Government Office for Science

Foresight

The UK passenger rail system: how and why is it changing?

Future of Mobility: Evidence Review

Foresight, Government Office for Science

The UK passenger rail system: how and why is it changing?

Professor John Preston

University of Southampton

December 2018

This review has been commissioned as part of the UK government's Foresight Future of Mobility project. The views expressed are those of the author and do not represent those of any government or organisation.

This document is not a statement of government policy.

This report has an information cut-off date of May 2018.

Contents

1. How is the rail system changing?

How will the rail system evolve between now and 2040?[1]

Examination of Office of Rail and Road (ORR) data between 1995/6 (arguably the last year of the publicly owned railway) and 2014/15 indicates that passenger kms increased by 108% (or around 3.7% annually)[2] and train kms by 46%[3]. Real receipts per passenger kilometre were broadly stable (up 3%)[4], reflecting the impact of fares regulation and the growth in advance-purchase tickets. Analysis using data from the Rail Industry Monitor (Cheek, 2016) suggests that real total operating costs per train kilometre have increased by 52%, partly due to increases in infrastructure renewals, and that real government support has increased by 79% (See Appendix, Figures 1–6) (Preston, 2017; Syarifuddin, 2016). ORR data shows that the rail freight market (measured in net tonne kms) grew by 67% between 1995/6 and 2014/15, but has shrunk by 22% in the last two years (to 2016/7) as a result of the continued contraction of heavy industry (coal, metals), although construction and domestic international (container) traffic continue to grow. By contrast, over the last two years (2014/15 to 2016/17) the franchised passenger market has continued to grow (by almost 5%, in terms of passenger kilometres), although there are indications this growth has stalled in 2017/18. Since the mid-1990s, the rail market has exhibited strong growth (ATOC, 2013; RDG, 2016), although concerns with the current structure have been raised by academics (for example the Centre for Research on Socio-Cultural Change, 2013) and the Transport Select Committee (HC 66, 2017). Moreover, there may be one-off reasons for the growth in certain traffic such as business traffic due to company car taxation and improved Wi-Fi connectivity (Le Vine and Jones, 2012). This report also highlights strong evidence for a generational shift by 'millennials' away from car-ownership and suburban living, to the use of public transport and urban living, while the strong growth in rail use in the north has been associated with economic restructuring, a white collarisation of the labour force and a growth in central city employment (Mott Macdonald et al., 2010).

The rail model developed for the Infrastructure Transition Research Consortium (ITRC) can provide some insights into future evolution, although it must be recognised that this is a broad-brush strategic model which is intended to give illustrative rather than definitive results (see Appendix, Figures 7 and 8 and also Tables 1 and 2 and accompanying text) (Blainey and Preston, 2016). Runs of the National Infrastructure System Model (NISMOD) Version 1 (which has been used by

---

[1] The emphasis will be on the national rail system and passenger traffic, which accounts for around 90% of train movements. The historic analysis makes use of previous studies, in particular Syarifuddin, 2016, as reported in Preston, 2017, and is intended to be illustrative of broad trends.
[2] From ORR NRT Table 12.4 – refers to franchised services. If non-franchised services are included, this increases to 110%. If extend to 2016/7, the increase is 118% for franchised services and 120% if also include non-franchised services.
[3] From ORR NRT Table 12.13 (and predecessors). Refers to grand total for all operators, excluding Heathrow Express. If extend to 2016/17, the increase is 47%.
[4] Calculations based on franchise passenger receipts and kilometres and adjusted to 2014 prices using RPI, based on Syarifuddin (2016).

Infrastructure UK and the National Infrastructure Commission) are given below for three scenarios (high, medium and low growth) and for six strategies. This report's findings are that, if growth is unconstrained by supply limitations, passenger demand will increase by between 84% and 101% between 2015 and 2040 (or around 2.6% per annum using the mid-point forecast). If supply limitations are taken into account (at least in terms of delays as the result of more passengers and trains), this falls to between 45% and 66% (or about 1.6%). Some useful comparisons can be made with estimates produced by the National Infrastructure Commission (NIC) (NIC, 2017, page 43, Table 10)[5]. Its central estimate of growth in passenger journeys between 2011 and 2043 from the unconstrained NISMOD is 98%. This is compared with growth estimates from Network Rail (Network Rail, 2013) of between 58% (for non-London commuting) and 115% (for London commuting). By contrast, NIC's use of models developed by the Department for Transport indicated several years ago that there could be a 48% growth in passenger journeys, (from EDGE – Exogenous Demand Growth Estimation) and a 58–59% growth in passenger kilometres (from NTM – the National Transport Model), with the latter having a more explicit treatment of supply constraints, including delays and overcrowding. What seems to be clear is that growth in passenger rail usage up to 2040 might be expected, but at a slower rate than in the past 20 or so years. It may be that in some markets (such as long-distance business travel to/from London) saturation may be reached and that peak rail might be achieved.

What is driving these changes?

ITRC distinguishes between external scenarios (related to demographics, macroeconomics and energy prices) and internal strategies (related to demand management, system efficiency and capacity provision which, in turn, are related to investment levels, technological progress and environmental concerns). With respect to external scenarios, rail demand is assumed to be a positive function of population, Gross Domestic Product (GDP) and petrol costs (as a proxy for motoring costs) (Blainey and Preston, 2013). The default is to assume constant elasticities and reversibility. However, as markets reach saturation there may be scope for GDP elasticities to decline and there is some indication of asymmetries, with rail demand being robust in spite of the decline in GDP following the financial crashes of 2007/8. With respect to internal strategies, rail demand management traditionally has been based on pricing, system efficiency has been focused on reducing costs per traffic unit and expanding capacity has focused on increasing receipts by providing faster and more frequent services though electrification and targeted infrastructure and rolling stock improvements.

There have been several rail scenario analyses that have attempted to determine key drivers (Armstrong and Preston, 2011). Early Foresight Analysis focused on the social acceptance of intelligent infrastructure and the rate of technological development and take-up of low (environmental) impact transport (Foresight, 2006). This influenced Network Rail's development of four scenarios based on the extent to

[5] Subsequent work (September 2017) forecasts increases in rail passengers between 2015 and 2037 of 11% to 33% based on DfT models and 11% to 27% based on ITRC models, assuming year on year increases in real fares.

which markets are globalised and the extent to which the sustainability agenda is adopted (Network Rail, 2009). More recently, as illustrated in Figure 10, work by Rand Europe for Innovate UK on Delivering Transport Innovation has identified three 2035 scenarios: Driving Ahead, Digital Divide and Live Local (Rohr et al., 2016). These scenarios are based on the differential uptake of six technologies (autonomous vehicles, next generation information and communication technologies, user apps, advanced manufacturing, internet of things and embedded sensors) and the consequent impact on economic growth and transport demand.

What are the implications for decisions needing to be made today?

A capacity crunch is on the horizon (if it has not already been reached). This is reflected by declining punctuality, particularly in London and the South East (RDG, 2016). This will require train and platform lengthening (as at Waterloo and for Thameslink), enhanced station capacity (as at Birmingham New Street and Reading), additional rolling stock (as in the Intercity Express programme) and additional infrastructure (such as new lines and grade separated junctions). The key investment is likely to be HS2. By 2033, this will add around 335 new route miles (543 km) to the national network that stood at 9,817 miles (15,913 km) in 2016. Although this only represents a 3.4% increase, the exclusive tracks will permit high capacity operations of up to 18 trains an hour. Moreover, by removing some high-speed services from the East and West Coast Main Lines, capacity will also be increased on these parallel routes as more homogenous (in terms of speed) services are operated[6]. Arguably, it is the potential for increased service homogeneity on both high speed and classic rail that is the main benefit of HS2 (Preston, 2012). Elsewhere, Crossrail will lead to a 10% increase in central London capacity (Crossrail, 2018) while, in northern England, the Great North Rail Project will permit an additional 2,000 services per week (Network Rail 2017a).

What are the research gaps in understanding how the rail system is changing?

The evolution of demand is relatively well understood, as evidenced by RDG's Passenger Demand Forecasting Handbook (PDFH) – Version 6 of which was released in 2018[7] – and by the DfT's WebTAG (Transport Analysis Guidance). Transport for London similarly has the Business Case Development Manual. The DfT (2015) has also undertaken a useful review of the reasons for road travel (see Table 3 of the Appendix) and there are clear corollaries with rail.

