Business models in rail infrastructure: explaining innovation

Article (Accepted Version)

Transport

Business models in rail infrastructure: explaining innovation
Lovell and Nightingale

ice | proceedings

Proceedings of the Institution of Civil Engineers

http://dx.doi.org/10.1680/jtran.16.00024
Paper 1600024
Received 29/01/2016 Accepted 09/06/2016
Keywords: management/public policy/railway systems

ice Institution of Civil Engineers
publishing

Business models in rail infrastructure: explaining innovation

1 **Katherine Lovell** MEng, PhD
Research Fellow, Science Policy Research Unit, University of Sussex, Brighton, UK (corresponding author: k.lovell@sussex.ac.uk)

2 **Paul Nightingale** MSc, DPhil
Professor, Science Policy Research Unit, University of Sussex, Brighton, UK

Policy decisions about the UK railway industry often draw on models and frameworks that treat technology and organisational processes as static and unchanging. As a result, policy makers often have limited understanding of how changes in policy will influence organisational knowledge, learning and the allocation of risk that subsequently affects innovation and system development. This paper applies a business model lens, focused on the mechanisms firms use to create and capture value, to connect policy decisions to subsequent changes in the organisation and industrial structure of the UK railway sector. By analysing innovation-related activity across several different governance structures, the paper highlights how policy impacts in network-based infrastructure sectors are mediated by business strategy, sometimes leading to unintended outcomes. The findings suggest that policy to improve the performance should focus upon coordination rather than just ownership. The application of a business model approach to complement existing economic and policy models in system analysis for policy decisions is advocated.

1. Introduction

Among the reasons given for the privatisation of British Rail (the nationalised organisation that owned and operated the mainline railway from 1962 until privatisation) was the assertion that a change in ownership and governance would lead to improved operational efficiency, superior planning and pressure for more effective capital investment and innovation (DoT, 1992; Jupe and Crompton, 2006). Despite this, the privatised railway industry in the UK has been criticised for producing an expensive, uncoordinated, un-innovative industry that required substantial public subsidy and was more concerned with corporate profits than traveller welfare and safety (e.g. Bowman *et al.*, 2013; Wolmar, 2001). Taking innovation as the means through which the form and performance of a railway system change, this paper uses a business model lens to examine innovation-related activity in the post-privatisation UK railway industry in order to understand changes in system development.

Privatisation was initiated and implemented externally by political actors outside the railway industry. Despite an expressed interest in innovation (DoT, 1992), decisions over the industry's structure were driven by a concern about the operational coordination of the network under private competition. How the railway system was going to develop, where innovation would come from and what it would change were all left uncertain. The railway system was now operated through private firms and its subsequent development was principally governed by their intersecting interests and activities. By exploring the changing business models of these firms, this paper helps explain their innovation-related activities.

Prior to privatisation, the nationalised British Rail was considered to be a declining and costly legacy industry that was losing market share to road transportation (Bradshaw, 1997; Pollitt and Smith, 2002). However, since privatisation, rather than declining further, demand for rail travel has grown (Preston and Robins, 2013; Tyrrall, 2004). The governance structure has continued to change in response to a series of accidents and numerous safety, investment and management problems, many of which can be linked to challenges in coordination. As a result, the initially deregulated privatised sector has become increasingly regulated and parts have been taken back into public ownership (Glaister, 2004; Murray, 2005).

Recently, attempts have been made to address the innovation deficit within the industry by encouraging innovative change (Lovell *et al.*, 2011; Palacin *et al.*, 2015); examples include initiation of the *Rail Technical Strategy* (DfT, 2007), the 'unlocking innovation' scheme run by the Railway Industry Association and Innovate UK, and Crossrail's innovation strategy (DeBarro *et al.*, 2015). One reason why technological developments do not appear to have been given much consideration within the original privatisation is that the policy and economic models used to design the industrial structure that would be launched, and to analyse the industry since, have limited ability to capture innovation. The models used in public economics – and particularly the models developed for the regulation of networked industries that are subject to numerous market failures – tend to treat technical change as an investment decision about exogenously developed process technology, rather than a cumulative process of capability development that is endogenously generated within firms. The economic models used to understand innovation, on the other hand, typically focus on competitive industries. These industries differ in important regards from the railways, which are capital-intensive, networked natural monopolies that provide a combination of difficult-to-substitute essential travel services and (sometimes commercially unviable) public goods. Given the power of economic models to help generate policy frameworks that enable the management of monopoly service provision in networked industries – and particularly their power in helping design contracts – the lack of attention to innovation can seem a minor issue. However, the post-privatisation experience of the railway sector suggests that it is a gap that is important.

