections

M. V. Lowson

Proc. Instn Civ. Engrs Transp., 1998, **129**, Feb., 14 – 19

Paper 11548

Written discussion closes 31 July 1998

A comparative analysis is given of the history of the three main forms of surface transport in the UK: the canal, railway, and car/road systems. There are common features in each of these systems, in terms of growth, technology utilization, and eventual decline. The analysis suggests that the era of dominance of surface transport by the automobile is now drawing to an end, and that it is reasonable to expect a new form of transport to come into being, involving new vehicles matched to a new infrastructure, and designed to meet new requirements, notably the issues of sustainability.

Keywords: history; transport planning; waterways and canals

Introduction

It is well known that transport is one of the crucial enabling technologies for civilisation, and controls the way in which a society develops. Looking back to the last century, the train was the dominant means of surface transport. The train shaped the whole development of Britain during Victorian times. Towns which had an early connection to the railway network grew at great pace, while towns without train connections, whether by accident or design, remained as backwaters. The form of town and city which developed was also controlled by the configuration of the railway network. The train also provided some of the largest industrial and business opportunities of the age.

2. In the present century, it has been the car which has provided the great force for social change. Cities, towns, and villages have been altered beyond recognition by the impact of the car, and the road network which supports it. Features of present-day living such as out-of-town shopping centres or the repopulation of villages, have only been possible because of the car and the associated road system, which is a dominant feature of the urban landscape.

3. An interesting example of the effect of transport technologies is Brunel's London to Bristol line, in which he chose the more northerly route as opposed to the more obvious direction through Marlborough. Swindon, created by Brunel to service the line, retains its dominance over towns to the south to the present day. Brunel's line and the A4 trunk road were both main arteries leading to the heart of Bristol. In the 1960s, largely as a result of chance, one of the major confluences of motorways in the UK, between the main east–west M4 and the north–south M5, was constructed around 10 miles north and west of the centre of Bristol. At the same time Bristol Parkway station was opened, less than a mile from the M4 corridor. The consequence was dramatic. Development in the centre of Bristol ceased, and new offices, shopping areas and residential estates opened in profusion to the north, totally changing the shape and nature of the city.

4. The car has also provided the great commercial dynamic of the modern era. Analysis suggests that almost the whole of the difference between the British and German economies in recent years can be explained in terms of the difference in the strength of the automotive sector.

5. Two hundred years ago canals gave rise to the first great revolution in transport capability. The canal provided the backbone of the industrial revolution giving, for the first time, effective and low cost transport both to get raw materials to the place of manufacture, and to transport the resulting goods throughout the UK. The Bridgewater canal, the first of the era, halved the cost of coal in Manchester. The network of canals in Birmingham was one of the main driving forces for its growth at that time. Canals were also an enormous financial opportunity, eagerly subscribed to by private individuals despite considerable risk. This, of course, was at a time investors could reap the full benefit of their risk-taking.

6. Thus, particularly in modern industrial societies, transport technology has had the dominating effect on development. This paper seeks to provide a historical analysis and comparison of these technologies, and draw some conclusions about possible future trends. For convenience, the UK has been taken as the basis for the study.

Build rates

7. The approach taken in the present paper is to analyse and compare build rates of the various forms of surface transport which have emerged in the UK. No means of transport can be used until it is built. After it is built its utilization will normally increase towards a limit set by the scale of the infrastructure. Thus build rate provides a measure of the most basic driving parameter in the development of a transport system. It has the further major

Martin V. Lowson, Advanced Transport Group, University of Bristol

benefit that relevant data are readily available, although not necessarily in directly comparable forms. For modern types of transport, data are available in tables of government statistics.[1] Good statistics are also available from the reports of the Board of Trade in Victorian times. In earlier times the best data are available from parliamentary records of approvals of schemes. The various forms of statistic are not directly comparable, but do provide a sufficiently good record to allow conclusions to be drawn.

8. The basic data developed are shown in Table 1 and plotted in Fig. 1. These give the build rates of the three principal forms of surface transport: canal, railway, and car/road. In each case the measure is one of the length of infrastructure required to support the system. For canals this has been taken as the length of canal. For railways the length of track has been taken as the proper scale. For cars it is somewhat more difficult to define a clear measure, but for reasons which will be argued in more detail later, the statistic chosen is the length of trunk road and motorway.