However, there is some debate about the extent to which rail demand growth is due to external factors (such as GDP growth) and the extent to which it is driven by internal factors (including the increased commercialisation of the industry following

[6] Decisions on how released capacity is to be used are yet to be taken, and could be a mix of scenarios (DfT, 2017a paras. 3.55-3.56).

[7] Contains sections on external factors (including modal competition), fares, generalised journey time, punctuality and reliability, crowding, rolling stock, stations, new services, access and competition.

privatisation in the mid-1990s). Preston and Robins (2013) attributed 69% of the demand change between 1994/5 to 2008/9 to internal factors. By contrast, Wardman (2006) attributed 75% of the demand change between 1998 and 2003 to external factors. This indicates that the relationships between the rail industry and the economy (and the dynamics thereof) are only partially understood. It is also apparent that one area that is less well understood is supply-side responses (including marketing), given the complex and fragmented nature of the rail industry. Another area where there is limited understanding is the impact of socio-demographics, despite the Rail Demand Forecasting Estimation project (ITS and Leigh Fisher, 2016).

2. How is the user engaging with the rail system?

How will this engagement evolve between now and 2040?

The National Travel Survey indicates that a relatively small proportion of the population regularly travelled by rail (in 2016 only 8% of adults used rail at least once a week and 41% have used rail less than once a year) (DfT, 2017c). A high proportion of rail users are commuters (48%) and 41% of users come from the top income quintile. Coombes (2012) observed that there had been a particular growth in longer distance rail commuting, which was ascribed to the growth in multi-locational, multi-professional households, with changing work patterns related to ICT use. This might be expected to affect access mode. The one-off National Rail Travel Survey (NRTS) conducted between 2001 and 2005, found that 58% of commuters walked to their originating station (DfT, 2010, Table 6, page 19). This might be expected to reduce as commuting extends into more rural and less suburban areas. It is also worth noting that this early survey suggested 63% of rail users were commuters, journeying to work and education (DfT, 2010, page 26), suggesting that much of the subsequent growth in rail demand has been for optional travel.

User views on the rail system are captured by Transport Focus, with its biannual National Rail Passenger Survey. Areas that have been consistently highlighted as concerns include information during disruption and value for money. More recently there has been research on sentiment-mapping using social media, such as Twitter feeds.

The Traveller Needs study by Transport Systems Catapult (TSC, 2016a) segments the travel market into five groups (percentage of population in brackets):

- default motorist (26%);
- local drivers (24%);
- dependent passengers (21%);
- urban riders (15%);
- progressive metropolites (14%).

Although such market segmentation has been undertaken by individual Train Operating Companies (for example, Eurostar), no such typology exists at a national level for rail[8]. PDFH segmentation is:

- by purpose (commuting, business, other);
- ticket type (open, advance, season);
- ticket class (first, standard);
- flow (London, non-London).

[8] Such a typology has been developed for the Netherlands (see Van Hagen, 2009).

There has been substantial growth in the use of advance tickets and some reduction in season tickets (perhaps reflecting part-time home-working). London continues to dominate the rail market. ATOC/RDG have developed the customer journey heartbeat based on available metrics which highlights key pinch points – some of which are related to the pre-travel stage, such as ticket purchase, as described by Wilson (undated). Overcoming these barriers might be seen as an incentive to develop rail as a Mobility as a Service (MaaS) offering, although the fragmented nature of the industry acts as a key barrier (TSC, 2016a).

An important change has been the increased use of mobile devices by travellers and the resultant more productive use of train travel time (Lyons et al., 2013), with implications for the value of time and appraisal (Wardman and Lyons, 2016). The increasing use of information technology and communications has led to interest in improving information on the degree of crowding on trains and at stations (Pritchard et al., 2017; Zhang, 2016) and providing more customer-centric information, for example Gould (2016) and Wesemeyer and Ross (2016). This has been enforced by an active developer community. Examples include the Open Capacity system developed for c2c (Essex Thameside) – see TSC, 2016b, and Trainline Engineering's BusyBot system.

What is driving these changes?

Technology changes and the behavioural responses to these changes are the key drivers for how users are engaging with the system, as exemplified by the switch from the provision of ticketing and information at stations to web-based delivery, but with telephone enquiries acting as an important intermediate technology. This may be reducing some barriers to mode shift to travelling by rail (for example, related to service information) but significant barriers remain (Blainey et al., 2012; Stanton et al., 2013) particularly relating to the perceived complexity of using the system, such as fares and ticketing.

What are the implications for decisions needing to be made today?

The key decisions relate to the extent to which the industry will embrace technology to engage with its users. This particularly relates to ticketing where, outside Greater London, the take-up of Smartcards and contactless payment is low, although the government is committed to introducing smart ticketing across most of the network in England and Wales by the end of 2018 (DfT, 2017b). To some extent there is also the issue of whether the national rail system provides a universal service, or customised services to different market niches (such as Megatrain).

What are the research gaps in understanding how the user will engage with the rail system?

A reasonable amount is known about current users, at least while they are travelling on the rail system. Relatively little is known about access and egress and pre-travel behaviour. Some of these gaps could be filled by a re-commissioned National Rail Travel Survey. However, the largest gap in knowledge probably relates to non-users, although the National Travel Survey can provide some insights.

3. How is technology changing the rail system?

Between now and 2040, which areas of rail are going to be most affected by technological change, and why?

The Rail Technical Strategy (2012) identified six technology development programmes:

- control, command and communications;
- energy;
- infrastructure;
- rolling stock;
- information;
- customer experience.

Building on this, the Network Rail Technical Strategy 2013 and the Rail Supply Group's Fast Track for Growth, a Capability Delivery Plan was published in 2016. This identified 12 capabilities, each with several milestones (see Appendix, Table 4).

There are issues in determining the future rate of technical progress in both the rail industry specifically and in the transport sector more generally. There are several consultancy reports that take a broadly optimistic view (Arup, 2014; Deloitte 2015; Atkins, 2015). RSSB take a more sanguine view with their (implicit) concern about rail industry readiness levels and Network Rail's emphasis on the need for demonstrations (RSSB, 2018). Some caution might be expected from a safety critical industry (and one which has had very good safety performance in recent years) but HackTrain (2016) highlights five barriers to innovation. These are:

- the franchising system is not designed to drive or reward innovation;
- procurement frameworks are unfit for entrepreneurs;
- data are fragmented, siloed and unreliable;
- the funding landscape is difficult to navigate and is not output driven;
- the culture in rail is resistant and reluctant to grasp innovation.

A partial response has been the establishment of the UK Rail Research and Innovation Network (UKRRIN, 2018), led by universities and focusing on digital systems, rolling stock and infrastructure. Key issues will be the extent to which the rail industry will be immune from disruptive technologies and the extent to which such technologies will be substitutes for or complements to rail services.

Of the developments listed in Table 4, good progress has been made in optimising energy use, for example in the development of C-DAS (Connected Driver Advisory Systems), as applied by Great Western. However, cut-backs in the electrification programme and the increased dependence on bi-modal trains (with both diesel engines and electric motors) could limit system energy efficiency. Good progress is also being made in personalising the customer experience. Energy efficiency and customer experience are both areas that have quick pay-backs and can be adopted by train operating companies in their franchising plans (typically for seven years, plus the possibility of extensions). Some progress has been made with running trains closer together, particularly with the development of European Train Control System (ETCS) Level 2 (which replaces lineside signals with in-cab signals) and Level 3 (which replaces fixed block signalling with moving block signalling). However, aside from some experimentation on the Cambrian line, ETCS Level 3 will not be rolled out until Control Period 7 (2024 onwards), at the earliest. Moreover, the alleged capacity gains of up to 40% (derived from Wendler, 2007)[9] could be illusory if pinch-points are not dealt with, particularly at London termini. Both the Transport Select Committee, and the government in their response, are cautious of this figure and favour instead a case-by-case examination of targeted interventions (House of Commons Transport Committee, 2017b). The high initial outlays for ETCS, the long pay-back periods and benefits that are split between the infrastructure authority (Network Rail) and the train operators may represent barriers.

Which areas are going to be least affected and why?

