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Rebuilding after the storm: the role of innovation in completing infrastructure system transformation

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Abstract

Infrastructure systems form an important skeleton to the functioning of society. They have often been developed and treated as systems for significant portions of their existence which leads to the extent and importance of interdependencies between elements being a key characteristic of these industries; to understand their developments a system view is taken. This paper considers the transformation of mature systems and the role of innovation in enacting it. The privatisations and restructurings of infrastructure industries in recent years are characterised as potential openings for system transformation. The case of the UK Railway industry is presented as illustration.

This paper finds the use of both the Multi-Level Perspective (MLP) and Large Technical Systems (LTS) frameworks provides a useful tool for examining these organisational restructurings and the possibility of system transformation in the aftermath. These potential transformations, that come without ready identified technological options for transformation but are rooted in changes to organisational structure, still appear to need changes in all three levels of analysis to succeed in transformation; the LTS framework is used to identify obstacles to the system achieving a transformation.

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Rebuilding after the storm: the role of innovation in completing infrastructure system transformation.

1 Introduction

To twist and torture the words of John Donne: “No product is an island”. All products, big or small, are linked to their designers, users and other aspects of the physical world; they are developed and operate within a broader set of connections. To study innovation, in many cases it is useful and sensible to bound the units of interest to a fairly small part of the physical world, the product, and certain organisational units. However, there are circumstances where it is the interconnections between what might elsewhere be identified as individual products, the individuals and organisations interacting with them and further connections between the two, that are significant in themselves. Existing research which considers the development of systems (e.g. Perrow, 1984; Hughes, 1987; Davies, 1996; Geels, 2002) highlights not particular technologies or organisational characteristics but the interdependencies between elements as a defining characteristic for the impact and development of these systems.

Infrastructure systems form an important skeleton to the functioning of society (Gil & Beckman, 2009; Helm, 2010); they deliver utilities and provide mobility. Although these industries contain many of the components studied elsewhere in the management literature, an overwhelming characteristic of their operation is their ‘systemness’. Whether we see them as inherently “best considered as systems” (Helm, 2010, p20) or simply acknowledge that they have been developed and treated as systems for significant portions of their existence, to understand their developments it is difficult to treat the organisations and subsystems of which they are comprised as autonomous units: a systems view is required.

This paper considers the transformation of mature systems and the role of innovation in enacting it. Existing research considering the management and development of these infrastructure industries has examined their emergence and growth (e.g. Hughes, 1983; 1987) and the substitution of a mature system with a new system was part of that theory development. This idea of substitution has also been examined elsewhere with, for example, the broader idea of technological transitions (e.g. Geels, 2002;). However the transformation of mature infrastructure systems is less studied (Geels, 2007). Much existing work on system change (transition and transformation) has focused on technological change; it addresses the ability of a system to move to/adapt around a new technology, for example introducing new technologies for sustainability[1] (e.g. Kemp et al., 1998; Frantzeskaki & Loobach, 2010).

In the latter part of the twentieth century many nationalised infrastructure industries underwent some form of deregulation and often integrated organisations were restructured to accommodate a new way of interacting with the existing physical system. In some systems this change in governance was linked to potential technological opportunities which were not being considered by the existing organisations; this was the case in some telecommunications privatisations (Rosenberg, 1994; Davies, 1996). However this has not always been the case and the privatisation studied in this paper came from a desire to change the way the management of the system operated without reference to missed technological opportunities.

I characterise these privatisations and restructurings as potential openings, or attempts to force, system transformation. In the systems literature connections between and co-evolution of organisational, physical and institutional elements are highlighted as important. Therefore, in the same way that the possibility of exploiting a very different technology requires the adjustment of institutions and organisations, we expect that a major change in organisation will require adjustments in the physical system and the way it is developed, in order for the system to continue to work effectively.

The case presented in this paper allows us to explore these ideas further. The UK railway industry was privatised in the mid-1990s; it was a late example within a series of privatisations of UK infrastructure industries. The Multi-level perspective (MLP) and Large Technical Systems (LTS) frameworks are used in the analysis; the organisational form of the industry has gone through several phases in between 1988 and 2000; each phase is initiated with a some level of redesign of the organisational structure and within each phase organisations and/or development of the physical system also adapt and change.

This papers finds the use of both the MLP and LTS frameworks provides a useful tool for examining these organisational restructurings as potential impetus for system transformations.

[1] This is a case of systems needing to respond to broader societal needs/changes but the mechanism for change is through a technological shift bringing with it a need for organisational and institutional change.

The former considers the importance of and interconnections between changes in the system's environment, the socio-technical regime within the system and the technological opportunities being developed in niches which are or become linked to the system. The LTS theory provides a view of such changes from the perspective of the system; pressures from the environment and how emergence of opportunities from niches are felt and discovered by those working within an existing system. The privatisation of infrastructure industries involves a considerable shift in the workings of the system which is initiated from the system's environment. However, once the new organisational structure is in place the system needs to function, technological regimes need to adjust that allow innovations to be incorporated into the physical system adjusting it to the operational requirements from the organisational structure.

In the next section of the paper I introduce a systems view, focusing on the MLP and LTS frameworks, and discuss recent literature considering infrastructure industries following restructuring. Section 3 introduces the research setting and a case study of the industry's development is presented. Section 4 concludes.

2 Literature

An important characteristic of infrastructure industries is their interconnectedness and path dependency; physical structures span large distances and last many years thus connecting decisions made and physical elements developed over time and space. So to understand the behaviour of elements within these industries it is often necessary to take a systems view acknowledging the importance of connections at the level of the industry. There are several systems based theories used in the examination of the behaviour of these industries; in this section I introduce system approaches and then focus upon two important frameworks for the study of infrastructure industries and consider how these frameworks can aid our view of restructuring of these industries as a form of system transformation.

2.1 Systems

System: "a complex whole; a set of connected things or parts; an organised body of things." (OECD, 1996).