Business models offer an alternative, complementary way of understanding dynamic changes in a firm, industry or sector (Baden Fuller and Morgan, 2010; Teece, 2010). In this case, business models offer a means of representing and analysing the interests and agency of the private firms that were reintroduced with the restructuring and privatisation of the sector. A business model is a simplified representation of a firm that captures how it (*a*) creates value and (*b*) captures value (Baden Fuller and Morgan, 2010; Teece, 2010). Economists have long recognised the importance of innovation in changing market structures, but have tended to see innovation in terms of the creation of value. As shown by the example of EMI's successful development – and unsuccessful commercialisation – of the computerised axial tomography (CAT) scanner, creating value is not enough for innovative success (Teece, 1986). Firms also need to be able to capture some of the value they create and turn it into profit.

The business model approach used here to analyse innovation activity in the privatised railway industry highlights that a system-level incentive is not sufficient for action where coordination between different actors is difficult. By considering both the creation and capture of value for the private sector, the study presented in the next section of this paper shows the connection between the structural changes following privatisation and the changing interests and coordination for innovation that were missed in the models that informed the initial privatisation process. While only an illustration of this approach, it does show how policy actors assessing or altering the organisational structure of infrastructure sectors can use considerations of how firms capture value to examine subsequent system development opportunities and, in doing so, identify and remove potential obstacles or undesirable development interests.

2. The study: changes in development activity across railway privatisation

To illustrate how a focus on business models can illuminate the industrial dynamic of the UK railway sector after privatisation, this study explores a historical account of the UK railway sector based on interview data, primary material and data on innovative activity taken from reports in the specialist industrial press. These provide information on the structural changes following privatisation and related changes in innovative activity. The analysis focuses on connecting changes in innovation activity to the structural changes in the industry that altered value flows within the sector, and hence how value was created and captured.

Section 2.1 discusses value creation and capture in the early days of Great Britain's railway system, a time when it was operated and developed by private organisations prior to nationalisation and the creation of British Rail after World War II. Section 2.2 describes the changing organisational structures that came with railway privatisation and some further adjustments made by policy actors following privatisation that changed institutions, organisations and the type of knowledge within the industry. Section 2.3 outlines the methods used to analyse changing innovation activity within the sector and describes changes in innovation activity in two areas: delay penalties and possession costs, and gathering information on the network. The former are linked to changes in opportunities to capture value that alter value creation activity while the latter features a new area of value that generated a response within the industry to find new ways to create and capture value. Section 2.4 discusses how a business model approach generates additional insights that complement existing policy and economic models for analysing the dramatic changes that came with privatisation in this industry.

2.1 Organisational structures in the private railway industry pre-nationalisation

Railways are a classic example of an infrastructure sector. The core infrastructure sectors of energy, water and waste, transport and telecommunications share three central features. First, they are based on the provision of essential services through capital-intensive, large technical systems or networks. Second, these large technical systems are subject to a range of market failures, typically either as natural monopolies where

competition is reduced and consumers can be exploited, or as public goods that provide services that cannot be effectively provided by the market. Large technical systems also typically generate a range of significant positive and negative externalities that complicate market provision and make their governance inherently political (Bozeman, 2007). Third, because of these multiple market failures, infrastructure industries are typically heavily regulated, with a variety of forms of regulation covering their ownership, operation and funding. Many require some form of subsidy for their public good features, with taxation complementing charges and/or license fees. They also often need oversight to solve the range of strategic coordination problems caused by their complex technical interdependencies. The resulting regulations tend to differ by country and change over time because the relationships between the underlying technology of technological systems, their associated market failures and governance solutions are unstable and dynamic.

These dynamic interactions can be seen in the history of the British railway system. In their early years, railways were governed as 21-year franchises, paying a 10% dividend, with specified rates (Stern, 2003). This structure was based on previous British experience with toll roads, and did not take into account the potential of railways to generate monopoly profits. The resulting monopoly profits, in a period of declining costs, led to the railway mania of the 1840s and the resulting rapid expansion of the British railway system (Stern, 2003).

As the railway system grew and started to be integrated, coordination and standardisation became more important. Standards such as the Stephenson gauge (1846–1892) (Johnson and Long, 1981) needed to be negotiated and enforced. Unfortunately, the uncoordinated early expansion led to a fragmented low-performance system with carriers exploiting their customers. The typical business model involved protecting a firm's monopoly profits by deterring market entry from competitors. This was done through threats of rates war, revenue sharing, price collusion, mergers, vertical integration to reduce competition (e.g. using monopoly profits to buy canal and dock companies) and predatory pricing on customers who lacked alternative carriers (Stern, 2003). Firms were able to capture significant value, and grew, but in so doing generated an inefficient, poorly coordinated, high-cost and high-price railway system (Casson, 2009). These problems were addressed by the Railway and Canal Traffic Act 1854, which enforced effective interchanges and fair pricing (Stern, 2003).