Automatic Train Operation (ATO) has existed in Britain since at least 1967 and the Victoria Line (and arguably since 1927 in the case of the Post Office Underground rail system that closed in 2003). However, trade union and consumer resistance has prevented driverless operations and has made even Driver Only Operation (DOO) problematic. Moreover, for complex mixed-traffic railways there remain technological issues with ATO. Similarly, there seems to be slow progress in timing trains to the second, in part due to competing positioning technologies, and in the development of real-time traffic control based on artificial intelligence. As with ETCS, the development of these technologies is limited by high initial costs, long pay-back periods and diverse beneficiaries. There also seems to be limited progress with gauging. Partly as a result of being the first rail system in the world, the British system generally has a constraining loading gauge (which determines the maximum height and width of vehicles); narrow tunnels, low bridges and platforms that are close to the track prevent the operation of double decker trains and high-sided container wagons. Perhaps the biggest lack of progress has been in developing a low-cost railway. The McNulty review (2011) identified an efficiency gap of something like 30% between Britain's railways and those on the continent and there is little evidence that this gap has been closed; indeed, it may have widened (see ORR, 2017). Network Rail cost over-runs, at least in England and Wales, mean that, as a result of the Hendy Review, renewals and enhancement works that should have taken place in Control Period 5 (2014 to 2019), will now over-run into Control Period 6 (CP6) (2019 to 2024). Moreover, the initial High Level Output Specification (HLOS) for CP6 for England and Wales (July 2017) did not include enhancements, although some provisions were made in October 2017. However, the Secretary of State expects decisions regarding specific enhancements to be dealt with separately, building on the principles set out in the Memorandum of Understanding between the

[9] This study found the ETCS level 3 increased capacity on plain track compared to level 1 by around 42%. However, it could be argued that for practical purposes the more appropriate comparison is between ETCS level 3 and level 1 with limited supervision. In this case, the capacity uplift is only 28%. These gains are likely to be further limited when junctions and stations are taken into account.

Department for Transport and Network Rail on rail enhancements (DfT, 2017d). Network Rail was deemed a nationalised industry in September 2014 and so can no longer borrow on the strength of its Regulatory Asset Base. This could mean that funding for investments will be limited in the short-to-medium term, requiring public private partnerships as proposed for the East West rail scheme and reflected by the call in March 2018 for market led proposals (DfT, 2018).

The pace of developments in Britain can be contrasted with those overseas. China has built a high-speed rail network of 24,000 route kms in the last 10 years, with a further 10,000 km under construction. Denmark will have converted its entire network to ETCS by 2022. The Netherlands has been at the leading edge of real-time train control for over a decade (Mazzarello and Ottaviani, 2007). Switzerland has a fully electrified network, with co-ordinated timetables and nationally integrated ticketing (Tyler, 2008). HackTrain (2016) notes that American railroads invest more in R&D than in Britain – the British industry is estimated to invest only 0.5% of revenues in R&D, compared to industry norms of 3.5%.

What are the implications for decisions needing to be made today?

Since the White Paper on the future of railways was published in 2004, the national rail system has had security of infrastructure funding, in terms of the five-year HLOS and the accompanying Statement of Funds Available (SOFA). In addition, the DfT has encouraged investment in rolling stock through the Inter City Express Programme (ICEP) and recent franchise awards, with two overseas manufacturers (Hitachi and CAF) setting up assembly plants in Great Britain, while the Rail Supply Group wants to double UK rail exports by 2025. However, given the reclassification of Network Rail and wider budgetary pressures on government, it is not certain that this surety of funding will persist.

What are the research gaps in understanding how technology will change the rail system?

One important gap is the lack of certitude on the extent of transaction costs in the rail industry (the costs of train operating companies, Network Rail, the rolling stock leasing companies and their sub-contractors doing business with each other, including profit-taking), although there are estimates that these could be as high as £1.2 billion per annum (Taylor and Sloman, 2013, page 331). Related to this is the limited evidence on the importance (or otherwise) of vertical integration (particularly between infrastructure and train operations) and the efficacy of incentive regimes in the absence of such integration. There is also the issue of the extent to which data integration technologies such as blockchaining and the internet of things could reduce these costs. However, the main gap probably relates to the extent to which a digital railway can achieve capacity increases while maintaining or improving quality of service, particularly in terms of punctuality. The likely impact of competing disruptive technologies is also a big uncertainty, as it is for high speed services Maglev and Hyperloop. However, these developments are likely to be some distance into the future, given that the Chuo superconductor maglev system being constructed in Japan will not link Tokyo and Nagoya until 2027, reaching Osaka in

2045, even though testing began in 1977; while Hyperloop is only just at the full-scale testing stage. Indeed, Hyperloop One began testing in Nevada in May 2017.

4. References

Armstrong, J. and Preston, J. (2011). Alternative railway futures: Growth and/or specialisation?. *Journal of Transport Geography*, 19(6), 1570–1579.

Arup (2014). *Rail 2050*.

Atkins (2015). *Journeys of the future, introducing mobility as a service*. Available at: http://www.atkinsglobal.com/~/media/Files/A/Atkins-Corporate/uk-and-europe/uk-thought-leadership/reports/Journeys%20of%20the%20future_300315.pdf

ATOC (Association of Train Operating Companies) (2013). *Growth and prosperity. How franchising transformed the railways into a British success story.* Available at: http://www.atoc.org/download/clientfiles/files/ATOC%20Growth%20and%20Prosperity%20report.pdf

Blainey, S., Hickford, A. and Preston, J. (2012). Barriers to passenger rail use: A review of the evidence. *Transport Reviews*, 32(6), 675–696.

Blainey, S. and Preston, J. (2013). *Assessing long term capacity and demand in the rail sector*. 13th World Conference on Transport Research, Rio de Janeiro, Brazil, 15–18 July.

Blainey, S. and Preston, J. (2016). Transport systems assessment, in Hall J.W., Nicholls R., Tran M. and Hickford A. J. (eds) *The future of national infrastructure: A system-of-systems approach*, Ch. 5, 88–113.

Bowman, A., Folkman, P., Froud, J. et al. (2013). *The Great Train Robbery: Rail Privatisation and After.* Centre for Research on Socio-Cultural Change. Available at: http://hummedia.manchester.ac.uk/institutes/cresc/sites/default/files/GTR%20Report%20final%205%20June%202013.pdf

Cheek, C. (2016). *Rail industry performance. Rail Industry Monitor 2016.* TAS Publications and Events Limited, Long Preston.

Coombes, M. (2012). *Changing commuting patterns*. Passenger Demand Forecasting Council Conference. PDFC, London.

Crossrail (2018) *Crossrail in Numbers*. Available at: http://www.crossrail.co.uk/news/crossrail-in-numbers#

Deloitte (2015). *Transport in the digital age: Disruptive trends for smart mobility*. Available at: http://www2.deloitte.com/content/dam/Deloitte/uk/Documents/bps/deloitte-uk-transport-digital-age.pdf

DfT (Department for Transport) (2010). *National rail travel survey: Overview report.* Available at: https://www.gov.uk/government/statistics/national-rail-travel-survey-overview-report

DfT (2015). *Understanding the drivers of road travel: current trends in and factors behind road use.* Available at: https://www.gov.uk/government/publications/understanding-the-drivers-of-road-travel-current-trends-in-and-factors-behind-roads-use

DfT (2017a). *High Speed 2 Phase two strategic case,* paras 3.55–3.56. Available at: https://www.gov.uk/government/publications/hs2-phase-two-strategic-case

DfT (2017b). *Connecting people: A strategic vision for rail*. November, sections 3.3–3.10. Available at: https://www.gov.uk/government/publications/a-strategic-vision-for-rail/connecting-people-a-strategic-vision-for-rail

DfT (2017c). *National Travel Survey: 2016*. Available at: https://www.gov.uk/government/statistics/national-travel-survey-2016

DfT (2017d). *Railways Act 2005 Statement: Statement of Funds Available*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/650973/railways-act-2005-statement-of-funds-available-2017-print.pdf

DfT (2018). *Rail market-led proposals*. Available at: https://www.gov.uk/government/publications/rail-market-led-proposals

Digital Railway (2018). *Digital Railway: A digital railway for a modern Britain.* Available at: www.digitalrailway.co.uk

Foresight (2006). *Intelligent infrastructure futures: Project overview.* Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/300334/06-522-intelligent-infrastructure-overview.pdf

Gould, N. (2016). *'Shortly arriving at …' Development of an innovative framework for customer-centric rail passenger information applications.* RRUKA annual conference, London. 3 November.

