All Shook up: An Exploratory Study of Innovation Routes for UK Railway Rolling Stock[1]

Katherine Lovell Roderick A Smith
Future Railway Research Centre, Department of Mechanical Engineering,
Imperial College London, UK SW7 2AZ
(Email: k.lovell@imperial .ac.uk, roderick.smith@imperial.ac.uk)

Abstract It has been more than ten years since British Rail's operations were divided into a competitive industry. This paper investigates the initiation and form of technology development work for rolling stock and the roles taken by the organisations involved that have evolved since privatisation. Data on industry practice were gathered using interviews so that informal actions and undocumented evidence could be used; the resulting information on industry technology development processes and nominated cases lead to the identification of five patterns of technology development being used in the industry. Case data is used to provide technology readiness level and impact measures for the patterns. It is shown that technology adoption is the significant mechanism for technological innovation in this market and suggested that strategic development in the rail vehicle product is occurring at the European level. The patterns identified provide a qualitative differentiation between the many inter-firm interactions required for technology development in this industry and the basis both for further study linking technology development practice to industry structure and for policy development.
Key words technology diffusion, industry structure, privatisation, rail

1 Introduction

The vertically integrated, nationalised British Rail was divided into a privatised, competitive industry in just three years between 1994 and 1997 [1] and its technology development and innovation structure was divided, with the industry, to be controlled by many organisations. It has been suggested that technology introduction processes for the industry were not fully considered as part of the privatisation process[2]. Ten years on, this paper investigates what technology development routes have evolved for the divided-up rolling stock side of the industry[3].

The UK rail industry, a relatively recent privatisation with an unusual product for a privatised industry, has similar system constraints to other former nationalised industries, such as the electricity industry (for example see [2]). There is some anecdotal evidence that the privatised industry has created innovation systems and processes over time. This industry can offer a new example to research connecting industry structure and technology development processes in addition to insights it may offer to the literature on the management of technological innovation.

2 Industry Background

British Rail was the nationalised vertically integrated organisation of the UK railway industry. The vehicle manufacturing organisation, BREL was a subsidiary of BR until 1988 [3] and at least up to this time British Rail developed very detailed specifications and retained much of the design control over the vehicles produced[2]. British Rail also had a research division, BR Research; this group existed to carry out scientific research and experimental development and the proven concepts could be applied by the engineering divisions of the company [4]. When the industry was privatised to contain many companies these structures for technological development changed with the industry.

The ownership of the infrastructure was separated from service operation in order to enable competition between service operators across the same infrastructure [5]. Although changes in European legislation lead to many European companies separating control of these elements, only Britain divided and privatised its railway operations as well [1].

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1 This research is part of a Rail Research UK project , project B7: Technology change model
2 Interview with senior engineer in the industry
3 Although different in character and structure from British Rail implementation of technology change in the railway infrastructure is still overseen by one organisation, Network Rail.

In the privatised industry structure Network Rail (previously Railtrack) has responsibility for the maintenance and renewal of the railway infrastructure across the whole of the national network.

However, the provision of railway services is divided into sets of routes; the Train Operating Companies (TOCs) bid for franchises of 7-12 years to gain the right to operate a service for that period. As a result of the limited tenure of the operators, rail vehicles are owned by the Rolling Stock Leasing Companies (ROSCOs) and the TOCs lease the vehicles they require. The Department for Transport (DfT) awards the franchises to the operators, regulates the operations side of the industry and it has recently begun procurement for a fleet of trains to replace the High Speed Train (HST) or Intercity 125 (IC125)[4]. It is compulsory for TOCs to be a member of The Association of Train Operating Companies (ATOC) which represents the operators to the industry and beyond, it co-ordinates aspects of the passenger fare structure and offers collective engineering support. The Rail Safety and Standards Board (RSSB) was formed in 2003 and has responsibility for co-ordinating industry standards and safety achievement; it also co-ordinates and manages a range of research work for the industry, this element of its work is financed by DfT. Figure 1 shows a simplified indication of the high-level financial flows relevant to the Rolling Stock industry.