Herbert Simon (1962) loosely describes a complex system as "... one made up of a large number of parts that interact in a nonsimple way." (p468). Where it is the connections and interactions between a set of entities that interest us, a systems view is useful. In addition to the two theories considered in detail below, research focused on systems is present in several areas of the innovation literature. At a high level there is work that considers national or sectoral innovation systems (e.g. Malerba, 2002). At a more detailed level of analysis there is research which considers complex products (Hobday, 1998; Baldwin & Clark, 2000; Brusoni et al., 2001). These systems based theories, although focusing on different issues and units of analysis, have several things in common. They all link to the innovation literature and so consider how innovations are developed for and incorporated into systems. As indicated above, they all focus on the interactions between many components and expect that the system becomes more than the sum of its parts. As part of this they incorporate the ideas of interdependence and hierarchy.

Simon (1962) describes a hierarchic system as "a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem" (p468). In this context hierarchy does not incorporate an idea of authority between vertical layers, but refers only to a structural division/nesting (Simon, 1962; Sanchez & Mahoney, 1996). All complex physical objects are organised using hierarchy (Clark, 1985). However, hierarchies can take many different shapes, in terms of the number of vertical levels and divisions within each level (Simon, 1962).

The form of hierarchy seen is linked to the view point of the builder or operator of a system. This is also true of what we consider to be the system of analysis. A systems view is used to deal with a complex situation of interconnected entities and the types of connections selected are linked to what is considered important. So, for example, if we were concerned with the design of complex products a railway vehicle might be an appropriate physical system of interest and the connections to focus upon could be the information links between different parts of the vehicle and, within the organisation developing it, the design collaborations required to get these physical interactions working.

Of interest for this work are the infrastructure industries that form an important backbone to the functioning of our society. Utilities networks such as water and electricity provision and transport infrastructure are key examples. Many of these industries were conceived as and continue to be viewed and developed as systems; what provides much of the challenge in operating and altering them is not the sophistication of the technology base but the interconnectedness of components, be those physical elements or organisational structures. The system of interest is the network, its operation and the organisations engaging with it.

2.2 Infrastructure systems

As highlighted by Markard (2011), two important theories used and explored in the study of infrastructure systems are the Large Technical Systems (LTS) view (Hughes, 1983; 1987) and the Multi-Level Perspective (MLP) (Kemp et al., 2001; Geels, 2002; 2007). The MLP uses systems thinking to consider the connections between society level developments and the form of physical products being used (Geels, 2002; 2007); issues examined with this view include how to change the technologies used to create more sustainable infrastructure systems (e.g. Kemp et al., 1998). The LTS view also acknowledges the influence of a system's environment upon its development; however, its main focus is upon the mechanisms and development at work within the system which lead it to change over time.

2.2.1 The Multi Level Perspective (MLP)

The MLP has been used for research into technological transitions, the replacement of one system by another, (Geels, 2002). The MLP builds on the concept of technological regimes

(Nelson & Winter, 1982) which is extended beyond the cognitive focus on problem-solving to incorporate existing knowledge bases, physical system, engineering practices, operation, technologies and institutions (Kemp et al., 1998). This perspective considers three levels of activity: the socio-technical landscape, economic conditions and societal issues in its environment influence system development; a system's socio-technological regimes, within the system there are regimes that direct the selection and development of technologies and practices for the system and therefore its path of development, these are linked to the existing physical system and organisational practices; within the system there are also niches, sections of the system which are relatively peripheral or have special requirements, they offer points of potential experimentation and change, one example is R&D projects (Kemp et al., 1998; Geels, 2002; Verbong & Geels, 2007). It is argued that transitions occur when changes are present in each of the three levels and they link together to reinforce each other (Verbong & Geels, 2007); so technologies can be well developed within a niche and show potential benefits but for a shift in system to occur there needs to be a shift in the socio-technical regime which, in turn, needs to be in step with the broader socio-technical environment.

Geels (2007) applies the MLP to transformations in infrastructure systems. He distinguishes between transitions and transformations by describing the former as about radical changes, the movement from one trajectory of development to another, and using the latter to refer to more incremental, though still significant, changes that involve the redirection of an existing trajectory (Geels, 2007). For mature infrastructure systems, with high sunk costs, considerable vested interests and firmly established practices and culture, the adaptation of existing development trajectories seems a more practical route to change; and in the case presented below the physical system is mostly unchanged by the privatisation process, therefore the system remains rooted in its past and its development will need to adjust its direction of development rather than start with a clean sheet.

In his application of the MLP to examine transformations as well as transitions, Geels (2007) highlights the need for more actor focused mechanisms within the MLP; it focuses on the creation of opportunities and shifts within the three levels of analysis, however there needs to be action taken to exploit these shifts and to make change happen. Actors within the system will not always react to such pressures and change is expected to be "contested and involving power struggles" (Geels, 2007, p133). The focus here is on the higher two levels of the MLP, however Geels (2007) highlights that if outsider firms are instrumental in the development of technologies adopted (and presumably their adoption – thus potentially altering regimes by influence actions) then the niche level of the MLP is also part of the process.

Geels's (2007) application of the MLP to the transformation of infrastructure industries provides us with three key insights. Firstly, we can see more clearly the differences between transformation and transition and the importance of transformation for infrastructure systems. Secondly, it presents some of the shortcomings of the MLP for the study of the actions and developments within the system which are significant in the transformation of a system: more so than for a transition to a new trajectory. Thirdly, in so doing, it highlights complementarities between the MLP and the LTS view.

The privatisation and restructuring of infrastructure industries provide a different means of initiating system change. For the study of these restructurings the MLP provides a useful lens. The MLP allows us to recast the privatisations and restructuring of infrastructure industries as an attempt to address a perception that these systems were out of step with society or that their performance was not in keeping with expectations. This leads to the impetus for change being injected via restructuring; however, we are left with the question of whether and to what extent a transformation will take place. The MLP does not provide a view of the mechanisms at work within the system; the questions of how an infrastructure system reacts and why can be better understood by examining the elements and actors within the system. To provide this internal view of system development I introduce the LTS framework.