HackTrain (2016). *The B.A.R.R.I.E.R.S. report: Bringing actionable recommendations to revitalise innovation and entrepreneurship in the rail sector.* Available at: http://railwayinnovation.com/barriers-report-from-hacktrain/

House of Commons Transport Committee (2017a). *Rail Franchising: Ninth Report of Session 2016-17*. Available at: https://publications.parliament.uk/pa/cm201617/cmselect/cmtrans/66/66.pdf

House of Commons Transport Committee (2017b). *Rail technology: signalling and traffic management: Government response to the Committee's Seventh Report of Session 2016-17.* Available at: https://publications.parliament.uk/pa/cm201617/cmselect/cmtrans/910/91002.htm

House of Commons Transport Committee (2017c). *Rail franchising.* House of Commons Transport Select Committee. Ninth Report of Session 2016–17. HC 66, 5 February 2017. Available at: https://publications.parliament.uk/pa/cm201617/cmselect/cmtrans/66/66.pdf

ITS (Institute for Transport Studies, University of Leeds) and Leigh Fisher (2016). *Rail demand forecasting estimation.* DfT, London.

Le Vine, S. and Jones, P. (2012). *On the move. Making sense of car and train travel trends in Britain.* RAC Foundation, London. December.

Lyons, G., Jain, J., Susilo, Y. and Atkins, S. (2013). *Comparing rail passengers' travel time use in Great Britain 2004 to 2010*. Mobilities, 8(4), 560–579.

McNulty, R. (2011). *Realising the potential of GB rail.* Report of the rail value for money study. Department for Transport and ORR, London.

Mazzarello, M. and Ottaviani, E. (2007). A traffic management system for real-time traffic optimization in railways*. Transportation Research Part B*, 41, 2, 246–274.

Macdonald, M. (2010). *Northern HLOS Growth*

Mott Macdonald, University of Southampton and Eden Business Analysis (2010). *Northern HLOS growth.* In: Passenger Demand Forecasting Handbook Version 5.1, Reference 258. ATOC, London.

National Infrastructure Commission (2017). *Modelling for vision and priorities.* July.

Network Rail (2009). *Network RUS: Scenarios & Long Distance Forecasts*. Available at: http://www.networkrail.co.uk/browse%20documents/rus%20documents/route%20utilisation%20strategies/network/working%20group%201%20%20scenarios%20and%20long%20distance%20forecasts/network%20rus%20-%20scenarios%20and%20long%20distance%20forecasts.pdf

Network Rail (2013). *Long term planning process.* Available at: https://www.networkrail.co.uk/running-the-railway/long-term-planning/

Network Rail (2017a). *Great North Rail Project.* Available at: https://www.networkrail.co.uk/our-railway-upgrade-plan/key-projects/great-north-rail-project/

Network Rail (2017b). *Digital Railway: Modernising Britain's railway to benefit passengers and support economic growth.* Available at: https://www.networkrail.co.uk/our-railway-upgrade-plan/digital-railway

ORR (2016). *Office of Rail and Road: NRT Data Portal.* Available at: https://www.gov.uk/government/publications/rail-market-led-proposals

ORR (Office of Rail and Road) (2017). *Annual efficiency and finance assessment of Network Rail 2016–17.* October.

Preston, J. (2012). High speed rail: About time or a waste of time?. *Journal of Transport Geography*, 22, 308–311.

Preston, J. and Robins, D (2013). Evaluating the long term impacts of transport policy: An assessment of rail privatisation. *Research in Transportation Economics*, 39, 134–144*.*

Preston, J. (2017). *The wheels keep on turning. Is the end of rail franchising in Britain in sight?* 15th International Conference on Competition and Ownership in Land Passenger Transport. Stockholm, 13–17 August. Accepted for publication in Research in Transportation Economics.

Pritchard, J., Preston, J. and Waterson, B. (2017). Train overcrowding: investigating the use of better information provision to mitigate the issues. *Transportation Research Record*, 2649, 1–19.

RDG (Rail Delivery Group) (2016). *Rail's transformation in numbers.* December. Available at: https://www.raildeliverygroup.com/files/Publications/2016-11_rdg_dataset.pdf

Robins, D. (2012). *Evaluating the long term impacts of transport policy: The case of passenger rail privatisation in Great Britain.* PhD Thesis, School of Geography, Faculty of Social and Human Sciences, University of Southampton.

Rohr, C., Ecola, L., Zmud, J., Dunkerley, F., Black, J. and Baker, E. (2016). *Travel in Britain in 2035: Future scenarios and their implications for technology innovation.* RAND Corporation, Santa Monica. Available at: https://www.rand.org/pubs/research_reports/RR1377.html

RSSB (2012). *The future railway. The industry's rail technical strategy 2012.* Technical Strategy Leadership Group, London. Available at: www.rssb.co.uk/rail-technical-strategy

RSSB (2017). *Rail capability delivery plan*. Available at: https://www.rssb.co.uk/rts/Documents/2017-01-27-rail-technical-strategy-capability-delivery-plan-brochure.pdf

RSSB (2018). *Rail Industry readiness levels*. Available at: https://www.rssb.co.uk/rail-technical-strategy/rail-industry-readiness-levels

Stanton, N., McIlroy, R., Harvey, C. Blainey, S., Hickford, A., Preston, J. and Ryan, B. (2013). Following the cognitive work analysis train of thought: Exploring the constraints of modal shift to rail transport. *Ergonomics,* 56(3), 522–540.

Syarifuddin, S. (2016). *Overall assessment of rail privatisation*. MSc Dissertation, Faculty of Engineering and the Environment. University of Southampton.

Taylor, I. and Sloman, L. (2013). Reunifying Britain's railways: obstacles and opportunities. *Public Money and Management,* 33(5), 329–336.

TSC (Transport Systems Catapult) (2015). *IM traveller needs and UK capability study.* October.

TSC (2016a). *Mobility as a service. Exploring the opportunity for mobility as a service in the UK.* July.

TSC (2016b). *Enabling innovation in delivering high capacity rail.* Available at: https://s3-eu-west-1.amazonaws.com/media.ts.catapult/wp-content/uploads/2016/03/10152533/TSC-Enabling-Innovation-in-Delivering-High-Capacity-Rail.pdf

Tyler, J. (2008). Perfect timing: An east coast taktfahrplan. *Rail Professional*, 136, 24–26.

UKRRIN (2018). *UK Rail Research and Innovation Network: A network of centres revolutionising innovation in rail*. Available at: http://ukrrin.org.uk/

Van Hagen, M. (2009). *How to meet the needs of train passengers? A successful customer segmentation model for public transport*. Available at: http://data.openov.nl/docs/Needscope%20ETC%202009%20def.pdf

Wardman, M. (2006). Demand for rail travel and the effects of external factors. *Transportation Research Part E-Logistics and Transportation Review*, 42(3), 129–48.

Wardman, M. and Lyons, G (2016). The digital revolution and worthwhile use of travel time: implications for appraisal and forecasting. *Transportation*, 43(3), 507–530.

Wendler, E. (2007). *Influence of ETCS on Line Capacity*. UIC ERTMS world conference 11–13 September. Berne, Switzerland. Available at: http://www.uic.org/cdrom/2007/14_ERTMS_conference07/docs/presentations/G4_wendler.pdf

Wesemeyer, S. and Ross, T. (2016). *Integrating data sources to enhance the experience for passengers with special needs and/or disabilities through privacy aware mobile applications*. RRUKA annual conference. London. 3 November.

Wilson, N (undated). *The Connected Customer*. RDG, London.

Zhang, Q. (2016). *Development of intelligent predictive models for crowding on trains using data-driven methodologies*. RRUKA annual conference. London, 3 November.

5. Appendix

Past trends

The key trends in the passenger rail market in Britain are based on the work of Syarifuddin (2016), drawing largely from data from ORR National Rail Trends (NRT)[10]. This analysis (and the accompanying graphs) goes up to 2014/15, but where appropriate updates to 2016/17 are given.