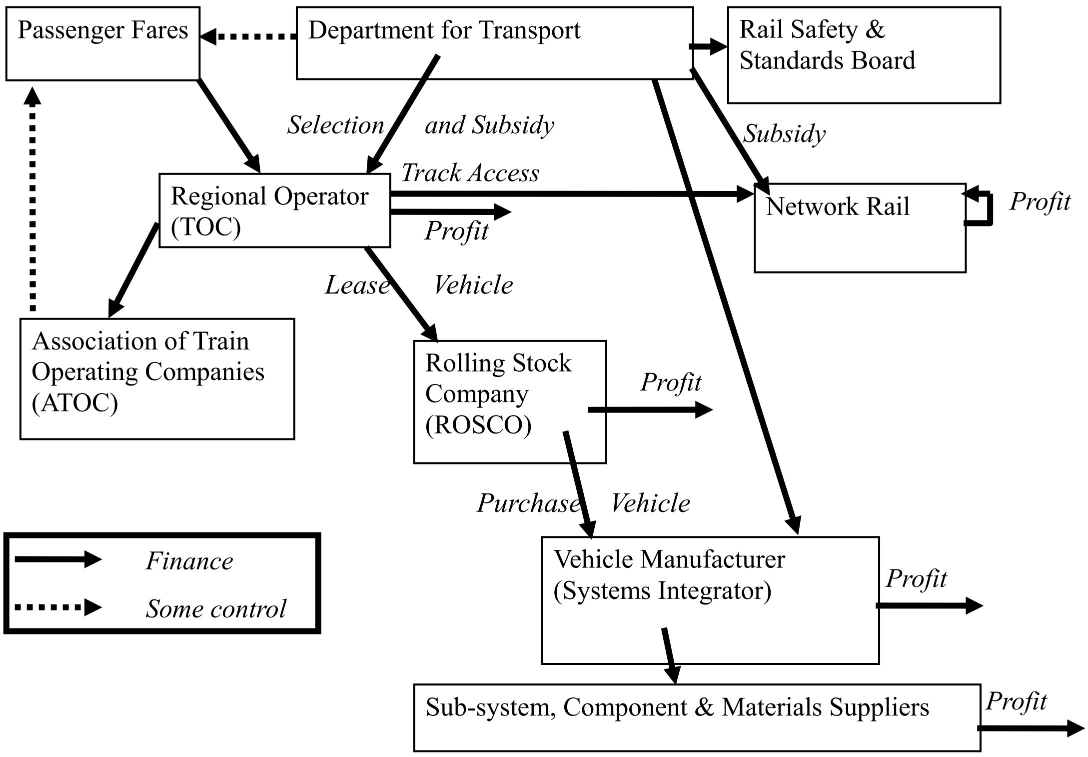

Figure 1 Schematic of the Principal Financial Flows Relevant to Rolling Stock

3 Data and Methodology

This work is partially based on a series of eighteen interviews, conducted in 2007 and 2008, with senior engineers from a range of organisations within the UK railway industry. Interviews were semi structured and focused on innovation processes in the organisation concerned and how they interacted with work in other types of organisation in the industry. Innovation in the industry as a whole was also covered. A prose document covering the issues discussed was produced for each discussion and was sent to the interviewee for comment. The work also draws on published industry sources, such as trade literature and government reports.

The use of interviews was selected to allow information on informal processes to emerge, and

[4] This is a recent change in approach and this paper considers the procurement processes used to date which are TOC and ROSCO initiated.

because not all aspects of industry practice are documented. It was felt that these elements were particularly relevant to technology change where, it could be argued, the industry is still evolving.

The data collected was in three forms: information on processes for the introduction or development of new technology, for example one role of an engineer might be to keep up to date with technology advances in an area of the product or industry; examples, or mini cases, of technology change or an aspect of the process nominated by the interviewee which in some cases have been investigated further using the trade press etc.; subjective information on possible problems or barriers in the industry and expected changes etc. The work presented in this paper draws principally on the first two forms of data.