2.2.2 Large Technical Systems (LTS) view

Hughes (1983; 1987) developed the theory that has become known as the Large Technical Systems (LTS) view. His work considers how infrastructure systems came into existence and how they develop over time. The individual that provides the core inspiration for this work is Edison; Hughes (1983) bases much of his work on a detailed study of the emergence and growth of electricity networks, however, he is able to generalise by considering work of other inventor-entrepreneurs (e.g. Elmer Sperry) and by following the transfer of the idea of the system to other geographical settings. Hughes (1983; 1987) creates a framework for the way in which systems expand, develop and mature, including an idea of the progression of expanding systems through various life stages.

The core view of a system used by Hughes (1983; 1987) has many similarities to that of another systems scholar, Perrow (1984). So I also incorporate Perrow's (1984) perspective in places throughout this discusion. Although Perrow's view of systems is similar to Hughes's, his interest in infrastructure systems was quite different: his focus was not on their development over time but on their operation and in particular their failure.

Both Hughes (1987) and Perrow (1984) view physical (and other) artefacts, the organisations that interact with them and the people that interact with these components, all as part of the same system; a system which is "both socially constructed and society shaping" (Hughes, 1987, p51). A key contribution of Hughes's historical examination of large technical systems is the joint consideration of organisational and institutional elements with "materially embedded technology" (Joerges, 1988, p16).

In concert with the broader discussion of systems thinking above, both authors identify interdependencies as a key characteristic of infrastructure systems; alteration or removal of one component requires appropriate adjustments in other components (Hughes, 1987). Perrow (1984) considers interdependencies as relatively complex or simple in terms of how easy it is to predict the connections between components[2] and adds the concept, important for system operation, of tight/loose coupling which is about the slack present in the operation of a system.

Hughes (1987) considers that system components are present and interact towards the achievement of the "common system goal" (Hughes, 1987, p51). However Hughes also considers the existence of a hierarchy of components within systems (in the same sense as Simon (1962), discussed above) and he expects a system will have different boundaries for different purposes/viewpoints.

Regarding system boundaries, both authors refer to a system and its environment. Hughes (1987) differentiates between a system and its environment in terms of the interconnections of components. If two elements influence one another, for example a change in either requires

[2] This is similar to the consideration of unknown interdependencies/uncertainty in work on complex products (e.g. Brusoni et al., 2001; Hobday, 1998).

adjustment of the other, they are both considered part of the system. However, if the effect is only one way then that connection forms part of the boundary between system and environment; the system can influence the environment (e.g. resource usage) or the environment can influence the system (e.g. high labour costs). Hughes (1983) expects boundaries to move. For example, in growth periods he describes the system as bringing more and more of the environment within its boundaries (Hughes, 1983); a coal production facility may be brought under the control of an electricity generation system so that requirements of the system can influence production and capacity of the plant as well as being affected by the plant's output.

In considering the establishment and development of infrastructure systems, Hughes (1983; 1987) saw the development of expanding systems as progressing through various life stages: invention, development, innovation, transfer, and growth, competition, and consolidation. Each of these refer to the major/dominating type of activity within than phase of development (invention, for example, does not stop once the system has moved from that phase). This sequence is not envisaged as a rigid linear progression but rather refers to the most prevalent characteristic at a given time and thus as emphasis shifts a system may move around within this categorisation.

To conceptualise how a system develops and expands, Hughes (1983; 1987; 1992) employs the concepts of reverse salients and critical problems; these are similar to the ideas of bottleneck and focussing device, respectively, introduced by Rosenberg (1969), also when discussing the development of systems. Reverse salient refers to an obvious element of a component's performance (relative to the system goal) which is holding up system development towards better performance. A critical problem or problems are defined, by those seeking system development, in response to the reverse salient which will be eliminated with the solution of the problem(s) (Hughes, 1983). Reverse salient refers to a point in a front (military or weather, for example) which is held back (Hughes, 1987); this image of an advancing line of a system, where points in the line can get ahead of others but all points are connected, is a useful representation of system development which highlights the relevance of interdependencies (known and unknown) within systems.

Important for our case of a mature system, momentum (Hughes, 1983; 1987) is also a concept linked to advancing trajectories of system development. The issue of inertia encapsulated within this idea is about the entrenchment and inflexibility that comes into the trajectories of development with increased maturity of the system. "Concepts related to momentum include vested interests, fixed assets, and sunk costs" (Hughes, 1987, p77); important elements include institutional adaptation, for example within the training of specialist engineers, and the existing physical system. Hughes (1983) discusses the impact of World War 1 on electricity systems, he finds this is a development which contained 'forces strong enough to disrupt the momentum of systems' (Hughes, 1983, p285) but he also notes the physical system in place at the end of the war brought aspects of the war time environment into the peace time system.

Hughes's view of the way systems' elements interact and co-evolve over time offers a useful perspective for examining how a restructured infrastructure industry gets itself functioning after major change, and how organisational and physical elements come to be adjusted to allow smooth operation within a new structure and possibly towards altered system goals. It is an understanding of these processes which will allow us to consider whether a fuller transformation emerges. The LTS framework indicates that for a system to be developing and to continue to adjust to its environment it needs to be producing and incorporating innovations[3] to address bottlenecks. Momentum can direct developments into a particular path and can reduce the ability of a system to adapt to less expected/longer term changes. The privatisations of these systems might provide an opportunity to reduce the momentum and produce new options for system development: an altered trajectory.