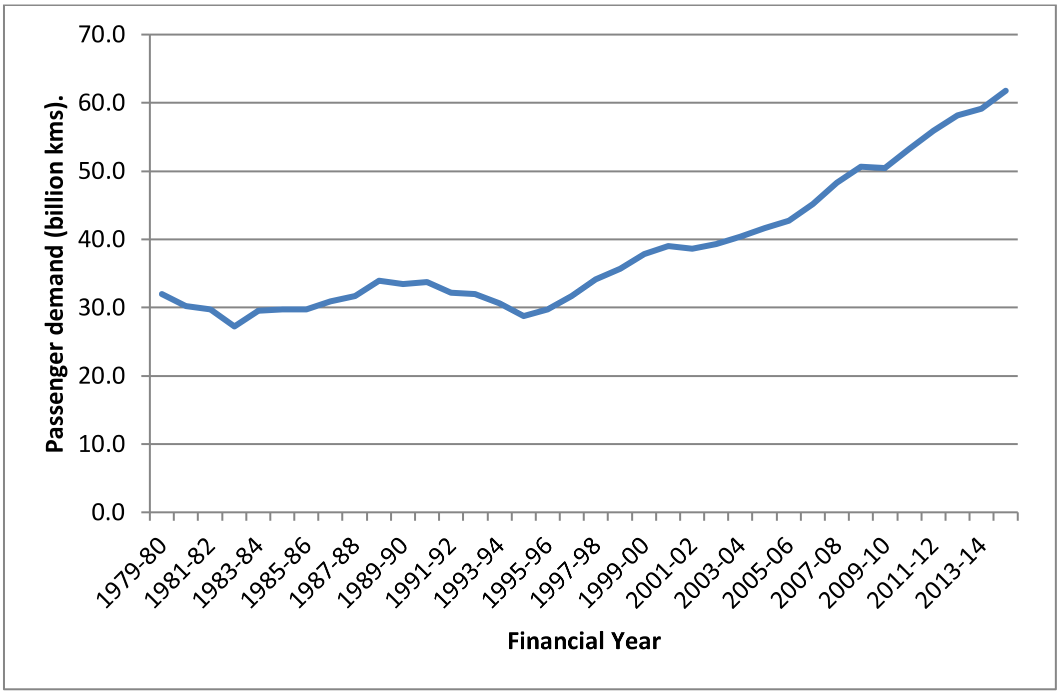

Figure 1: National rail passenger demand (billion kms)

Figure 1 illustrates the fact that passenger demand has broadly doubled since privatisation (1995/6 to 2014/15). Some of this growth will be due to exogenous factors, notably rising incomes for most of the period (but not around 2008) and rising road journey times. The latest data shows further growth of around 5% (to 2016/17), albeit with signs of a slowdown in some markets.

[10] http://dataportal.orr.gov.uk/.

Figure 2 shows receipts per passenger km, which is used here as a proxy for fares. This shows a broadly stable pattern (with just a 3% increase over the whole period) but with a decrease in the first phase of privatisation (due to fares regulation)[11] and modest rise thereafter. It should though be noted that the increase in mean receipts will be moderated by the increased prevalence of advanced purchase discounted tickets. As a result, ORR's fares index shows substantial increases in real terms over this period.

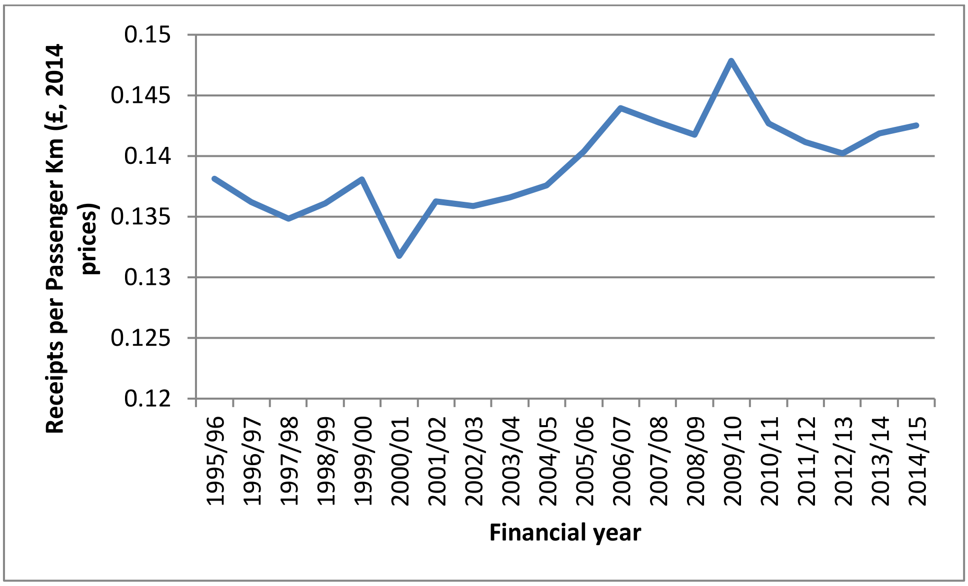

Figure 2: National rail receipts per passenger km (£, 2014 prices).

[11] Around 50% of all fares are regulated, with increases being limited to RPI between 1996 and 1998, and to RPI-1% between 1999 and 2003. Since 2004, increases of up to RPI+1% have been permitted.

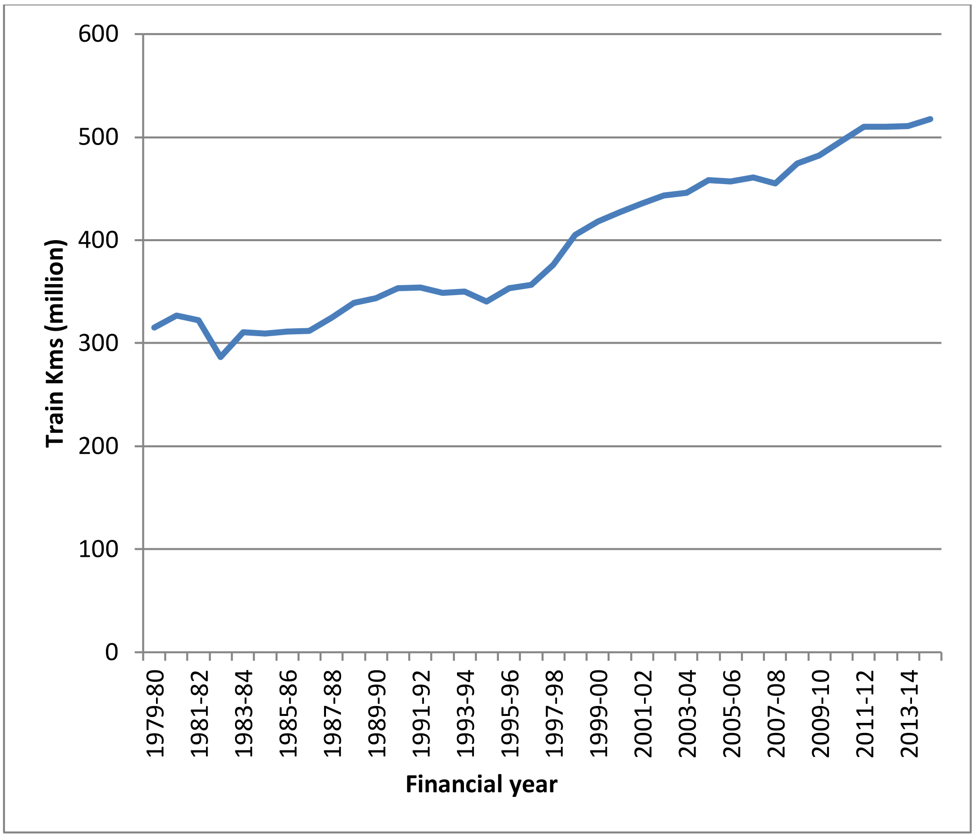

Figure 3: National rail passenger rail supply (train kms, million).

Figure 3 indicates that, since privatisation, there has been an almost 50% increase in train kilometres operated on the network (Syarifuddin, 2016), but that this has stabilised since 2010, with a hint that, in key parts of the network, capacity limits have been reached.