However, success was short-lived. From around 1890, petrol-powered road transport increasingly provided competition for traffic, costs started to increase for the first time and profits were cut by inflation. Firms were unable to pass these new costs onto their customers because their prices were regulated. As a result, profits, dividends and share prices fell sharply in the first decade of the twentieth century (Cain, 1972; Stern, 2003). Since firms' monopoly positions were now eroded, increased rates led to traffic transferring to the road network, and not – as had previously been the case – increased income.

The resulting economic mess had to be nationalised during World War I (1914–1918), setting the scene for the 1923 amalgamation of 123 private railways into the 'big four'. However, problems continued and on New Year's Day 1948 the newly created British Transport Commission brought the 'big four' private railways into public ownership (Allen, 1982). The problematic operation of the industry led to the Beeching report in 1963 (Beeching, 1963) and the subsequent extensive restructuring of the network around major trunk routes and reduction in its size. It was initially intended that the railways would be self-sufficient and self-funding, but the Transport Act 1968 introduced subsidies for the provision of unprofitable, socially beneficial services (Allen, 1982). Over time, the costs of these subsidies grew. One motivation for privatisation was to reduce this increasingly costly subsidy (Harris and Godward, 1997: pp. 63–64).

In addition to showing the importance of coordination between private organisations, this historical background highlights the role of organisational and political actors and interests in directing and altering the railway system. Likewise, the analysis of development activity following privatisation presented in the following section shows that, although perhaps unintended, restructuring of the sector and privatisation in the mid-1990s adjusted the technology of, and possibilities for, the future form of the railway system.

2.2 Analysis of changing structures over privatisation

The decision, in 1992, to privatise the industry and the subsequent structural alterations were externally imposed rather than internally generated by actors working within the existing system (for a contrast see the work of Hughes (1987) on how an overarching infrastructure systems-goal can generate shared motivations towards change). These external interventions altered the system's structure, and therefore the location and types of interactions needed for the system to operate effectively. Within an integrated organisational structure, tensions between where value was created and captured would have limited influence on innovative activity. Innovation was guided by a system-wide idea of value, and a focus upon value creation – without attention to value capture – was sufficient.

The privatisation and restructuring of British Rail between 1992 and 1997 saw the organisation divided both vertically and, introducing competition, horizontally. The operation of railway services was to be offered by way of regional franchises, let for 7–12 years through a process of competitive tender. The infrastructure came into the ownership of a single private organisation, Railtrack. However, Railtrack was set up to be an owning and contract-holding organisation, not one focusing on technological capabilities (Gourvish, 2002: p. 402), and it

purchased infrastructure maintenance and renewal services from contractor organisations also set up from within British Rail. Mechanisms for coordination between the different organisations (such as track access charging), as well as principles and organisations for regulation, were set up as part of privatisation. From the decision to privatise in 1992, the decisions over the industry structure, the reorganisation of British Rail and the launch of these new organisations into the private sector took just 5 years.

The launch of the privatised industry in 1997 was followed by further externally initiated structural changes to adjust different elements of system behaviour. Langley (1999) highlights how these different external interventions can be used to divide and bound periods of railway system operation and development, with the periods between interventions capturing different phases of system operation. These, in turn, provide cases of the railway system operating in different ways, represented in Figure 1 and described in Table 1.

As shown in the previous section, railway systems change over time. These changes can come from either internally generated adjustments to organisational boundaries as actors attempt to improve overall system performance, or from external interventions. The restructuring of the railway industry at privatisation and the organisational changes introduced in 2001 changed the location and form of the boundaries between the organisations that operated and developed the railway. A simplified representation of value flows within infrastructure delivery is shown in Figures 2 and 3. Such changes in organisational boundaries can change how people and processes interact at those boundaries, what gets delivered between organisations (or divisions within British Rail before privatisation), the form and location of the transactions, and their costs and benefits. For example, a move from operating both vehicles and infrastructure within the same business unit (as existed before privatisation, after the 'Organising for Quality' (OfQ) restructuring) to a situation where infrastructure delivery and vehicle operation are defined and costed in 'track access' agreements changes the infrastructure delivery organisation's requirements, rewards and priorities.

In the next section, the impact of privatisation and other externally generated structural changes on the development of the railway is considered using business models to explore

- how changes in organisational boundaries lead to changes in what is considered valuable
- the movement, removal or entry of the knowledge bases needed to create value
- the mechanisms available to capture value.