9. In each case the build rates have been estimated over a ten-year period. Entries in Table 1 give the actual length of build achieved in the previous ten years. In Fig. 1, these data have been non-dimensionalized against the peak rate for each form of transport, to allow a more direct graphical comparison.

Table 1. Build rate in kilometres/ten years

Year	Canals	Railways	Trunk roads	Motorways
1760	93			
1770	876			
1780	355			
1790	164			
1800	1660			
1810	251			
1820	277			
1830	172	157		
1840	30	2233		
1850		7407		
1860		4806		
1870		6955		
1880		3502		
1890		2767		
1900		2133		
1910		1717		
1920		920		
1930		145		
1940		0	4953	
1950			8322	
1960			305	153
1970			883	904
1980			486	1498
1990			717	515
2000				

Canals

10. The first set of data refers to canals. This has been obtained courtesy of Mr R. A. Jamieson, Archivist at the National Waterways Museum, Gloucester. In this case the data are on the lengths of canals (actually built) approved via parliamentary bills. The date of these bills is known, with the greatest peak, 'canal mania', in 1793. Canals were not opened immediately on passage of the bill, since first they had to be constructed. Typical rates of construction were around 6 miles per year. Dates of opening of canals are not necessarily known in all cases. Further, many of the canals were opened in sections, so that it would require a considerable amount of detailed

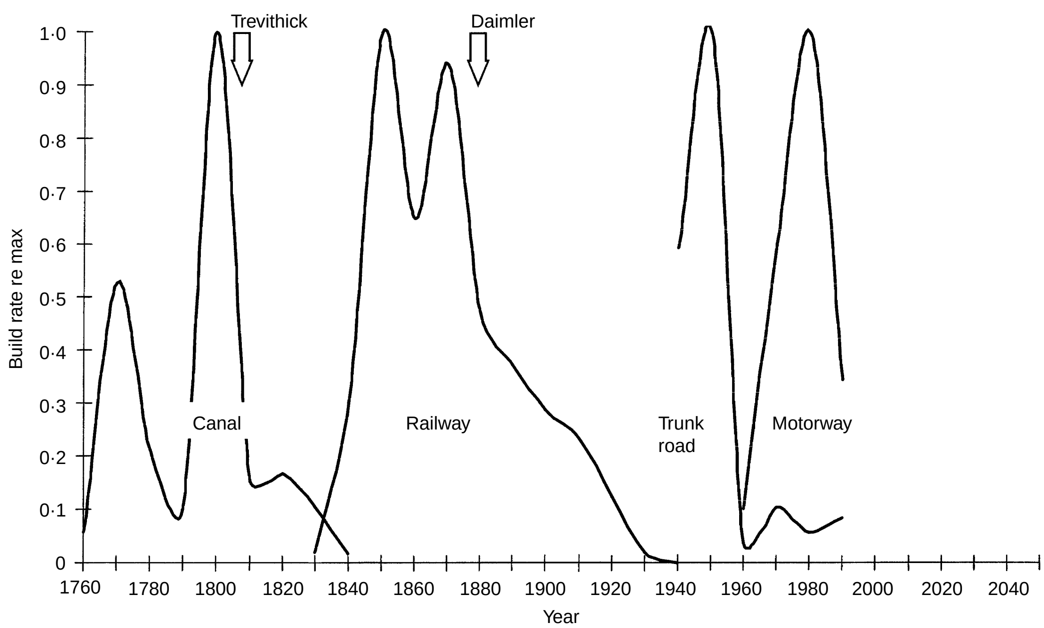

Fig. 1. UK transport history

historical research to establish the first time of availability of the whole canal system. For the purposes of the present analysis the timing of parliamentary approvals gives a reasonable estimate of build rate.

11. Although a canal was built in Lincolnshire in Roman times, canals in Britain were a relatively late development compared with continental Europe, where the Milan Grand Canal was built in 1209, and the first lock in the Netherlands in 1253 (although the first lock in China was recorded in 983). There was some canal building in the UK later than shown in the figure, notably the Manchester ship canal, but this does not influence the general conclusions which can be drawn from the main bulk of the data, dominated by the boom years of canals in the UK between 1760 and 1830.

12. The canal figures have many points of interest. The double peak in build rate is the most striking feature of the curve. In fact the two peaks correspond to rather different technologies of canal building. The first corresponds to the level James Brindley canals which largely conformed to the contours of the land. This was done in order to avoid locks, which add to cost and also lead to operational difficulties, the key issue being the supply of water for lock operation. Canals built during the second peak of activity attacked the problem more directly, cutting straight through the landscape, with complex assemblages of locks, holding pounds, and a plethora of other canal technologies.