2.2.3 Studies of privatised infrastructure industries

Hughes's LTS view has been applied to later studies of infrastructure systems and, in a few cases, in studies of recently deregulated/restructured. Davies (1996) uses the LTS framework to consider developments in the telecommunications industry. Using systems thinking he adds the concept of economies of system to those of economies of scale and economies of scope; economies of system come from improvements in a system's economic performance through the alterations of the configuration of the system, changes in the connections in play.

Geyer and Davies (2000) study developments following the restructuring of two railway sectors, the UK and Germany. They examine the role of projects as an engine for innovation and find that the interfaces between projects and the operational system have changed with the restructuring

[3] In physical system and/or processes/structures

and continue to develop. They argue the interface between supplying project and operational system is an important element in understanding innovations in the system.

Markard and Truffer (2006) characterise the electricity industry as a LTS and consider how its liberalisation has altered innovation processes in electricity supply. This study finds that following liberalisation, although there has not been a direct shift in technology interest there seems to be the potential for the loosening of the technological regime in play; this might offer a window of opportunity for the establishment of new regimes. Markard & Truffer (2006) point out that this should not be interpreted as market liberalisation being an external factor causing a particular shift or technology preference but as a driver which altered the search and innovation processes meaning that there is a possibility of loosening of existing technological regimes; they expect processes of system re-stabilisation to follow the restructuring.

Although not using this theoretical framework, a similar empirical story is told of the post-liberalisation electricity industry by Künneke (2008; Künneke et al., 2010). Following its restructuring the industry went through a period of settling down. Künneke (2008) presents a view of an industry where organisational set up no longer matches the interactions which were used to run an existing physical system; he expects that organisational form or the structure of the physical system will need to be altered to allow the system to function effectively and finds evidence of opportunities being developed for both adjustments and it is yet to be seen what future structure will be established in the industry. Künneke et al., (2010) highlight instances of failures in infrastructure systems following organisational restructuring; they use transaction and system ideas to identify a need to align organisational processes and the way the physical system functions and critical points where misalignment threatens system coherence. Both of these papers touch upon the need to have innovation processes functioning following restructuring so that the physical (and we might add the organisational) components of the system can be adjusted and the system can re-stabilise/re-establish itself; we might also say reconfigure itself around new structures/ways of operating.

Jamasb and Pollitt (2011) find that the liberalisation of the electricity sector in the UK accelerated the decline in R&D going on in the sector. Although there were increases in the commercialisation of innovations in this period they predict problems for the generation of innovation for the industry in the longer term; they argue that a new innovation system is needed for the sector which will fit with the new organisational structure because the centralised innovation set up of the past is no longer appropriate for this system.

These studies provide a view of infrastructure industries following organisational restructuring. There is a need for re-stabilisation in the wake of these events, as the system reconnects and establishes new ways of operating. If there need to be changes in processes and/or the physical system (and there is no overarching system architect in control as there was in their creation by inventor entrepreneurs) then there need to be processes in place for innovations to emerge to alter any newly established reverse salients and to allow systems to develop. New reverse salients will be introduced within the restructuring process; this can be from a change in system goals or from the change in organisational structure which needs to interact effectively with the unchanged physical system.

In this study of the UK railway industry a similar situation is encountered. The organisational components of the system have been restructured and there needs to be a period of connections reforming in the system so that organisational processes and the operational needs of the system adjust to realign/reconfigure the system, potentially offering economies of system (Davies, 1996). For those connections to reform/adjust there needs to be processes in place to identify reverse salients in the system (which will reflect system goals) and to provide innovations to allow the systems adaptation. This means, using language from the MLP, the technological regime from the old system will need to change once it has been loosened by the restructuring; it needs to reflect selection requirements to produce a realigned system. Following that we would expect it to stabilise into a new regime and an altered infrastructure system. Having considered Hughes's LTS perspective on these systems I would not expect this to provide only two paths, as anticipated by Künneke (2008)[4], but that changes in components of different types, across the system would be possible.

A case study of the privatisation and restructuring UK railway industry as an example of impetus for system transformation is presented in the next section. The MLP perspective allows the division of the case into a series of phases linked to the involvement of the environment in

[4] Künneke (2008) expects that one set of components will change to meet the other (organisational components versus physical) and that one of two system structures will emerge.

system structure and the LTS framework is used to examine system developments within each phase.

3 The UK Railway industry 1988-2000

The UK Railway industry was privatised and restructured in the mid-1990s, although the initial idea emerged a decade earlier. In this process the organisational components of the system were altered but the physical system remained unchanged; as Künneke et al. (2010) observe across liberalisations, this change was focused on developing functioning markets and there does not appear to be concern that the physical system will not smoothly adapt accordingly.

Using the MLP discussed above, we can link the restructuring of the organisational components of this system to the system's environment having changed over the years since British Rail was created and so the nationalised monopoly mode of operation no longer fitted with society's needs or practice. As a result the system was modified. After restructuring there needs to be a period of re-establishment for the system as processes for the operation and development of the unchanged physical system by the new organisational components are put into practice and adjusted to improve connections between elements. Hughes's LTS framework aids the study of these adjustments within the system; using the LTS view, I look for the establishment of innovation routes and adaptations to a technological regime being made (reverse salients leading to organisational and tech innovations).

However, in this system there are several adjustments of the structure which come, at least partly, from outside the system. So I characterise the system as having gone through several phases; each phase is initiated with some restructuring with input from the system environment and within each phase the system operates and develops under its own steam. These phases and the transitions between them are described below and summarised in Table 1. For purposes of brevity, I will discuss only the passenger railway industry in detail.

3.1 Method

This section presents an industry case based principally on archival and secondary sources reporting changes in the industry; data also include interviews conducted between 2008 and 2010. The industry's development is separated into phases according to points where there have been changes in organisational components generated with some involvement from outside the system. These are identified principally using historical accounts of the industry (Gourvish, 2002; 2008); these histories focus on the political and organisational events leading to change in the industry.