2.3 Changes in development activity

To explore changes in development activity, this study used historical accounts, 23 interviews with senior engineers and engineering managers in the railway sector conducted between 2007 and 2009 (see also Lovell *et al*. (2011)) and secondary data to analyse changes in how value is created and captured after structural changes in the industry. The analysis focuses on three sub-samples of development activities. The interviews investigated the innovation processes present in the sector and explored how the industry developed before and after privatisation. The interviews lasted for 60–90 min. Sensitivities in the industry at that time meant that interview records were handwritten and then typed up as notes (rather than recorded and transcribed). The interview records were sent to interviewees for comment and validation.

To capture development activity before, during and after privatisation, the study focused on railway infrastructure development

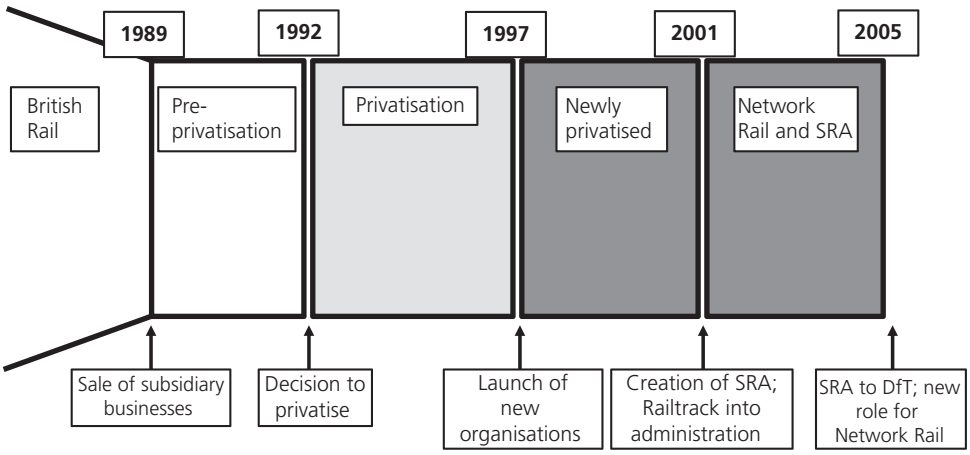

Figure 1. Phases of system operation identified in this paper as a timeline

Phase	System form	Dates	Phase description and start and finish
1	Pre-privatisation system	1989–1992	The sale of British Rail's subsidiary businesses provides the railway system that will be privatised in 1992. The most relevant sales are completed in 1989. During this phase the British Rail Board is directing the system
2	Privatisation	1992–1997	Privatisation was initiated in the 1992 Conservative party manifesto and developed in the white paper that followed and the Railways Act 1993. Plans for the privatised industry were developed alongside the continued operation of the existing system. Shadow organisations were set up within British Rail, and were subsequently privatised between 1993 and 1997
3	Newly privatised	1996–2001	From 1996, market interactions were increasingly used to coordinate the industry. Three serious accidents occurred between 1997 and 2001. In 2001, the railway system was altered again with the creation of the Strategic Rail Authority (SRA). The SRA took a strategic overview of the railway system and took over franchising. Shortly after the launch of the SRA, Railtrack was placed in administration
4	Network Rail and SRA	2001–2005	The SRA maintained a system overview between 2001 and 2005, while Network Rail was created to take over infrastructure management. The Rail Accident Investigation Branch (RAIB) and Rail Safety and Standards Board (RSSB) were set up. In 2005, the SRA was abolished and many of its functions were taken on by the Department for Transport (DfT)

Table 1. Phases of system operation and development 1989–2005. The phase boundaries are marked by structural changes outside the control of railway system actors. The phases represent different ways of operating and developing the railway system

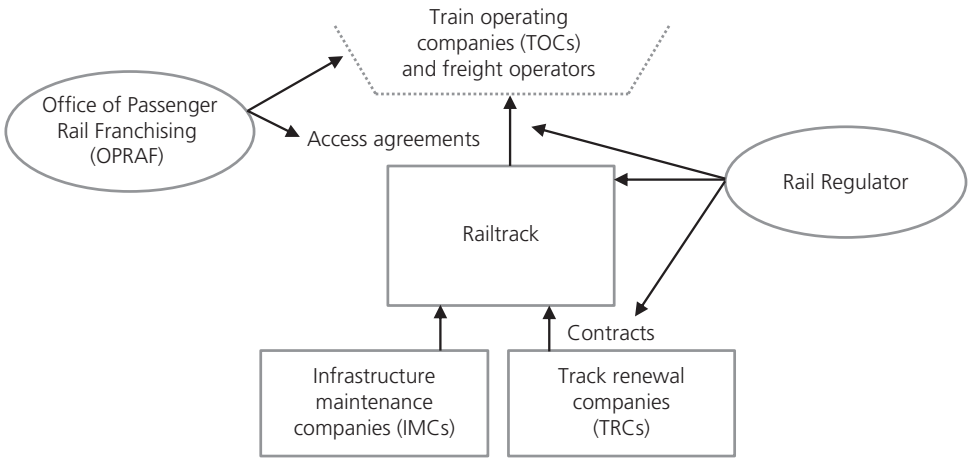

Figure 2. Value flows in the organisational structure for infrastructure delivery between 1997 and 2001