13. Canal boats also saw development. Early canals more closely resembled rivers, and so were suited to craft little different to those used on rivers. Indeed, the first canals were river navigations. Later canals, dominated by straight sections and locks, necessitated different forms of boat. The 7-foot wide narrow boat, designed to match the standard lock and bridge gauge of 7 ft 6 in, had reached a refined state by the time of the second wave of canal building. Thus it was the canal system as a whole—canal and boat—which had to be optimized to provide a truly effective means of transport. The historical evidence shows that this optimization process took around 30 years.

Railways

14. The key technology which gave rise to the railway was the invention of the high pressure steam engine by Richard Trevithick in about 1800. The earlier atmospheric steam engines invented by James Watt, and finally built in 1776, had inadequate power : weight ratio to have any real use for surface transport, beyond that of a winding engine. Trevithick's first attempt to use his new engine for transport was on the road in 1801, but this was a failure as an effective transport system. Trevithick's steam locomotive successfully ran on iron rails in 1804 to fulfil a bet, although when it arrived at its destination (Penderyn near Merthyr Tydfil) it was left there to act as a stationary engine. The full exploitation of the steam locomotive required the invention of the rolled wrought iron rails by John Birkinshaw in 1820. Despite this, many railways built at that time continued to use plate track on which wagons could also run. In any case, locomotive technology was not sufficiently developed to offer reliable transport of passengers. Horses were normally used for passenger transport on the Stockton and Darlington railway (opened in 1825) despite the availability of George Stephenson's 'Locomotion'. Winding engines offered another alternative technology. Thus railways are normally taken as commencing in 1830 with the opening of the Liverpool to Manchester railway, using Stephenson's Rocket. This was the first substantial railway to rely completely on steam power, and also the first to depend for a significant portion of its earnings on the carriage of passengers.

15. It is interesting that in the case of the railway both the track system and the vehicle came about almost simultaneously, so that a full transport system technology was available from the start. However this technology required considerable development. Early steam engines were only able to run effectively on the flat. A 1 in 70 gradient at Camden Town required the assistance of a winding engine until 1844.[2] Despite these limitations railways attracted considerable support, leading to 'railway mania'. In 1846 219 Acts of Parliament authorized 4538 miles of new line at a capital value of £133 million. (Not all of these were built.)

16. The rate of growth of railways is also shown in Fig. 1, based on data from Mitchell,[3] for dates before 1900, and from Reference 1 after 1900. In both cases the data correspond to actual lengths of track available for use based on an interpretation of the reports of the Board of Trade. These data have been used to provide an estimate of the construction rate in ten-year periods. It is intriguing that again the rate of growth shows a double peak. The first corresponds to the 'railway mania' of the 1840s. The second peak does not appear to correspond to any particular event, but examination of railway technology does suggest reasons why this may have come about. Early steam engines were notoriously dangerous. More than 100 people were killed by boiler explosions during the early part of the railway era. Looking at some of the designs, featuring, for example, square pressure vessels, it is evident that the technology took some time to mature. Early locomotives show a wide variety of experimentation. By the 1870s the locomotives emerging were recognizably the same in general form as those still in operation in the 1950s.

17. As in the case of canals the major construction period of the railways was over in about 50 years, from 1830 to 1880. However, after 1880, railway building in Britain did not entirely stop. A residual level of railway construction continued right up to 1940. This is perhaps a little surprising. The invention of the railway for all practical purposes stopped canal building dead. But this was not the case for the impact of the next form of transport—the car.

Cars

18. The key technology for the car is now recognized as the invention of the high speed petrol engine by Gottlieb Daimler, patented in 1885. This was largely based on the gas engines developed by Nikolaus Otto (1867). Surprisingly in retrospect, internal combustion engines were not widely used for transportation in the early days. Bunch and Hellemans[4] point out that, in 1900, of 4192 cars manufactured in the US, 1681 were equipped with a steam engine, 1575 with an electric motor, and only 936 with an internal combustion engine.

19. Trevithick had run a steam carriage on roads in 1801, and in 1831 a steam-powered ten-seat bus ran between London and Stratford. The consequence was legislation, sponsored by supporters of horse-drawn carriages, which imposed prohibitive tolls and other conditions on the use of steam power on roads, not repealed until the end of the century.