3.2 Background

British Rail (BR) was the vertically integrated nationalised owner, developer and operator of the UK railway network before privatisation. BR was formed in 1962 (p2, Gourvish 2002) and had presided over considerable technological development of the railway network as well as its rationalisation (the Beeching cuts were proposed in 1963 (Allen, 1982)). In 1979 a new government was elected; it wished to reduce the size of the public sector and an increase the role for private business across nationalised infrastructure systems. Between 1993 and 1997 (Gourvish, 2008) BR was restructured and privatised to form a competitive market for the provision of railway services and the development of the railway system. The Government's motivation for the introduction of competition has been linked to anticipated European legislation (Nash, 2008), reducing state subsidy of the industry (Harris & Godward, 1997, p63-64) and a political commitment to the power of the markets and transactions (Glaister 2004; Tyrrall, 2004).

3.3 System Phases

Phase 1 begins with the paring down of BR by separating off subsidiary businesses, in particular the vehicle manufacturing organisation. This moved the system boundary and created a clearer division with a vehicle supply industry. This initiated a period where the core system is run and reorganised by the BR Board; Organising for Quality which followed was a centralised restructuring.

Phase 2 is a period of transition where the core industry is privatised. Structural decisions are made principally outside the industry but the BR Board are involved in executing changes and the BR organisation provides an incubator for new organisational structures to get going before privatisation and at this stage tensions and issues can be resolved with the guiding hand of centralised decision makers. While the focus is on restructuring issues arise around the continued development of the system. Orders for new vehicles dry up which has an effect on the vehicle manufacturing capabilities held in the UK, many redundancies and some closures follow. It is also likely that infrastructure investment suffers similarly although this is not as transparent at this stage, later reports have suggested a lack of investment in this period. This phase ends as the core organisations are launched into private ownership in 1996 and 1997. As this happens in stages there is an overlap between phases 2 and 3.

Phase 3 presents an operating, newly-privatised industry; the core organisations have been launched into the private sector and are beginning to find their modes of operating. This is a period of great activity and industry publications show many ideas for new products being offered to the system from all quarters of the supply industry, this includes entry into the market by overseas firms. New rolling stock is ordered and vehicle manufacturers combine their maintenance capabilities built up over the last few years with vehicle building to offer new types of contracts. The relationships between Railtrack and Infrastructure service companies are difficult to get right and several contracting arrangements are put forward by Railtrack. Access arrangements between TOCs and Railtrack is also an area of conflict which develops overtime – the Rail Regluator intervenes in 1995 and there are signs this area is still problematic when Railtrack gets into trouble in 2000 as TOCs complaints surface amongst other critics (Gourvish, 2008). One thread of problems within both of these relationships is the safety management process run by Railtrack, this issue is difficult to co-ordinate and Railtrack do not have sufficient information available about the state of the network to run the new type of process required in the post-privatisation system.

As early as 1998, following the election of a new government in 1997, plans emerge to make some structural changes to the industry. These propose a change to the regulation setting with the introduction of the Strategic Rail Authority (SRA) which is to allow co-ordinated thinking for the railway system and to provide strategic development decisions. In order to do this a reorganisation of the regulation arrangements is required. However as these plans are being formed a series of railway accidents, all resulting in passenger fatalities occur: Southall, September 1997; Ladbroke Grove, October 1999; Hatfield, October, 2000. In the end the SRA was launched fully in 2001 and the failure of Railtrack would follow shortly afterwards. These elements represent another period of transition for the industry and a very different industry emerged. Although a shadow organisation was in place from 1999, provision for the SRA was made in the Transport Act 2000, shortly after the Hatfield accident which also drove major changes, for this reason I end Phase 3 in 2000.

The three phases are outlined in table 1 and are described in more detail below.

Table 1 System phases

Phase	Dates	Initiation	System developments	Supply industry
1: The core system	1989 – 1993	Sale of BR's subsidiary businesses; in particular the vehicle manufacture and overhaul organisations	BR Board's restructuring of the organisation into a functional structure (OfQ).	Vehicle manufacturing sector gained BREL which now interacts with BR in the same arena as other organisations.
2: Privatisation of the core	1993 – 1997	Decisions on privatisation and the new structure were taken by government with support from BR and outside sources. Resulted in the Railways Act 1993.	Process of constructing the new industry structure: Railtrack, TOCs, two regulation organisations with close input from ROSCOs and infrastructure service companies. Contracts between these organisations and Railtrack, and the TOCs as well as the franchising agreements were difficult areas to resolve.	Joined by former BR organisations. Organisations built up new capabilities ready for new opportunities in the privatised industry.
3: New privatised industry	1996 - 2000	Launch of the principal organisations into private sector completed in 1997.	New attempts at some inter-organisational relationships emerged. Implementation of innovations was difficult.	Innovations started to emerge for the system; some came with new business models.

3.4 Industry Development

3.4.1 Phase 1 – The core system (1989-1993)

The first move towards increased private sector involvement was the decision to sell BR's subsidiary businesses; amongst these, the most important for the railway system and its future development was the sale of the mechanical engineering works, British Rail Engineering Limited (BREL). BREL was restructured and its sale, completed in 1989, meant construction and heavy maintenance capabilities left BR; other maintenance was retained in subsidiary British Rail Maintenance Limited (BRML). The core component of BREL was sold to a management and employee buyout (MEBO) with considerable support from Trafalgar House and Asea Brown Boveri (ABB). In March 1992 ABB bought out Trafalgar House to own a majority share of the business.

Following the sale of the subsidiary businesses BR continued to operate as an integrated company. It now purchased new vehicles and heavy maintenance from the private sector, one player in that sector was now BREL. Gourvish notes that in the two years prior to its privatisation BREL's work for BR which was single sourced provided an operating surplus where as competitive contracts gave a deficit (Gourvish, 2002, p209). After its privatisation, BREL had problems with delivery to schedule and product quality to British Rail (particularly with an order of Class 158s) (Gourvish, 2002, p246). Interviewees discussing this period in restrospect also describe it as a period of learning for BREL which needed to develop the skills to do some design work in-house, rather than manufacturing to detailed specifications provided by BR engineers; it will also have been a period of increased opportunity for other organisations within the vehicle supply industry.