(specifically problems identified in infrastructure performance and projects set up to improve it) and sampled activity over three 12-month periods drawing on the specialist industry publication *Modern Railways*. This generated samples of (228, 293 and 377) innovation initiatives for each of the three periods. The sample phases are described in Table 2 and Figure 4 shows their position within the historical periods described in Table 1. The themes found in the analysis of development activity were investigated further, using interviews, secondary and industry publications, and extended into

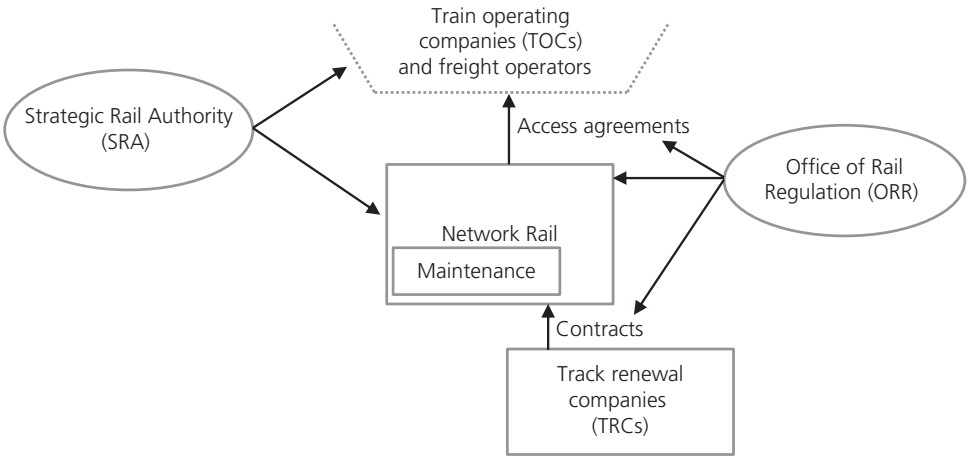

Figure 3. Value flows in the organisational structure for infrastructure delivery between 2001 and 2005

Within phase	Time period	Focus of analysis
1: Pre-privatisation	January to December 1990	Development processes under British Rail, before the privatisation plan was set out. Data collection ended just before the new 'Organising for Quality' (OfQ) initiative was implemented
2: Privatisation	June 1992 to July 1993	Development processes before structural changes had begun but after the decision to privatise had been announced
3: Post-privatisation	October 1998 to September 1999	Development following privatisation and restructuring. This data sample concluded just before the Ladbroke Grove accident (5 October 1999), the second of the series of rail accidents that influenced subsequent restructuring decisions

Table 2. Summary of data

the fourth phase of system operation outlined in Table 1 (i.e. 2001–2005, Strategic Rail Authority (SRA) and Network Rail).

After privatisation, several adjustments to the railway system's organisational structure, processes and focus of innovative activity can be traced back to changes in value creation and capture. Two are now discussed in more detail. The first – delay penalties and possession costs – changed value creation and created new opportunities for value capture. The second – gathering information on the network – generated a new way of creating and capturing value.

2.3.1 Delay penalties and cost of possessions

A number of new development activities emerged after privatisation related to punctuality, improving maintenance processes and avoiding delays – areas not heavily represented in earlier periods. The changing focus is illustrated in Figure 5, which shows projects focused on advancing system-wide knowledge (rather than the local implementation of knowledge that had been developed elsewhere). Punctuality was also a target area for British Rail, so new innovation in this area was not a response to a performance characteristic that was newly valuable post-privatisation. The innovation activity for reducing delay and possession time in the post-privatisation phase shows a variety of developments in different areas of technology and involving a range of actors, suggesting this is not just intense activity in one place but a range of new responses to a, now monetised, area of performance.

Extending the data analysis to include local installation projects, in addition to activity advancing system-level knowledge, shows a series of developments in high-output maintenance equipment. According to Dow (2014), tampers were introduced onto the network before 1960 and Gourvish (2002: p. 213) refers to this kind of maintenance equipment being purchased in the 1980s. This suggests the change in focus does not reflect a new ability to access or combine knowledge bases.