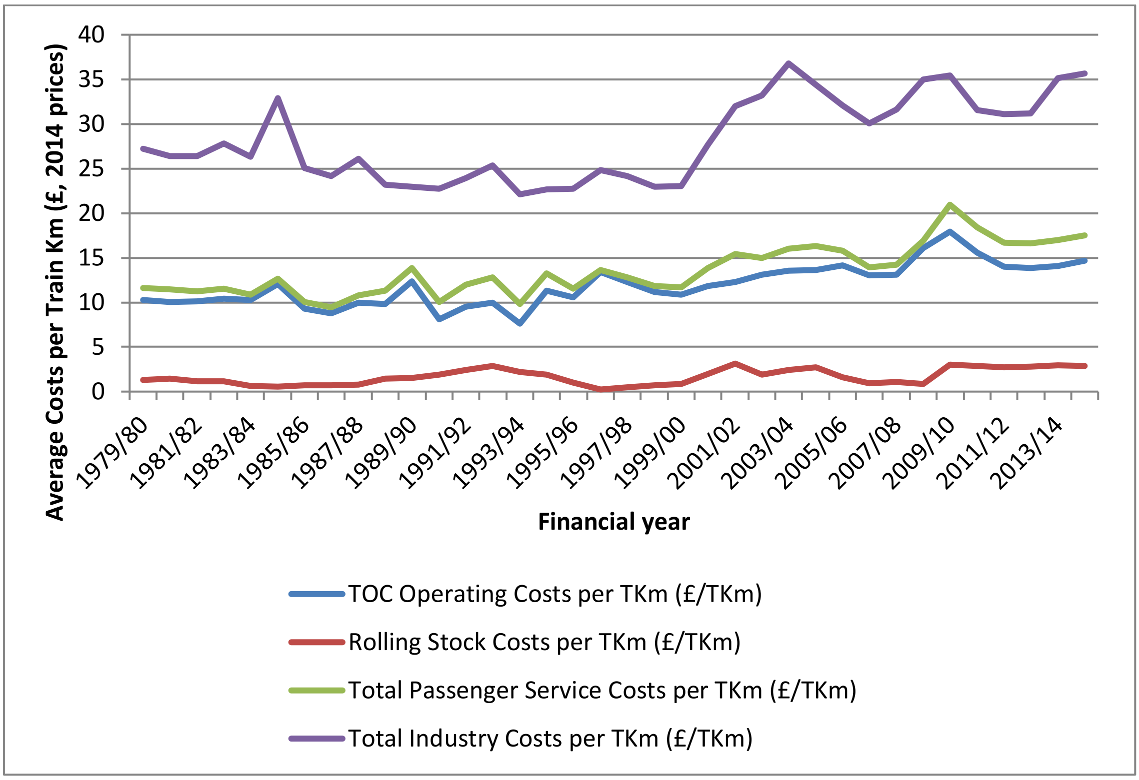

Figure 4: National rail average costs of rail operations (£ per train km, 2014 prices).

Figure 4 shows that the average cost of rail operations has increased by over 50% since privatisation, with most of this increase occurring following the Hatfield accident in 2000 (Syarifuddin, 2016, after Robins, 2012). Figure 5 shows that much (but not all) of this increase was related to infrastructure renewal costs, with the increase pre-dating Hatfield in 2000. If pre-privatisation trends had been maintained, the counterfactual indicates that modest reductions in infrastructure renewal costs might have been expected.

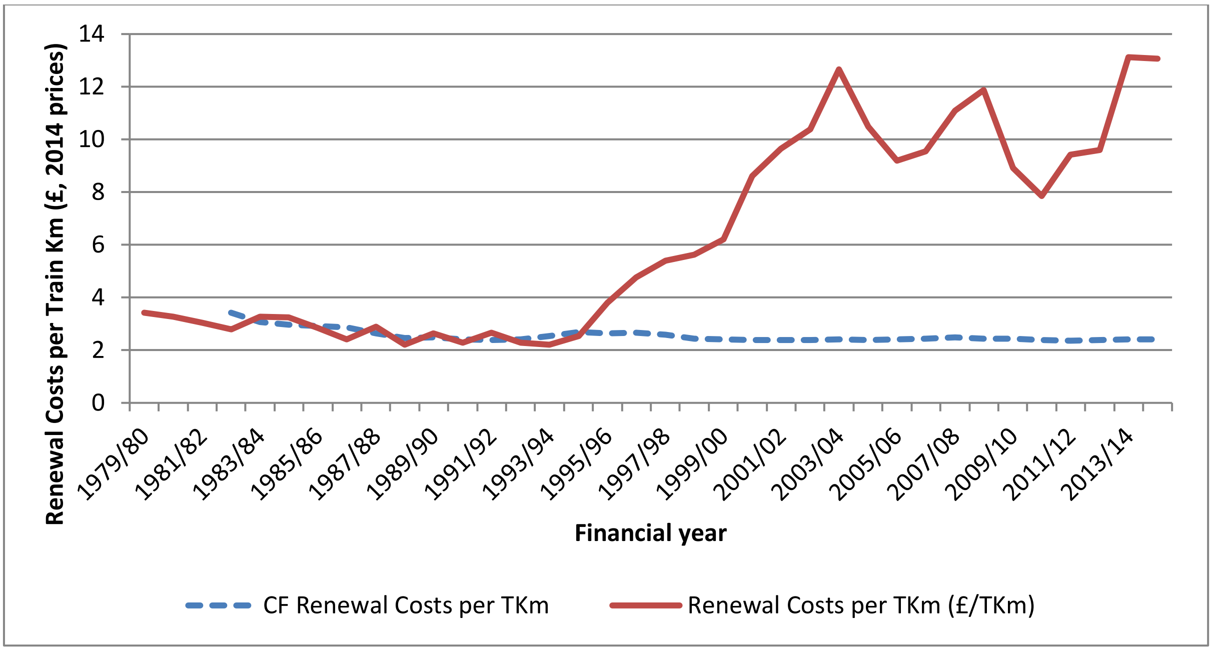

Figure 5: National rail actual and counterfactual (CF) renewal costs (£ per train km, 2014 prices)

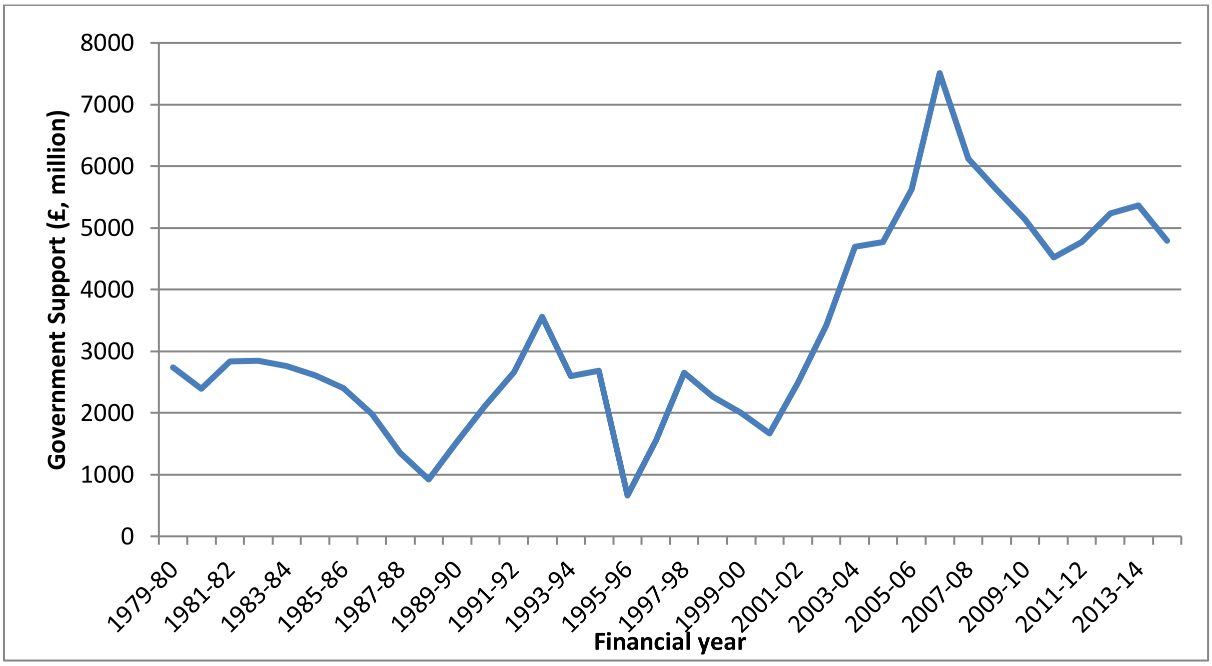

Figure 6: National rail government support to the railways (£ million, 2014 prices).