In 1988, the BR board, considering organisational options for BR, decided to move towards a structure based on sectors of the business; the intention was to create a more transparent financial set up which would allow these business units to be run autonomously and each buying services from private firms in a competitive environment. The board began the reorganisation of British Rail which became known as Organising for Quality (OfQ) and that would pave the way for the division of BR at privatisation. The name 'Organising for Quality' had emerged by June 1990, in response to the board's focus on safety and quality in this period (following the accident at Clapham Junction (12^{th} December 1988)).

The OfQ initiative, completed in 1990, saw the division of British Rail into a five businesses which each had a group of profit centres within it. Business units would own all the assets and manage the production process. The holding company, and with it the BR Board, could then focus on higher level issues: strategy, investments, safety etc. Although a central engineering group remained at headquarters, the rest of the engineering functions within BR were decentralised into the five businesses as part of the restructuring. Responsibility for safety standards at Headquarters passed to the Group standards; this was a new body of two parts: Group Technical Standards and a Group Operational Standards.

As demonstrated by the OfQ initiative, control of the operation of the system and its structure was held centrally by the BR Board in this period. The reorganisation, OfQ, was conceived and directed by the BR Board.

3.4.2 Phase 2 – Privatisation (1993-1997)

The issue of privatisation of the core industry re-surfaced in the early 1990s. The decision to proceed and on the basis of a track owning organisation and separate operating companies, crystallised with the white paper "New Opportunities for the Railways" published in July 1992 and formalised in the Railways Act 1993. The Bill was principally an enabling measure and did not deal with the new institutions in detail. The new structure for the industry was developed by the Department of Transport (DTp) with input from BR Board, consultants and outside experts. The structure selected was for an independent track authority, Railtrack, and separate operating companies to be created; while the Freight and Parcels businesses were to be sold, a franchise model was to be used for passenger operations.

Plans included two regulatory bodies, one to oversee the franchising process (the Office for Passenger Rail Franchising (OPRAF), lead by the Franchising Director), and the other a regulator (the Office for Rail Regulation (ORR), lead by the Rail Regulator) to protect consumer interests and to check issues around access to the infrastructure. Shadow regulators were appointed just before the launch of the 1993 Railways Act, however, the regulation set up was not pre-determined and was to develop as privatisation and the new structure developed. Both regulators were to be subject to guidance from DTp..

Railtrack was set up to own and manage the railway infrastructure. It was first created in shadow form as a division of BR in March 1993 and established as a government owned company on 1 April 1994. It was sold into the private sector via floatation on the stock market in May 1996. The internal structure of this organisation was different from the structure used by BR following OfQ. In the setting up of Railtrack, it was intended that it would own the track and signalling but not the engineering activities. Railtrack would buy in all of its engineering requirements, not just renewal and new construction work but also detailed inspection and monitoring functions, and so it was to be " an access, capacity management and sales organisation" (Gourvish, 2002, p402).

The organisational units that were going to provide Railtrack with the maintenance and renewal of the infrastructure were created from existing post-OfQ profit centres; these became 7 Infrastructure Maintenance Units (IMUs) and 7 Track Renewal Centres (TRCs) which were sold to Management Buy Outs and engineering consultancy and contracting firms (e.g. WS Atkins and Balfour Beatty). A critical issue in launching the infrastructure maintenance structure was to be the form of the contracts between these units and Railtrack; over 100 contracts were drawn up (before the sale of the 14 units) providing for maintenance and renewal within Railtrack's zones for periods of up to 7 years. "Difficult negotiations on pricing, benchmarking, performance and other elements continued throughout 1994 and into 1995." (Gourvish, 2002, p404). This process was a balancing act between the need to have contracts which made the purchase of the 14 units attractive to the private sector whilst providing value for money for Railtrack.

BR's post-OfQ 19 profit centres were developed into 25 franchises; they were established into Train Operating Units (TOUs) within BR in April 1994 and became Train Operating Companies (TOCs). They were sold to MBOs and existing private sector organisations (many of them bus operating companies) in 1996-7. Franchise agreements would be decided and overseen by the Franchising Director who in the first instance would negotiate access and charges with Railtrack and prospective operators would then bid for them. An access charging regime for franchisee's use of the railway infrastructure was set up by ministers and officials in the DTp. It should be noted that, compared with the regime for charging for infrastructure in place under OfQ, these access charges produced very different results; overall infrastructure charges were higher because Railtrack used a higher capital charge and now all users (not just principal users) now had to pay towards fixed costs (Gourvish, 2002). In 1994/95 these charges formed a big proportion of BR's costs and there were demands from both BR Board and the Rail Regulator for review soon after.

To provide vehicles to the TOCs, BR's fleet of vehicles was divided between three Rolling Stock Companies (ROSCOs), initially set up inside BR. The fleet was transferred in April 1994 and a master lease signed on 15 July. These companies were to own the vehicles and be responsible for the heavy maintenance for them, however the organisations were set up without in-house maintenance and they would need to purchase it.

The safety regime in the new industry structure was centred on safety cases; these are a statement of how safety would be handled by the organisation. All users of the network had to have their safety case validated by Railtrack (and Railtrack's was to be validated by the Health and Safety Executive (HSE)). The standards and safety directorate, set up as part of OfQ, moved to Railtrack to operate as a ring fenced activity.

A representation of the new industry structure is shown in figure 1.