4 Findings

4.1 The technology interest of organisations

Table 1 shows the principal organisations involved in technology development in the rail industry and, in particular, the initiation of work. The drivers/triggers for technology interest for each type of organisation are derived from consistent responses from interviewees and information on organisation activities. The technology activities section refers to work done to capture information on technologies and market needs by each organisation type; this information is from the innovation processes data. The technology activities field also includes tracking of legislation changes; this is not included in the table because it can be a market (new requirements to meet) or a technology (need to include technology x) initiator for technology work and because all the effected companies featured deal with keeping up with legislative changes in very similar ways[5].

There are cases where the different technology interests of TOC and ROSCO have lead to a technology change requested by one party being blocked by the priorities of the other. For example, if a ROSCO would like to introduce a change into a new vehicle which offers a payback period of longer than the TOC's use of the vehicle[6]. It is not clear whether these mismatches in incentive are a problem with the structure of the system or if they represent an appropriate check to make sure all points of view are considered.

The Technical Service Companies (TESCOs) and specialist technological organisations are engineering/technical consultants to many members of the industry, in all sections. The TESCOs build their technical expertise and personnel to be able to assemble teams to tackle many industry projects[7]. Many TESCOs do not often do R&D except on a consultancy basis. These work patterns are reflected in the weighting of their technology activities towards technology awareness, as shown in Table 1.

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[5] Although the industry suppliers and TOCs are also aided by their industry associations.

[6] A two year payback for a technology in a new vehicle is required for a TOC on a new 7 year franchise (according to a ROSCO engineer).

[7] Many of the TESCOs originated from the engineering departments of British Rail

Table 1 Technology Development Organisations, Incentives for and Activities to Initiate Technology Work

Organisation	Interest in technology/driver	Technology activities (inputs)	
		Technology awareness	Market/performance requirement
TOC	Increase demand and/or capacity	Rail industry technology information[8]	Local/market need (particularly for a new vehicle) and passenger contact
	Decrease costs (initial and running costs)	(plus ATOC best practice sharing)	Operational requirements (e.g. reliability/ maintainability)
ROSCO	Reduce Whole Life Cost (WLC) of vehicle	Rail industry technology information	Information from TOCs at initiation of contract and suggestions throughout
	Increase future revenue (leasability/value)		Review of vehicle performance to reveal opportunities/problems (this approach was raised by one ROSCO)
Manufacturer, subsystems and component suppliers	Meeting industry's specifications	Rail industry and other industries (often based on vehicle structure and surveying done by subsystem/competence specialists).	Vehicle market information: expected invitations to tender and market values (e.g. cost, capacity, mass and reliability for UK)
	Competing for contracts	Close relationships with suppliers. Certain types of supplier supply many industries.	Customer contact and specific requests (likely to be sub-system /component specific)
ATOC	Collective work for TOCs (including future TOCs)	Rail industry technology information	Investigate industry trends
			Relationships with TOCs (including Engineering Council)
RSSB	Collective work for UK rail industry		Suggestions from industry and input from cross-industry advisory bodies (SICs, R&DAG[9])
TESCOs and specialist technical organisations	Compete for engineering/research contracts	Rail industry technology awareness and some outside the industry (more difficult – likely to be for cross-over components)	Customer requirements for a project
			General information on industry direction/trends (and for specialist technical organisations information is gathered on the industry to identify applications for the specialisation).
RRUK[10]	Academic	Significant in specialist fields	Industry input but not direction
Universities	Academic	Significant in specialist fields	Industry input but not direction
			Customer requirements for direct research work (e.g. manufacturer)
DfT	Improved performance of industry	Rail industry technology information	Industry contact
	Reduced costs/subsidy of industry		Political input

Other organisations with a role in technology change are described in Table 2.

[8] This includes contact with suppliers
[9] R&D Advisory Group
[10] Rail Research UK is a consortium of universities collaborating to provide an engineering science base for the UK rail industry. It is funded by EPSRC.