20. Perhaps the most surprising feature of Fig. 1 for the car/road, is the long time that it took, after the appearance of the basic technology, before it reached a fully competitive position with the railway. It is clear why this was so. This was because Daimler and others put their effort into devising improved vehicles rather than a complete transport system. The inadequacies of the road system, originally devised for horse-drawn conveyances at lower speeds, remained a severe limitation to the effectiveness of cars in the UK until the 1940s.

21. In the UK it was the development of the trunk road after World War II, and subsequently the motorway system, which enabled the massive expansion of the motor vehicle traffic. This development was driven by the considerable increase in demand for personal travel, both from economic growth, and from social factors such as greater leisure time. Railways were still being built until the development of the trunk road, which must be seen as a key element in the development of the car-based transport system as a whole. This is why data on trunk road and motorway developments have been selected for comparison in Table 1 and Fig. 1. The data in this case have been taken from Department of Transport statistics.[1]

22. It is intriguing that once again there appears to be a double peak in the development of the transport infrastructure, again over a period of just about 50 years (1945–1995).

Discussion

23. Inevitably any discussion of these issues is considerably simplified. For example, the move from canal to railway was dominated by the change of carriage in freight, whereas the move from railway to car depended far more on the carriage of passengers. No discussion has been presented of the development of the road/turnpike. This is because their history has depended far more on local issues than national trends. Further, the gap in development between railway and road was partially filled by the tram. The tram represents an intermediate form of transport, but had a rather short lifespan in historical terms. The existence of the tram during the early part of the present century is not believed to affect the basic arguments presented.

24. In each case the data show that the full development of a transport technology takes about 50 years. An initial boom occurs as the new ideas come into being, followed by a second period where ideas both in technology and in operation have matured, and the full capability of the system as a whole can be realized.

25. There is also an important message from the development of the car. That is that vehicle technology by itself is not enough. The car only reached a position of dominance once an effective form of infrastructure had been developed. A successful transport system requires optimizing both vehicle and infrastructure. This occurred in parallel in the case of both the canal and the railway.

26. An interesting feature of Fig. 1 is that the key invention for the next form of transport is found to occur shortly after the appearance of the peak build of the currently dominant system.

27. It may also be noted that the key to the developments has been the appearance of technologies, not the appearance of science. The science underlying canals was simple, requiring only elementary hydraulic engineering. The development of hydraulic science was due to Euler and Bernoulli in the mid 1700s. It is not clear that the great engineers of the time such as Brindley were aware of the relevant mathematics, or even that it would have been of much value to them if they had. Most of the engineering decisions were driven (as today) by the most careful calculations of cost. Trevithick's steam engine was developed at a time when it was generally believed that heat was a form of weightless fluid. It was not until 1847, well into the railway age, and after the 'railway mania' of the 1840s, that Helmholtz gave the first statement of the law of conservation of energy.

28. The key breakthrough for each of the developments analysed here has been the integration of the basic technologies in some form of initial demonstration. Scientific discoveries have been of lesser significance.

29. It is especially instructive to examine the early history of railway developments. Many of the companies created to provide transportation undertook long studies of alternative technologies for the task, which might be achieved by canal, plate railway, winding engine or locomotive. There appears to have been no inhibition about the use of new technologies, despite the fact that the notion of continual change, with which we are so familiar today, was far from being generally recognized. This seems to have been due to the fact that the key engineering discipline was cost. It is interesting that Henry Booth, the Treasurer of the Liverpool and Manchester railway, also played a key role in proposals for the improvement of the boiler technology, being the first to recognize the value of a multitube boiler for effective steam raising. It is difficult to imagine an equivalent today.

30. The transportation objectives of the three types of transport system studied here differ. The incentive for the canal was the requirement to move bulk goods, and the exploitation of the fact that a single horse could move as much as 50 t at 4 miles per hour on a canal, compared with a limit, even on the better roads, of a few hundredweight at half that speed. Canals did carry occasional passengers on the packet boats, but passengers were not a major part of their operations. Railways, too, have depended on bulk carriage, but from the start the railway has also relied on income from passenger traffic as a significant element of its profitability. Cars are directly linked to personal transport, although even today many people do not have access to a car and must use other forms of transport. Nevertheless, it is clear that the truck has also benefited enormously from the modern trunk road and motorway system. Indeed the dimensions of the road system are set by the requirements of the largest trucks. Thus a further historical trend has been that successive surface transport systems have become more and more dominated by the needs of personal transport.