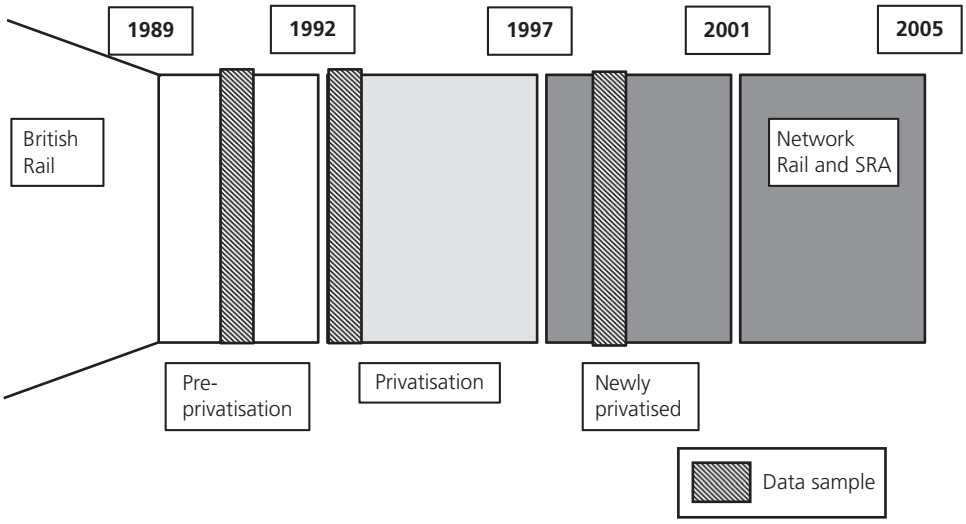

Figure 4. Samples of development activity. The figure shows the three sample periods on the timeline of phases from Figure 1

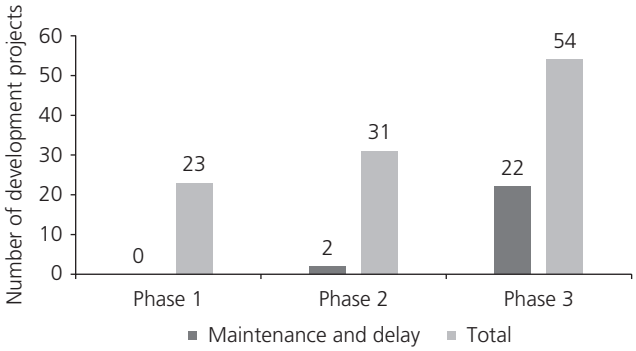

Figure 5. Maintenance and delay entries within total system knowledge development projects in the three phases of development activity

Instead, more machines were required after the organisational structures were changed. However, looking across the range of maintenance- and punctuality-focused projects in the 1998 data sample, they include Balfour Beatty and Railtrack improving coordination and renewal planning, the development of an ultrasonic rail-flaw detection cart, a computer-based maintenance estimating system and work on a new metallurgical make-up of crossings to improve wear. This variety and, in some cases, high degree of novelty indicates development in this area goes beyond simple renewal or roll-out of existing equipment.

Interviewees highlighted the importance of reliability in driving technology development for vehicles and operations as well as infrastructure in the post-privatisation railway. The privatisation process led to the creation of delay penalties to reduce the financial losses suffered by parties delayed by others. The Rail Regulator was given responsibility for allocating blame for delay-minutes accrued on the network and companies were required to pay penalties to one another accordingly. Similarly, the infrastructure operator also has to compensate train operators for times when the infrastructure is unavailable. This puts a commercial value on the number and length of infrastructure possessions.

These mechanisms – delay penalties and possession charging – generated new opportunities to create and capture value that, in turn, have affected innovative activity and the development direction of the railway system. As a senior manager within Railtrack noted 'These high [delay] penalties give a business case for innovation to reduce the occurrence of delays'.

Delay penalties were a way of connecting a firm's punctuality performance to its profit, and the introduction of compensation for infrastructure possessions placed a price on infrastructure availability. These new financial mechanisms emerged in response to the additional coordination requirements created by the newly introduced operational structure: they put a price on delay and infrastructure availability for each operational organisation and this provided an incentive to improve punctuality, reduce delays and reduce possession time. This triggered development activity to capture more value and a series of (process) innovations to improve overall system performance.

2.3.2 Gathering information on the network

Following privatisation, new challenges emerged related to the product acceptance processes needed to ensure that new or altered additions to the system are compatible with, and safe to be connected to, the existing system. Examples of related

developments captured in the post-privatisation data sample include

- the changed structure of system review panels within the product acceptance process
- the creation of a database (parts and drawings system 2000 (PADS 2000)) for products accepted onto the network
- changes to access conditions and group standard to reflect a new traction and rolling stock acceptance process.