Table 2 Organisations with an Indirect or Non-initiating Role in Technology Change

Advisory Group for Rail Research and Innovation (AGRRI)	Cross industry group advising on research direction and strategy for the industry
Railway Industry Association (RIA)	Represent and inform rail industry suppliers (including on legislation, significant developments, e.g. IEP, or trends)
Systems Interface Committees (SICs)	Cross industry groups focusing on system interfaces (e.g. vehicle-track) and they function. They are working with RSSB to identify R&D projects[11]
Network Rail	Sets the standards for and regulates track access for new technologies and vehicles
Notified Body (NoBo)/Vehicle Acceptance Body (VAB)/Conformance Certification Body (CCB)	Independent organisations provide accreditation for a new design of vehicle/component that it meets the safety standards required.

4.2 Patterns of technology development

Consideration of interview data on organisational processes, with support from case data, lead to the identification of five patterns of technology development being used in the industry. The development modes have been named selector, informed user, collective, key supplier and future system. These are shown in Table 3 and are characterised by the initiating organisations, enabling condition[12], description of the project initiation/form and technology cases which fit into each pattern. The table also contains information on the Technology Readiness Level (TRL) [6] at which such a project would be expected to start from; this is based on technology cases from the industry considered to have travelled this route. The final measure included is an estimate of typical technology impact from this route for change; this is comparative and is estimated by the author from qualitative case data.

The selector pattern requires a set of appropriate innovations to be available from the supply industry. Technology scanning takes the form of attention to the trade press, industry reports, trade fairs, contact with suppliers etc. This kind of technology change is a substitution; it is often a change in the model of component used. Initiation of the project at TRL 9 and a low impact on vehicle performance fit with these characteristics.

The informed user mode is a response to a market requirement or want[13] and it often involves the use of technology established in other industries. The examples encountered seem to transfer technologies employed in a similar context, perhaps in a related industry. In a project where they have identified the problem to be solved, an increased commitment, relative to the selector mode, is expected from the user; the TRL and the impact estimate appear to reflect this.

The collective approach is also an opportunity for TOC and ROSCO (and other organisations in this case) to affect industry development processes; ideas to benefit the industry can be put forward by organisations across the UK rail sector. These projects can be R&D or they can be to produce information, for example, on the impact of change (legislation, hidden benefits of improving certain performance parameters etc.) In certain circumstances similar projects have also emerged to put pressure on industry suppliers where the rail industry is a small part of their market.

The systems integrators tend to contain divisions to supply the complicated or strategically important subsystems/components of their product. The key supplier pattern features part of the systems integrator acting as an internal supplier, for components or competences supplied (an example of a

[11] http://www.rssb.co.uk/sysint/sysic.asp

[12] It is expected that both a technology idea and a market need would be required for a technology development project to succeed. Enabling condition refers to the apparent driving element towards technology development work being initiated; for example a technology is found to improve an important aspect of product performance; it is likely the company is already aware of the importance of an area of performance which the technology will help to improve but it is the technology idea which appears to provoke action.

[13] Note that a technology idea to pursue may be required in order to identify a supplier to work with but the market need appears the driver.

competence supplied featured is crashworthiness). This approach is similar to that of the informed user in that technologies tend to be transferred from other related industries at the component/subsystem level; this is reflected in the similar TRL and impact measures. However, key supplier is identified as a separate category because the initiation and incentives are different. As in the informed user mode, the TRL here reflects the empirical evidence of technology being transferred from similar/related industries; the design work featured in this category is also relevant as designs are frequently adapted from an earlier generation.

