Department for Transport

Ref:RVFM10003

Rail Value for Money Study: Phase 2b
Package 9 – Achieving Value for Money from Improving the Management and Delivery of Innovation in the GB Rail Industry: FINAL REPORT

Date: 25th May 2011

Plan Design Enable

ATKINS

Guidance on using this report

Report Structure

This report is structured into 4 parts:

Part 1 – An Executive Summary – which outlines the findings of the Main Report at the highest level.

Part 2 – A Summary of Findings – a précis, intended for the majority of users who need to understand the research work that has been conducted, the findings, the critical parts of the rationale underpinning those findings and recommendations. This Part 2 is also intended for use as the principal source of material for preparation of wider reports by the RVfM team.

Part 3 – Main Report – this is the Report in full detail and is intended for those who wish to delve deeply into the research work, explore the concepts and approaches advocated and see the various facets of the subject. Innovation Practitioners and those who will take forward the Recommendations and Implementation Plan are likely to be the main users.

Appendices – Supporting material not included in Parts 1-3 but which may be referred to if required.

New Terms and Definitions

Throughout this document a significant number of terms and acronyms are introduced which, whilst new to the rail sector, are commonly used to explain and describe the processes of innovation that are applied in other sectors and which are beginning to be utilised in rail. Indeed these terms, once familiar, are useful to understand the concepts themselves.

We are conscious that readers may find it helpful to understand these terms – as they read the document rather than having to refer back to a glossary. Therefore, embedded within the text are call-out "pull-quotes" which guide the user; these follow the style illustrated here to your right.

> **Explanation of Term**
>
> This rounded box is known as a "pull quote".

Acronyms have been included in Appendix A.

Given the focus for the work – improving the management of innovation in GB rail – it is inevitable that new terminology will accompany the acquisition of new thinking, skills and approaches. However, we have tried to balance the needs for clarity and understanding with the need to reference terms and models which are commonly used in the innovation processes of other sectors.

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Part One

1 Executive Summary

We report our findings for the Rail Value for Money team on the evidence, barriers to improvement, and the analysis of the opportunities to achieve cost-efficient value for money from the improvement of the management and delivery of innovation in GB rail. A précis of our findings is in Part 2 and the full report in Part 3. We built on a number of previous innovation studies from GB rail, spoke extensively with key industry stakeholders and analysed the innovation performance and capabilities of GB rail compared with the past, two overseas railways and three other industries, all five of which provide learning, insight and best practice that has assisted us in developing our recommendations.

Our analysis revealed that the industry is underperforming at innovation and the most significant difficulties arise from poor behaviours, lack of a systemic perspective and difficulty in working across organisational boundaries, whether commercial, technical or managerial. As a result, business drivers are misaligned, conflicting and parochial and objectives are not aligned to deliver overall rail system benefit for the taxpayer. Whilst individual organisations within the industry have made, in some cases, significant investments in innovation capability, at best, they are able to succeed only within their own span of control and can only go beyond when the right systems leadership behaviours are present.

There is no shared framework or approach for understanding or positioning the value that different organisations are able to contribute. Other railways and industries have, in many cases, addressed precisely these challenges and have, as a result, advanced significantly beyond the innovation capabilities of GB rail. We have developed a user-friendly "innovation index" which shows precisely how these gaps in capability can be analysed. The index indicates that GB rail appears to have a poor innovation capability by comparison to the Aerospace Manufacturing, Energy Generation & Supply and Defence sectors, overseas rail systems in Japan and the US and indeed even compared to itself twenty years ago, although a moderate improvement has been made since ten years ago."

Innovation is challenging, complex and requires deep systems thinking capabilities. We have used tools and frameworks that take account of this complexity and, whilst we have made every possible attempt to present our analysis in clear, jargon-free language, the subject is one where new concepts and requisite terminology are indispensable – there is a significant learning curve to the development of innovation capability to high performance levels. We have developed a practical and straightforward plan by which enabling processes, structures and systems for innovation can be implemented within the industry. These take account of the requirements of stakeholders, the need to work with intermediate institutions and partners and the fair allocation of both value created and risk. We have also developed a potential model by which open collaboration between organisations can be achieved.