A key element of this challenge was availability of information on the shape and state of the network. Much of the local infrastructure knowledge held within British Rail, and the ability to build upon previous designs and practices, fell outside Railtrack at privatisation. Gourvish (2002: p. 402) highlights Railtrack's specific decision not to incorporate the previous level of engineering expertise held within British Rail and to function as 'an access, capacity management, and sales organisation…'. An interview with a senior industry professional formerly within Railtrack highlights one consequence.

> Initially Railtrack did not have the information about the infrastructure or its requirements needed to make decisions about the safety of changes for incoming rolling stock.

Interviews and archive material reveal post-privatisation developments in measuring and assessment equipment such as LaserRail's infrastructure measurement equipment and Amey's proposed development of a track recording train and the development of an ultrasonic rail-flaw detection cart. The new delay and possession costs discussed earlier will have influenced these developments, but they were also a response to the need for new knowledge to operate and change the more organisationally fragmented system that emerged after privatisation.

The need for new knowledge about the installed infrastructure system after privatisation can be seen by changes in product acceptance processes. In the Network Rail and SRA phase, Network Rail had to learn about its network and engaged in a range of measurement and recording activities, including the creation of a national asset management database. For example, in 2003, Network Rail contracted Omnicom to apply its system to generate a visual and positional record of infrastructure.

In this privatised system, additional value can be created by the infrastructure owner by collecting and processing information about the state of the network. With the removal of much local maintenance and specialised engineering knowledge from the infrastructure owner, the need for this information was introduced with privatisation; the new technical knowledge required to generate this information would not have been seen as essential under the previous British Rail structure. In the Network Rail and SRA phase, contracts are placed with industry suppliers to run measurement trains and generate databases containing measurement data on the state of the network.

These new opportunities for value creation emerged from the new organisational structure that was created at privatisation. New ventures (e.g. LaserRail) and new areas of expertise were built up within existing firms to create and capture value from infrastructure information. In this case, the locations of opportunities to create value in the industry changed at privatisation and both innovation activity and ways to capture value from its results have been created in response.

2.4 Discussion: privatisation and development in the UK railway system

The changes in innovation-related activity following privatisation of the railway system highlight how policy decisions that change organisational structure and governance can influence the form of the socio-technical system being developed. By looking at business models and how opportunities for value creation and capture are altered by structural changes, it is possible to understand better the connections between the structural decisions made as part of privatisation (which were intended to shape the operation of the industry) and the subsequent development trajectory for the railway system that was generated after privatisation.

Changes regarding track access and reliability, discussed previously, highlight that the introduction of delay penalties and track access charges to coordinate operation was effective in creating a way for firms to capture value from improvements in punctuality and reliability. However, thinking in business model terms also highlights that there can be cost and capability barriers to sufficiently coordinating knowledge and capabilities, held in different organisations, to create value to respond to opportunities to capture value.

Furthermore, assisting coordination within the restructured industry has itself become a source of value. The developments linked to information generation discussed earlier show a new business opportunity created in the sector and the innovation activity analysis discussed in Section 2.3 shows that organisations have responded by finding new ways to create and capture this value (i.e. by developing new business models along with new technology).

3. Conclusions

The experiences of the UK railway system after privatisation suggest the need for better understanding of how firms will respond to changes in regulation and organisational structures. The structural changes at privatisation were focused upon introducing competition to, and driving efficiencies within, system operation; the organisational processes and knowledge bases required for innovation were not addressed. Business models focus on how firms capture as well as create value,

which can help explain the location of innovative activity and how it develops.

The history of the restructuring of the railway system shows that reform cannot be implemented in a clean switch from old to new, but that policy changes initiate further alterations as organisations respond. Over time, the mechanisms of value creation and value capture interact to change the nature of market failures and policy needs for infrastructure systems.

For the future development of transportation infrastructure sectors, coordination, rather than ownership, is the key (and overlooked) issue. Competition is only one element of this – it can produce incentives for innovation by private firms but, for the system's development to respond to incentives, organisations with the appropriate capabilities to generate innovations need to be able to capture value from innovation activity. More recent initiatives in UK railways, such as the *Rail Technical Strategy* and programmes to encourage innovation, represent attempts to generate opportunities for organisations to capture value from innovation. Despite the costs to create and maintain this additional layer of coordination, it is necessary in a system where business models do not fit together to enable action upon system-level interests. The business model approach presented in this paper can be used alongside existing models for system analysis to guide policy and management decision-making.

Acknowledgements

This paper draws upon research undertaken as part of several projects: Rail Research UK (2007–2009), PhD research funded by the Engineering and Physical Sciences Research Council (EPSRC) and the International Centre for Infrastructure Futures (ICIF) (2015–present). The authors gratefully acknowledge the funding bodies, EPSRC and ESRC, behind those projects and the individuals in both the railway industry and in academia that participated in and assisted this work.