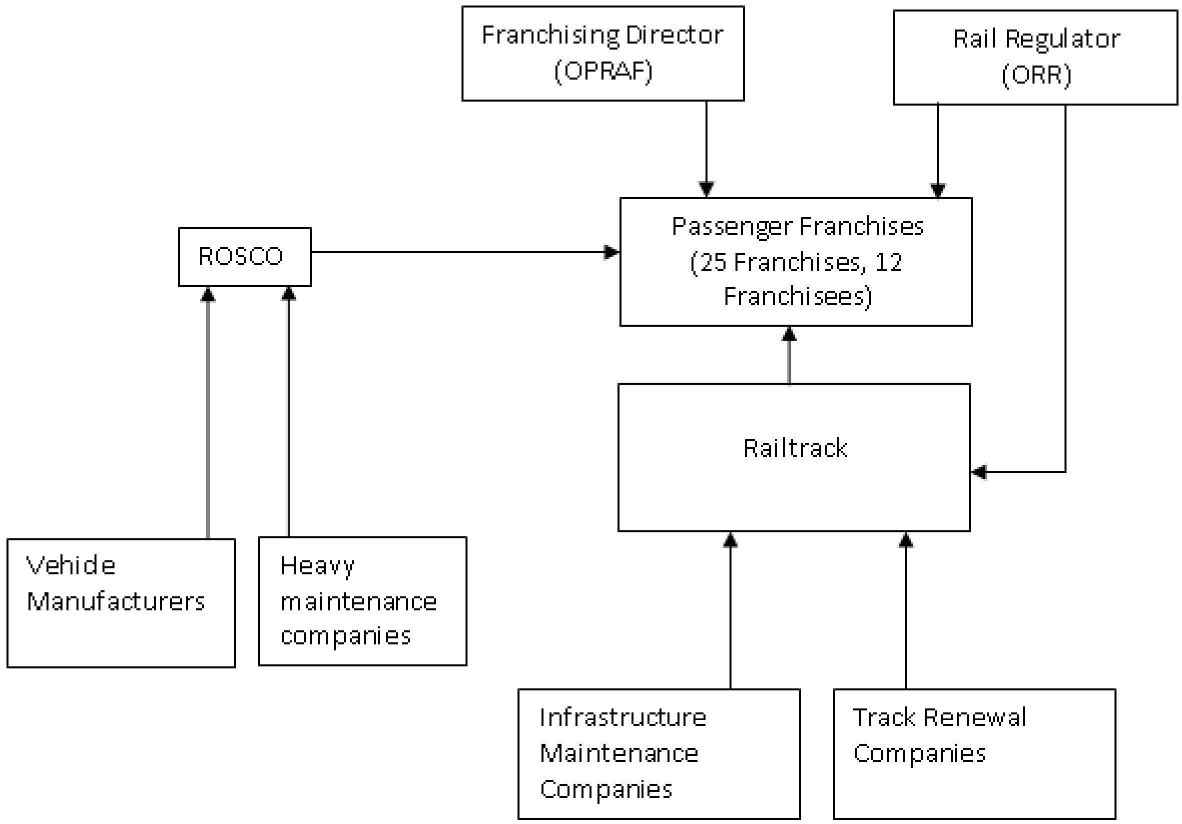

Figure 1 Industry structure in 1997 adapted from Gourvish (2008, p2)

Throughout this period of restructuring the core industry the supply industry was also developing. The orders for new rolling stock had ceased but manufacturers started building up maintenance and vehicle development capabilities ready for the new industry launch. Technical Service Companies (TESCOs) are set up, often with purchases of engineering elements of BR, and they and existing multi-industry consulting engineering companies also build up capabilities with a number of acquisitions, strategic restructuring and collaboration agreements being announced in these years.

Within the core system, after the new structure had been constructed but remained within the BR umbrella, there were already concerns over some of the relationships and financial mechanisms being proposed between organisations. TOCs were unhappy with proposed access charges and the draft franchise agreement. After a review the Regulator decided to constrain Railtrack's access charges in early 1995. Issues with the draft franchise agreement included the potential for requirements on new TOCs to continue to use vehicles bought by ROSCOs for the previous franchise.

Safety also proved to be an issue of interest even before the organisations were launched. Problems with a backlog of safety accreditations for new products and examples of organisations having to revisit aspects of their safety cases were emerging. There was also a case of Railtrack being ordered to improve the condition of the infrastructure by the HSE; this was linked to its ability to manage its contractors and improvements were sought in these processes by the HSE. However, problems with these links continued following the launch of the organisations into the private sector.

3.4.3 Phase 3 – New privatised industry.

Following the launch of TOCs, orders for new and modified vehicles re-appeared, several of these purchases and refurbishments were requested by OPRAF in the franchises. New ideas were presented by the vehicle manufacturers and their suppliers, for example platform vehicle designs from Adtranz (formerly ABB Transportation). These vehicles were no longer being manufactured then handed over, design, build and maintain contracts were now being used. New offerings to the network also came from the supply industry overseas which was putting forward ideas. Collaborations were emerging to provide capabilities on a particular project e.g. ROSCO and TESCO working on tilt technology. This was not just true for the rolling stock supply sector. TOCs began to experiment with new service offerings and some information system innovations. New signalling suppliers were appearing and Railtrack and its contractors began to purchase track maintenance and renewal machines.

Where TOCs used design, build and maintain contracts with vehicle manufacturers, it could reduce the number of organisations with contractual relationships with the TOC and saved them the commissioning process for new vehicles. It also provided learning opportunities for rolling stock manufacturers dealing with new requirements from this restructured system (interactions with customers and the criteria for success changed with privatisation) and new responsibilities for designing to open specifications.