The most important conclusions we draw from this work are as follows: firstly, that although the "domestic" business case for introducing industry innovation enablers is clear and strong, it pales next to the annual €14bn prize of global markets for rail industry innovation. Secondly, that each organisation in the industry must make significant efforts in its own right to build internal innovation capability. Thirdly, it is clear from the success of other railways and sectors that a robust, collaborative approach to innovation and its governance must exist at industry level and that the formation of an Innovation and Growth Team to drive this approach is essential. This team must function successfully within the context of governance by the proposed GB rail System Authority. Fourthly, this approach must align with the national approach to "innovation for UK plc", embodied in the principles of the Hauser Review and supported at the highest levels of government. This means working effectively with intermediate institutions such as Technology Innovation Centres and the Technology Strategy Board, building open collaboration / intellectual property models with academic and industry partners and, most importantly of all, beginning the long and difficult process of culture change in the industry to embed the right behaviours, capabilities and systems thinking.

Part Two

2 Summary Report

Achieving Value for Money from Improving the Management and Delivery of Innovation in the GB Rail Industry

Overview

Key activities we undertook were:

- Reviewing and building on previous work including that of RIA, TSAG, Arthur D Little[1] and other industry parties, as well as highlighting alternatives or challenges to these for resolution, we engaged extensively with key GB rail stakeholders and those from other sectors.
- Identifying and developing a practical means of incentivising the industry to focus on carrying out research, encourage development and undertake affordable testing.
- Analysing and diagnosing GB rail's innovation 'health and maturity' using a variety of self-derived and open-sourced innovation and maturity framework models and established innovation principles from other sectors[2] to index performance against "what good looks like" to determine where GB rail's performance is failing and what actions need to be taken to promote success.
- Using frameworks and tools to enable analysis of all relevant aspects of innovation systems' structural integrity and process maturity. This analysis produced insights about the relationships of subsystems and system actors, revealed tensions, lacunae and both strength and weakness – these qualitative aspects that affect current GB rail innovation system integrity and process maturity.
- Assessing innovation approaches and performance in other sectors (e.g aerospace, energy and defence) and other countries' railways (e.g. Japan and US) and mapping these using our frameworks and tools.
- Researching how other sectors employ testing and evaluation to drive innovations into effective commercial application.
- Applying our knowledge and experience of the development and implementation of innovation systems to deliver a recommended best practice approach which will improve the speed and effectiveness and minimise the cost of the introduction of innovation into the GB rail industry, outlining potential monetary benefits.
- Deriving a proposed practical implementation plan (which assumes governance by a GB rail System Authority).

From this work we found that:

- Innovation does not appear to be valued or managed as part of the front-end improvement process for GB rail, though strong signs exist (the rollout of the new Network Rail innovation management process and the ongoing RIA innovation conferences) that a groundswell of support for change is building.
- Within the context of an 'innovation management system' there is no shared framework for understanding or positioning the role or value that different organisations bring to innovation.
- The business drivers in the GB rail industry continue to be defined in ways that are contradictory to collaborative innovation despite the shared technical priorities as expressed through TSAG /

[1] Including the work commissioned by the RVfM team earlier.
[2] Full details are given in the main report but the principle diagnostics are : The Innovation System Structure (ISS); Innovation Process Maturity Spiral (IPMS); Hauser Principles.

TSLG and the Rail Technical Strategy, for example infrastructure managers focused on infrastructure development, train operators being focused on delivering the franchise.