Note: this is total support – most of which (particularly post 2000) is to cover infrastructure costs, including enhancements.

As can be seen in Figure 6, if 1994/95 is used as the base year (as 1995/6 is distorted by privatisation receipts), overall government support to the railways has increased by almost 80% in real terms. There was a decrease in support initially (as might be expected from experience in other countries and sectors) but it more than doubled after 2000, since when it has been broadly constant. The latest data (ORR, NRT, Table 1.6) indicate that, between 2014/15 and 2016/17, total government support to the railways decreased by 15%.

Future forecasts

ITRC examines seven transport strategies as follows:

TR0 – Decline and decay

This is the do nothing' or 'status quo' strategy in which no replacements are found for fossil fuels, no additional capacity is built and there is no further technological innovation. While current rail electrification projects are completed, no further electrification occurs, and there are assumed to be no significant changes to rail journey times.

TR1 – Predict and provide

Demand-modelling drives infrastructure construction, with infrastructure built when capacity utilisation reaches a given level. There is large-scale road building and widening, along with construction of additional railway lines, moderately rapid rail electrification and airport and seaport expansion. It is assumed that technological innovations for established modes will continue under this strategy, leading to some improvements in fuel efficiency. There are no financial constraints. The ongoing release of latent demand means demand growth continues throughout the 21st century, while there is a low take-up of alternative fuels. To some extent, this is the approach adopted by Network Rail in the route studies (for example, Wessex) and the predecessor route utilisation strategies.

TR2 – Cost and constrain

This strategy is driven by environmental, financial and congestion-related imperatives. There is congestion-pricing for all modes and a national workplace parking levy. There is a moderate take-up of alternative fuels and a small amount of additional infrastructure.

TR3 – Adapting the fleet

This strategy involves rapid technological development that enables wide-ranging modernisation of the vehicle stock. Increased engine efficiencies reduce energy use, while there is extensive deployment of hybrid transmissions and regenerative braking. There is a high take-up of alternative fuels and the development of lighter materials reduces vehicle weights and increases fuel efficiency. There is rapid rail electrification and moderate level of infrastructure construction. For rail, improvements in acceleration and braking performance increase the maximum train density permitted on a link and reduce generalised journey times.

TR4 – Promo-pricing

In addition to congestion-charging (as in TR2), this strategy also sees the introduction of emissions-based pricing. This is accompanied by a high level of take-up of alternative (low emission) vehicle fuels, along with fuel efficiency improvements as in TR1 and TR2. The strategy also includes a moderate quantity of infrastructure construction, along with rapid rail electrification.

TR5 – Connected grid

This involves extensive use of Information and Communication Technologies (ICT) to enhance the operation of transport systems. Smart logistics systems are used to optimise freight movements. Digital control permits maximum capacities to be increased on roads and railways. There is a high take-up of alternative fuels and large improvements in fuel efficiency. Rail electrification is assumed to occur at a rapid rate, with committed electrification schemes implemented until 2021 and then 300 track km electrified per year. The elasticities of transport demand with respect to GVA are progressively reduced to reflect substitution of ICT for travel. Through better management of existing infrastructure, little additional infrastructure needs to be constructed. This links with the Digital Railway concept[12] and the control, command and communication theme of RTS.

TR6 – Smarter choices

'Soft' interventions to promote more sustainable travel are implemented as part of a national 'smarter choices' scheme, which leads to a reduction in trip rates for road transport. Drop-off boxes and consolidation centres become widespread for freight. Public transport interchange is enhanced, along with a moderate level of rail electrification (committed schemes to 2021 and then 200 track km per year) and vehicle efficiency improvements. A small amount of additional infrastructure is constructed.

[12] See: https://www.networkrail.co.uk/our-railway-upgrade-plan/digital-railway/ and http://digitalrailway.co.uk/ for more information.

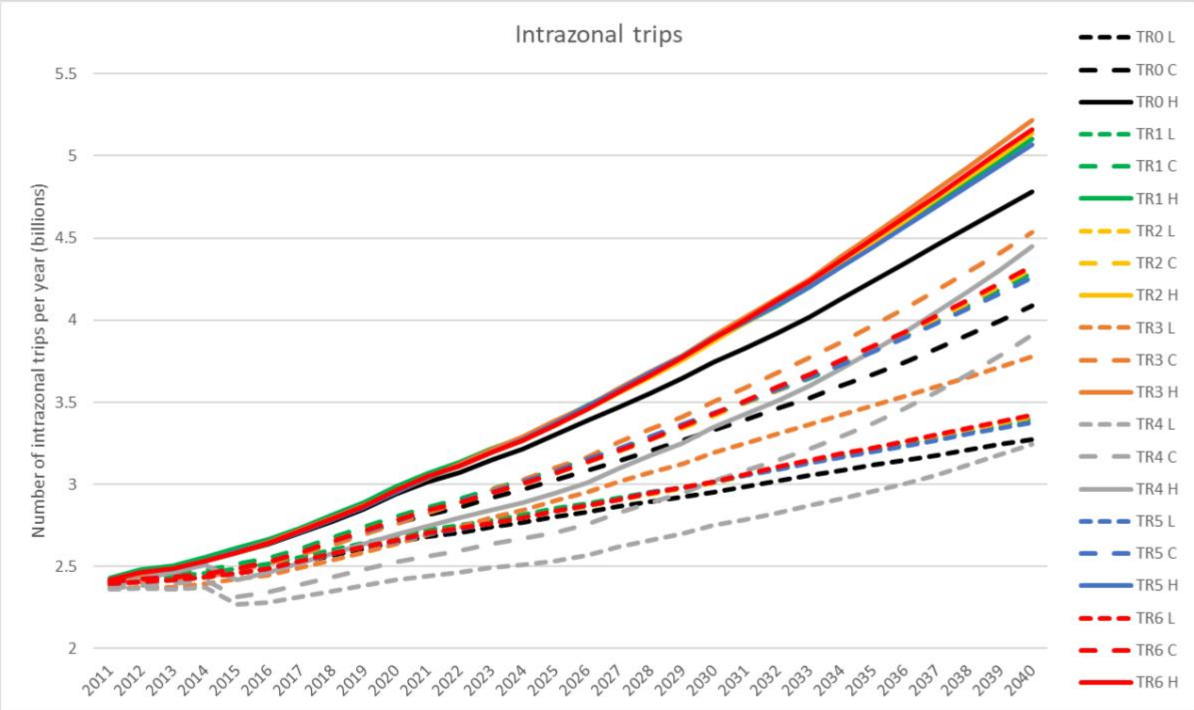

Figure 7: ITRC forecast intrazonal demand 2015–2035

The intrazonal model, illustrated by Figure 7, is based on the ORR station usage data combined with elasticity models which forecast the demand impacts of changes in population, GVA, rail travel cost, car fuel cost and (exogenously specified) average generalised journey time (GJT). It includes functionality to allow future capacity enhancements to be incorporated in the model forecasts by increasing the number of stations in particular zones (with their base demand levels being predicted separately), but this option has not been used in the forecasts presented here. Fare and GJT elasticities vary by zone, based on PDFH advice. Growth is unconstrained. If the high growth scenario is focused on, it is found that most of the do-something alternatives (TR1, TR2, TR3, TR5 and TR6) lead to rail demand growth of between 95% and 101%, while the do-minimum scenario (TR0) and TR4 (where growth is constrained by pricing) leads to growth of 84–85% (see Table 1).