In 1997 Railtrack unveiled a new process for train safety cases, although the technical requirements for obtaining the case remained unchanged. There was now a Rolling Stock Acceptance Board (RSAB) to oversee the process of obtaining safety cases from start to finish. However in 1999 it was reported that Railtrack, the Railway Inspectorate, vehicle manufacturers and TOCs were in negotiations to try to solve problems with structure gauge which could delay the introduction of new vehicles onto the network. In addition, later on that year there is a further change in structure for Railtrack as its Safety and Standards Directorate is moved from within Railtrack to become a more independent organisation. Interviews allow a retrospective view of these events to be taken by those involved. An engineer who had been a senior safety person within Railtrack discussed these developments. It becomes clear from his comments that, particularly with the structural gauge problems, there was an issue of how much information Railtrack held on its assets. In BR, the development of vehicles could be done with vehicles being developed for particular routes and knowledge of these routes could be relatively easily acquired as needed or past designs could be adapted. Raised in other interviews was the need for ROSCOs to use their fleet across the network over time and so vehicles now needed to go anywhere; however, the infrastructure (particularly its loading gauge) was far from uniform. We can characterise the problem of how to ensure vehicle (and other component) safety for operation on the network as a reverse salient which has been generated by the industry restructuring. In the past, vehicles could be assigned to particular routes for long periods, relevant information could be gathered from colleagues or past design and testing was relatively easy to arrange. Now these arrangements are not available more codified information on infrastructure constraints are needed.

Another, but more critical reverse salient, is the form of Railtrack's contracts with infrastructure service companies; Künneke et al. (2010) might refer to this as a critical transaction, and one which was not resolved. It had already proven a problem before launch. After floatation Railtrack begins to use extended arms-length contracts with some contractors. The work needed (e.g. fault in a bridge) is identified by Railtrack then the contractor inspects the site, engages consultants to recommend repair and then proposes action (to be approved by Railtrack); the contractor will then budget for and arrange all the repair work. This is described as one move by Railtrack in a trend towards giving more responsibility to outside contractors and can be seen as a way of simplifying monitoring of contractors. In 1998 this kind of approach is extended to all the infrastructure service units taking on area contracts with Railtrack. Under this new regime contractors will be expected to help Railtrack manage its relationships with other organisations and there is change to the renewal-maintenance distinction, Railtrack found the original "arbitrary, mechanistic and source of dispute" (Modern Railways, January 1998 "Railtrack's new maintenance plans" p14). The contract templates are adjusted further in 1999 into the IMC2000 contracts and the first of these contracts are let in early 2000. Unfortunately the reports following the serious accidents between 1997 and 2000 indicate that this relationship was not fully resolved. And, following the failure of Railtrack, its successor brings many of these infrastructure services back in-house.

3.5 Discussion

Having characterised the privatisations of infrastructure industries as impetus for system transformations, this case study of an infrastructure system undergoing such a restructuring demonstrates system mechanisms at work. We see the system in three phases of operation. In the third phase the newly restructured system is launched into the private sector and away from the central hand of co-ordination which had been present up until now.

In this third phase we see that innovations, often developed outside the core system, are becoming available and we see that selection criteria have change with TOCs and Railtrack keen to introduce new products and processes. However the implementation is more difficult. A major reverse salient identified is how to get innovations accepted for safe introduction into the system. A number of options are tried and although there is no evidence for safety being threatened by premature acceptance, there is a problem that it is preventing the system from adapting. Selection criteria are changing but translating these changes to the system is difficult. This could prevent the system adjusting its development trajectory; unless it can act upon changing preferences the impetus towards transformation will be lost.

A further, more critical reverse salient is also observed; the relationship between the infrastructure owner and infrastructure service companies not only has the potential to impair system development but the safe functioning of the system is also threatened. Several attempts are made to adjust this relationship however problems with effective monitoring on behalf of the infrastructure owner persist. These problems come to be linked to safety failures of the system and later the company itself also fails. This relationship can be categorised as a ‘critical transaction’, in Künneke et al.’s (2010) terms: essential to provide sufficient support to ‘critical technical functions’ which must be executed to reach the minimum technical performance needed from the system.

The former reverse salient identified is perhaps just as interesting. It does not prevent the minimum performance of the system, it is possible to use conservative measures for safety acceptance which will ensure safety, however it does prevent system development and the connection of niche developments and new selection needs generated from the restructuring driven from the system's environment.

Of course this case does not present the full story of this system; there will be many areas in which the system needs to adjust but we can see some of the points where transformation appears to have been blocked.

4 Conclusion

In this paper I have considered the restructuring and privatisation of infrastructure industries as impetus for system transformation. Existing research on system transformation does expect technological and organisational factors to be at work. However, it has tended to focus on changes in the system's development path being driven primarily by an alternative technological option. Some privatised industries provide examples where organisational restructuring was introduced with the intention of altering system behaviour but without technological options clearly available to form part of this change. The case study of the privatisation of the UK railway industry provides an extreme example in terms of the absence of identifiable technology alternatives for the system.

The MLP and LTS frameworks are used to consider these restructurings and a potential path to transformation. The MLP aids the consideration of the links between the system's environment, which is driving the change, niches for innovation development and changes in the technological regime being operated at the system level. The LTS view aids the closer inspection of the developments within the system: how restructuring is affecting system operation and the development choices taken by actors within the system.

In the examination of the case of the UK railway system, the MLP enables the identification of a series of phases of system operation and the LTS framework is used to consider developments of interest for system transformation within these phases. This approach aids the identification of key elements of the development of this system. Points are identified where reverse salients, generated by restructuring, are being tackled with new ideas but have not yet been resolved. One of these is linked to system failures and the other to problems implementing innovations into the system. They are not just causing system underperformance but preventing the alteration of its development trajectory.

The use of MLP and LTS together could be extended to allow comparison between different restructuring and privatisation examples which could lead to a more general understanding of the mechanisms at work within infrastructure systems with the potential of undergoing transformation. This, in turn, could provide insight for both policy makers and actors within these systems in attempting to effect infrastructure system transformations.

This case study may also have more to offer. Following the third and final phase examined here the industry underwent two further, though less extensive stages of restructuring driven by the system environment. An examination of these phases would provide several cases of restructuring within the same basic system and their comparison could offer insights into the different characteristics of restructuring as well as system response.

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