The future systems approach is rare amongst the cases studied. Strategic approaches to R&D definition were described in organisation process data; the small set of examples could be caused by the strategic (and therefore sensitive) nature of the information or that, as the industry develops, these advanced projects are yet to emerge in large quantities. One example encountered is the AGV (Automotrice Grande Vitesse), a vehicle combining many technology advancements in components and subsystems to create the next generation TGV; this, like the other case featured for this approach and unlike the other examples covered in this work, is not a case specifically for the UK industry. The other example in this category is a rail industry focused development from a UK University. This work was encountered by a senior engineer from a vehicle systems integrator; he pursued it because he saw potential to address a future (Europe wide) need. This individual was important in initiating and maintaining the collaboration and technology transfer, between university and company, which occurred. The presence of such a technology champion in the only UK originating case in this category indicates that this technology route may not be fully formed; it is possible that it will not materialise and that this case is an anomaly

It should be noted from these results that the relatively low TRLs, particularly in the patterns used for competitive technology development, indicate technology adoption and transfer, rather than its development, is the dominant mechanism for technology change in the rail vehicle market; this is also supported by comments of several interviewees. Russell [7] argues that technology adoption is a traditional trait of the UK rail industry[14]. There is some evidence that high levels of regulation and the extent of approvals required for new technology restricts technology change in the industry and the introduction of technology in stages of adoption, to reduce the technology development steps between implementation, might be a logical response; this should be considered in further work. High levels of technology adoption could also be linked to the small size of the industry[15].

An additional area of technology development serving this industry is the independent development work of component and subsystems suppliers to develop standard products for the industry which enables the selector process. It is not covered as a standalone mode of development because it seems to be relatively disconnected, in terms of direct UK rail industry input, from the selector process it serves and first impressions indicate a relatively conventional business to business supply chain. However, these technology stages have an important role in the technology adoption and transfer, which has been identified here as the significant mode of technology change, and it should continue to be considered in further work.

[14] Though he goes on to question whether this approach has continued in the same form into modern times.

[15] The industry background working paper by the competition commission for their investigation into the rolling stock leasing market [8] (http://www.competition-commission.org.uk/inquiries/ref2007/roscos/pdf/working_paper_industry_background.pdf) gives the total net book value of rolling stock (and in some cases railway assets) of the three main ROSCOs = £6252.8m assuming a life of 35 years this gives an estimated annual renewal market of £178.7m.

Table 3 Key Types of Technology Development Identified

Project type	Selector	Informed user	Collective	Key supplier	Future system
Initiating organisations	TOC & ROSCO	TOC/ROSCO/ Systems Integrator[16]	Industry	Systems integrator as an internal supplier	Systems integrator
Enabling condition	Technology found in railway market	Problem/ market driver the initiator wants to meet[17]	Suggestion from industry Strategic project from within organisation or its advisors	Technology found in another industry/ design idea	Strategic/ whole vehicle view to match future needs
Description	Product/ component change at refurbishment/ into new vehicle	Set up a project with a supplier (and maybe other organisations) Examples all transferred technology from another industry	Collective project at industry level or part of European project (ATOC/ RSSB/ project-specific group)	Internal development project	Perhaps working with suppliers on next generation product. Spotting technologies to incorporate
Examples	LED lights Electronic AWS receiver	Selective door opening TAPAS Bogie coatings	Biodiesel VTISM/WLCM	Aerospace materials Hybrid engine Bogie designs Crash simulation	AGV project Technology transfer from academia
TRL at which organisation becomes involved	9 (developed and approved)	7 (might be earlier on occasions)	4 at the earliest, and often implementation is not included (TRLs 4-6)[18]	6/7	4 (this route would be followed to implementation)
Impact on vehicle performance	Low	Med	Indirect impact so it is difficult to compare	Med	Med/High

4.3 Rail vehicle procurement

Procurement of rail vehicles is an important process for the introduction of technology developments onto the UK rail network and outcomes from projects in all of the development patterns above can be implemented this way. However, it is also an important process for technology development in its own right.

Examples of procurement encountered seem to be spread between the selector and informed user patterns described above. Advanced developments of new vehicles for the UK network, such as the High Speed 1 and the Virgin Pendolino, are more likely to follow the informed user pattern; less sophisticated vehicles, for example an EMU (electric multiple unit), seem to be closer to the selector pattern.