Some future projections

31. The analysis also permits some projections of the future to be made. It appears almost inescapable that new forms of surface transport will appear during the next century, so that versions of Fig. 1 prepared in 50 years time will reflect the building of new types of system. It would indeed be surprising if technologies invented more than 100 years ago in the case of the car (or tram), and more than 150 years ago in the case of the train, could continue to have much potential for solution of new transport problems of the next century. A new transport system must also be expected to have consequences on the nature of the society in which people live and work equivalent to those caused by the previous great changes in transport technologies.

32. It is clear that we are now past the peak of motorway building. The message from the historical analysis is that it would be reasonable to expect the key technology developments for the next form of transport to be occurring now.

33. However, history also tells us that it takes around 20 years before the technology is brought together to provide something of direct benefit to the population. It also tells us that the total time for development of a transport technology is 50 years from the first demonstration of the critical enabling technologies (longer in the case of the car). On the other hand the historical record also tells us that the rate of growth in the first few years is explosive, with massive changes in each case within ten years after the first introduction.

34. The present day is characterized by a far more explicit recognition of the importance of change, so that perhaps a more rapid uptake of new technology could occur. This is balanced by an appallingly complex legal and regulatory framework, so that in many areas change is almost impossible. Safety and planning regulations for transport are based on experience from previous technologies, much of which is unlikely to be of relevance to the new. Nevertheless, the message from history is that a new form of transport technology is now due.

35. A further message from the historical analysis is that a complete change of system is required to provide a useful benefit. Trevithick's high pressure boiler would have provided comparatively little overall advantage applied to the canal system. Although powered canal boats are now commonplace, they have not provided any significant benefit in the capability of the canal as a means of transport over what was originally available from the horse. The optimum canal system required compromises which were built into the canal system by the engineers of the day, but which now provide a basic limitation on their effectiveness. In the same way, the introduction of diesel engines on trains did little to help the competition of the railway with the car. The design compromises of the railway system, which led to very heavy rolling stock and proportionately massive infrastructure, made it effective in Victorian times, but prevent the railway being used to solve transport problems effectively today, except in special circumstances.

36. In the same way it seems likely that the compromises built into the car-based system,

notably the large scale of the infrastructure, sized around the 40 t truck, must lead to significant inflexibility in application of new technologies to improve transport of the future.

37. Today there are new problems and priorities. The rights of all individuals are now given far higher priority than in earlier times. Pollution, whether by emissions, noise, or simply visual intrusion is now recognized as a vital aspect of overall quality of life. Minimization of the use of energy and other resources is now acknowledged as having high priority. Entirely new technologies such as computing are also now available. These issues were not part of the design compromise built into any of the existing transport systems. It is clear that the world cannot sustain a growth of the car/road system in presently developing countries which paralleled that in the West.

38. The message from the historical analysis appears to be that we must look to a new system, with a new vehicle and infrastructure if we are to provide a significant step forward in transport capability. History also suggests that this system would be strongly oriented towards personal transport, sized to meet personal transport needs. This would not exclude smaller-scale freight transport on a new system. Existing transport technologies will not disappear. The car and truck can be expected to contribute significantly to transport in the future in the same way that trains, and even canals, continue to contribute to transport today, albeit in a rather different manner from in their heyday.

Conclusions

39. An analysis of build rates of the three great transport technologies of the industrial era—canal, railway and car/road—has shown remarkable similarities in the speed and nature of their development. In each case a period of some 50 years was required to bring the technology to full flower. After this period each has had a diminishing benefit, as a new technology has come into being.

40. The analysis suggests that the era of dominance of surface transport by the automobile is now drawing to an end, and that it is reasonable to expect a new form of transport to come into being, involving new vehicles matched to a new infrastructure, and designed to meet new requirements, notably the issues of sustainability.

References

1. *Transport Statistics Great Britain*. HMSO, Annually.
2. Dyos H. J. and Aldcroft D. H. *British Transport*. Leicester University Press, 1969.
3. Mitchell B. R. *European Historical Statistics 1750–1970*. London University Press, 1975, 581–584.
4. Bunch B. and Hellemans A. *The Timetables of Technology*. Simon and Schuster, 1993.