Table 1: Intrazonal growth – central assumption (station ons and offs, billion per annum)

	TR0	TR1	TR2	TR3	TR4	TR5	TR6
2015	2.58	2.62	2.59	2.39	2.42	2.59	2.59
2040	4.78	5.11	5.14	5.22	4.45	5.07	5.16
% Growth	85%	95%	98%	101%	84%	96%	99%

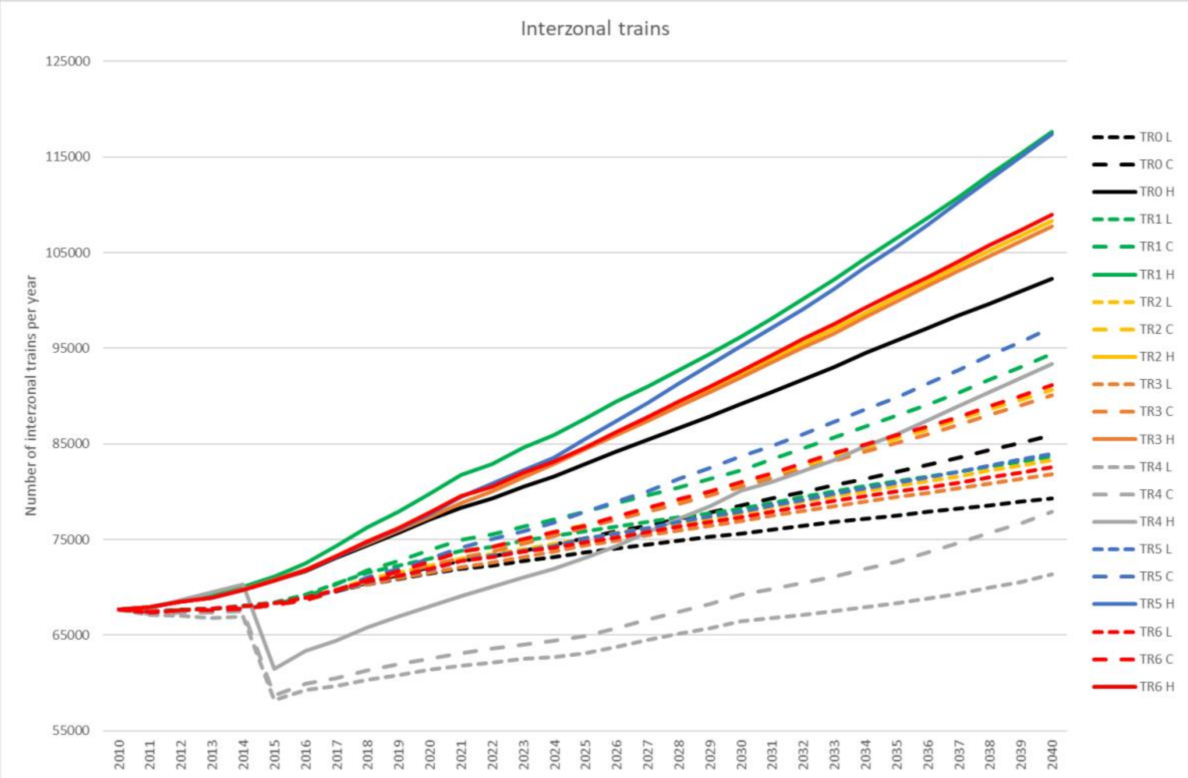

Figure 8: ITRC model interzonal demand forecasts 2015–2035

The interzonal model, illustrated by Figure 8, is based on train timetable data for 11,424 links, with base service levels adjusted using an elasticity-based model in response to changes in population, GVA, delays (as a function of capacity utilisation), rail operating costs, and car fuel costs. This model takes into account capacity constraints, based on a generalised measure of average track capacity for the busiest hour of the day. It can be seen from Table 2, again based on the high growth assumption, that market growth is more limited. The largest growth of 66% is with strategy TR5, with strategy TR0 having growth of 45% – which gives an indication of possible supply side constraints. Strategies TR1, TR2, TR3, and TR6 have growth between TR0 and TR1 (although note that TR4 has a much lower base figure because punitive pricing is assumed to take effect from 2015). These growth figures relate to train movements, and therefore can only be used as a proxy for passenger demand growth if it is assumed that train loads (and by default train lengths) will remain constant.

Table 2: Interzonal train movements – central assumption (Number of trains passing count points per day)

	TR0	TR1	TR2	TR3	TR4	TR5	TR6
2015	70,686	71,156	70,707	70,766	61,501	70,718	70,708
2040	102,263	117,645	108,285	107,739	93,364	117,359	108,924
% Growth	45%	65%	53%	52%	52%	66%	54%

An alternative approach to assessing the extent that rail demand is choked off by supply-side constraints is to compare the intrazonal and interzonal growth forecasts. The least amount of trip suppression is for TR1 (Predict and provide), where the difference between intra- and inter-zonal growth forecast is 30 percentage points. The largest amount of trip suppression is for TR3 (Adapting the fleet) where the difference is 49 percentage points

Table 3: The drivers of road travel

Area of interest	Trends/drivers
1. Traditional economic factors	1.1 Fuel prices
	1.2 Parking
	1.3 Taxation
	1.4 Role of income
	1.5 Other
2. Reduction in driving levels for young people	2.1 Changes in car costs
	2.2 Technology
	2.3 Living locations
	2.4 Legal restrictions
	2.5 Impacts of changes in tertiary education
	2.6 Employment levels for young people
	2.7 Changing attitudes to driving
	2.8 Other
3. Developments in land-use	3.1 Increasing urbanisation
	3.2 Travel trends in urban areas
	3.3 Other
4. Population structure and demographics	4.1 Population ageing
	4.2 Immigration
	4.3 Changes in household size/occupancy
	4.4 Other
5. Employment levels and patterns	5.1 Teleworking
	5.2 Part-time working
	5.3 Changes in household size/occupancy
	5.4 Other
6. Technology	6.1 Teleworking
	6.2 Online shopping trends
	6.3 Social media
	6.4 Mobile internet access
	6.5 Video-conference, Skype
	6.6 Provision of information
	6.7 Other
7. Use of company cars	7.1 Taxation Policy
	7.2 Other
8. Substitutes	8.1 Mode shift
	8.2 Shift to new alternatives
	8.3 Increasing car occupancy
	8.4 Increase in international travel
	8.5 Other
9. Supply effects	9.1 Impact of congestion
	9.2 Impact of reliability
	9.3 Quality of road supply
	9.4 Effects of policy, e.g. reallocation of road space
	9.5 Other
10. Changing attitudes	10.1 Attitudes to the environment
	10.2 Attitudes to cars
	10.3 Attitudes to health, e.g. walking, cycling
	10.4 Other
11. Market Saturation	11.1 Saturation in car ownership
	11.2 Saturation in car usage
	11.3 Other
12. Other	

Source: DfT, 2015.

How technology is changing the rail system

Table 4: rail technical strategy, capability delivery plan.

Capability	Milestones			
	A	B	C	D
1. Running trains close together	Demonstration of closer running	Moving block	Platooning	Virtual coupling
2. Minimal disruption to train services	Full RCM potential	Smart assets deployed	Guaranteed asset availability (peak time)	Support activities scheduled by AI[13]
3. Efficient passenger flow through stations and trains	Real-time communication led capacity increase	Level access	Double throughput capacity	
4. More value from data	Enterprise coordination & cooperation	Information business models	Integrated enterprise information system	
5. Optimum energy use	No new carbon imported into railway	Smart grid available	Discontinuous electrification	No carbon based fuels in railway operations[14]
6. More space on trains	Enterprise gauging business plan	Low cost gauging toolsets	Flexible interiors	(E?) Increased gauge across UK network
7. Service timed to the second	Optimised national timetable	Precise positioning	Network wide situational awareness	Autonomous perturbation recovery
8. Intelligent trains	GoA 2: Semi-automatic operation	GoA 3: Driverless operation	GoA 4: Unattended operation	Autonomous Trains

[13] Also Milestone E: 100% Enterprise availability (peak time)
[14] Milestone E: Zero carbon use in railway.

Capability	Milestones			
	A	B	C	D
9. Personalised customer experience	Integrated journey emissions	Integrated data services	Virtual concierge	Seamless experience
10. Flexible freight	Rail light freight applications ready for deployment	Established freight policy	Light freight standard franchise	Autonomous freight handling[15]
11. Low-cost railway solutions	Low-cost business plans	Delivery facility	Roll-out & export	Migration to main line
12. Accelerated research, development and technology deployment	Collaborative working environment	Industry alignment on technology delivery	Enhanced development and testing facilities	Policies that support technology development

RCM = Route Condition Monitoring; AI = Artificial Intelligence; GoA = Grades of Automation.

Source: RSSB, 2016.

[15] Milestone E: Autonomous freight trains.

This publication is available from www.gov.uk/go-science

Contact us if you have any enquiries about this publication, including requests for alternative formats, at:

Government Office for Science
1 Victoria Street
London SW1H 0ET
Tel: 020 7215 5000
Email: contact@go-science.gov.uk