Since privatisation the lower specification vehicles have become more standardised, manufacturers have developed product platforms and design is increasingly modular; this is reflected in the match to the selector pattern for such projects. These differences indicate that, although all vehicle procurements

[16] The selector and informed user modes were observed in the activities of TOCs and ROSCOs but co-operative development with external suppliers was also a feature of the data on vehicle systems integrators and it is expected such work will follow this path.

[17] There was one case which fits this pattern except that a supplier approached the initiating organisation with a suggestion to meet a performance/market driver. This challenges the enabling condition characteristic or suggests more than one enabling condition should be considered should be considered for each pattern. This case may need further consideration in the future, however, at this stage in the research the authors consider the market driver the significant condition in this case despite the different order of events.

[18] These projects are often information based e.g. on impact of introducing a change rather than technology development, so this does not always apply.

can be orders of small batches of products specific to the purchaser's requirements, all are complicated integrated systems and are developed and manufactured by the same organisations, some UK rail vehicle development shows many characteristics of innovation in Complex Product Systems whilst other purchases do not. (This also supports Hobday's inclusion of only high speed trains in CoPS identified his 1998 paper [9]) What is not clear, is whether these increases in the use of product platforms will continue and will remove the complex product systems development approach from the industry or whether a hierarchy of products will be established which will allow technology changes to filter through it.

An examination of the changes in technology routes used for vehicle procurement over time will show the development of this divide in approach to innovation and offer further information on the links between industry structure and technological innovation. Study of the extent to which all the technology development routes have been used over time can trace the evolution of technology development since privatisation and add further to this research topic. The relatively recent developments which have seen the DfT take a greater role in vehicle procurement indicate that this aspect of the industry will continue to change.

5 Conclusions

The patterns of technology development in UK rail vehicles (Table 3) which have been identified by this study allow some qualitative differentiation to be made between the many interactions between firms involved in technology development for and in rail vehicles. These patterns can provide a benchmark to organisations studying their own innovation processes and projects.

Tables 1 and 3 also begin to connect rail industry organisations' incentives with the innovation activities executed and the type, and likely impact, of the project which may result. This work has not confirmed any direction of causation in these connections and further work will be required to improve understanding of these patterns and to establish causal links.

This work has highlighted the importance of technology adoption for this industry. Organisations' commercial technology interests and their market and technology awareness priorities are identified. There is also an indication that strategic developments in the rail vehicle product are being made at a European level, this is important for organisations in a market with a significantly different structure to other railways in Europe. These results can initiate and support policy development in the field.

This paper also suggests there is potential to use these patterns of innovation, or a similar structure, to categorise case studies of technological developments and so chart the use of the different technology development modes over time. This would allow the evolution of approaches to technology development in the industry since privatisation to be described and further research into the connections between industry structure and technology development. Many of the recently privatised industries studied in this context provide commodities; the rail vehicle industry can offer similar infrastructure constraints and a different type of product.

References

[1] Nash, C., Passenger railway reform in the last 20 years – European experience reconsidered[J]. Research in Transportation Economics, 2008, doi:10.1016/j.retrec.2008.05.020

[2] Künneke, R. W., Institutional reform and technological practice: the case of electricity[J]. Industrial and Corporate Change, 2008, 17(2):233-265

[3] Gourvish, T., British Rail 1974-97: from integration to privatisation[M]. Oxford University Press, 2002:243-246

[4] Potter, S., Roy, R., The development of high speed trains, Block 4 case studies[M]. Open University, 1996

[5] Bradshaw, W. P., Competition in the Rail Industry. Oxford Review of Economic Policy, 1997. 13(1): 93-103

[6] Mankins, J. C., Technology Readiness Levels, A White Paper, Advanced Concepts Office, Office of Space Access and Technology, NASA, 1995

[7] Russel, C. A., The developing relations between science, technology and the railways[J]. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, 1998, 212(3):201-208

[8] Competition Commission, Rolling stock leasing market investigation: industry background working paper. Competition Commission, London, 2007

[9] Hobday, M., Product complexity, innovation and industrial organisation[J]. Research Policy, 1998, 26(6):689-71