REFERENCES

Allen GF (1982) *Railways: Past, Present and Future*. Orbis Publishing, London, UK.

Baden Fuller C and Morgan M (2010) Business models as models. *Long Range Planning* **43(2–3)**: 156–171.

Beeching T (1963) *The Reshaping of British Railways*. HMSO, London, UK.

Bowman A, Folkman P, Froud J *et al.* (2013) *The Great Train Robbery: Rail Privatisation and After*. Centre for Research on Socio-Cultural Change, Manchester, UK. See http://www.cresc.ac.uk/sites/default/files/GTR%20Report%20final%205%20June%202013.pdf (accessed 28/01/2016).

Bozeman B (2007) *Public Values and Public Interest: Counterbalancing Economic Individualism*. Georgetown University Press, Washington, DC, USA.

Bradshaw WP (1997) Competition in the rail industry. *Oxford Review of Economic Policy* **13(1)**: 93–103.

Cain P (1972) Railway combination and government, 1900–1914. *The Economic History Review* **25(4)**: 623–641.

Casson M (2009) *The World's First Railway System: Enterprise, Competition, and Regulation on the Railway Network in Victorian Britain*. Oxford University Press, Oxford, UK.

DeBarro T, MacAulay S, Davies A *et al.* (2015) Mantra to method: lessons from managing innovation on Crossrail, UK. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **168(4)**: 171–178.

DfT (Department for Transport) (2007) *Rail Technical Strategy*. Her Majesty's Stationery Office, London, UK.

DoT (Department of Transport) (1992) *New Opportunities for the Railways: The Privatisation of British Rail*. Her Majesty's Stationery Office, London, UK.

Dow A (2014) *The Railway: British Track Since 1804*. Pen & Sword Transport, Barnsley, UK.

Glaister S (2004) *British Rail Privatisation – Competition Destroyed by Politics*. University of Bath, Bath, UK, CRI Occasional Paper 23. See http://www.bath.ac.uk/management/cri/pubpdf/Occasional_Papers/23_Glaister.pdf (accessed 21/06/2016).

Gourvish TR (2002) *British Rail 1974–97: From Integration to Privatisation*. Oxford University Press, Oxford, UK.

Harris NG and Godward E (1997) *The Privatisation of British Rail*. A & N Harris, London, UK.

Hughes TP (1987) The evolution of large technological systems. In *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Bijker WE, Hughes TP and Pinch T (eds)). MIT Press, Cambridge, MA, USA, pp. 51–82.

Johnson J and Long RA (1981) *British Railway Engineering: 1948–80* (Bond RC (ed.)). Mechanical Engineering Publications Ltd, Bury St Edmunds, UK.

Jupe R and Crompton G (2006) 'A deficient performance': the regulation of the train operating companies in Britain's privatised railway system. *Critical Perspectives on Accounting* **17(8)**: 1035–1065.

Langley A (1999) Strategies for theorizing from process data. *Academy of Management Review* **24(4)**: 691–710.

Lovell KA, Bouch C, Smith A *et al.* (2011) Introducing new technology to the railway industry: system-wide incentives and impacts. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit* **225(2)**: 192–201.

Murray I (2005) *No Way to Run a Railway: Lessons from British Rail Privatization*. ASI (Research) Ltd, London, UK.

Palacin R, Golightly D, Ramdas V and Dadashi N (2015) Evaluating the impact of rail research: principles to maximise innovation uptake. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, http://dx.doi.org/10.1177/0954409715610604.

Pollitt MG and Smith AS (2002) The restructuring and privatisation of British Rail: was it really that bad? *Fiscal Studies* **23(4)**: 463–502.

Preston J and Robins D (2013) Evaluating the long term impacts of transport policy: the case of passenger rail privatisation. *Research in Transportation Economics* **39(1)**: 14–20.

Railway and Canal Traffic Act 1854. *Victoria. Chapter 31*. Her Majesty's Stationery Office, London, UK.

Railways Act 1993. *Chapter 43*. Her Majesty's Stationery Office, London, UK.

Stern J (2003) Regulation and contracts for utility services: substitutes or complements? Lessons from UK railway and electricity history. *Policy Reform* **6(4)**: 193–215.

Teece DJ (1986) Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy* **15(6)**: 285–305.

Teece DJ (2010) Business models, business strategy and innovation. *Long Range Planning* **43(2–3)**: 172–194.

Transport Act 1968. *Chapter 73*. Her Majesty's Stationery Office, London, UK.

Tyrrall D (2004) The UK railway privatisation: failing to succeed. *Economic Affairs* **24(3)**: 32–38.

Wolmar C (2001) *Broken Rails: How Privatisation Wrecked Britain's Railways*. Aurum Press, London, UK.