- In a multi-sector industry, where infrastructure provision, supply chain and train service delivery are not vertically integrated, the innovation investment costs and benefits fall unevenly such that creation of a business case to deliver significant "whole-system" innovations is problematic. Innovations that can be delivered within individual company resources and aligned with current industry business drivers are progressed, but the wider system benefits are not taken.
- Each stakeholder's innovation objectives are not aligned to deliver overall rail system benefit for the taxpayer. Consequently, current roles and responsibilities within the railway governance framework need to be adjusted and new / additional responsibilities need to be defined.
- Metrics (benefits) are not clearly defined as to the value of improvements relative to the whole railway system, although it is recognised that the improvements are valuable and need to be defined, but only in a tactical and technical context. The improvements are not valued in relation to the railway system or railway industry or in terms of the export benefits for "UK plc".
- Indexed against non- GB rail comparators, GB rail currently under-performs; significantly, it also underperforms compared to past performance. Other sectors manage innovation more effectively than GB rail, adopting a 'structured innovation management system', coordinated to channel new methods, ideas and products into commercial service, with cost-saving or revenue benefits.
- Unlike aerospace, defence and to a large extent the rail industries of, for example, Germany, France and Japan, there does not appear to be a systematic method of exploiting development work for the greater good of the GB rail sector, or the GB rail sector in a global context for the greater good of the UK economy. Effective application of the Hauser principles requires recognition that the GB rail industry operates in a global market. If GB rail is to manage innovation effectively at industry level, there must be clarity of focus as to which parts of the industry "value stack" should be developed into world-beating capabilities – as GB rail once had. All the stakeholders consulted view this proposed development as welcome, recognising that revenue from overseas growth can be used to subsidise the cost of GB rail.
- Instead of being lifted and dropped into use, there is significant customisation of commercially available innovations, adding questionable benefit for GB rail and driving costs into the sector.
- TSAG's work is consistent with good innovation practice, and should be built upon, but it cannot of itself deliver the step change required, particularly on whole-railway system innovations. Commercial and contractual drivers do not currently promote this focus.
- Innovation is stymied by adversarial, procurement-driven relationships and a lack of clear accountability. When impasses are reached, horse-trading rather than leadership is the rule. Stakeholders recognise that some innovation happens despite these factors and instances of success have relied in the past on strong personal relationships. Time and again, misalignment of commercial drivers is cited as a reason that whole-system value is not sought.
- Only by taking a system-wide view of the business case can significant innovations be driven forward, particularly those that need significant investment effort, testing and evaluation to reach mature Technology Readiness such that commercial application is practicable to cross the so called "valley of death" / "mountain of uncertainty".
- GB rail currently has insufficient provision for (and makes insufficient use of) testing and evaluation as a means of optimising new innovations and pushing them to a state of Technology Readiness. This is in contrast particularly with the Japanese rail sector which invests in, and makes exhaustive use of such facilities, but more generally with most other comparator sectors we have examined.
- In complex industrial systems which are a public good, such as the railway, it is governmental organisations like the Technology Strategy Board or industry associations that often provide bridging support and funding. However, when, as in GB rail, the risk associated with delivering innovation affects multiple stakeholders, no one organisation (even Network Rail) can truly act in isolation. This is the gap (dubbed the "valley of death" in GB rail) where innovation generally runs into its biggest problems.

And therefore we recommend that:

- The key priority is establishment of a **Rail Innovation & Growth Team (RIGT)** to emulate best practice from aerospace and automotive and the Niteworks partnership from the Defence sector. It should develop an industry vision for innovation (as opposed to technology) similar to that outlined in the National Aerospace Technology Strategy (NATS).
- The RIGT should provide a means for improving all three modes of innovation: 1) traditional internal and supplier-led innovation; 2) “outside-in” / “lift-and-drop” leveraged from other railways and other industries and 3) the most challenging, namely the collaborative development of industry platforms. The RIGT’s remit should follow that described in detail in our report, covering the entire Technology Readiness Level cycle and enabling the alignment of people, processes, structure and culture around the Innovation Process Maturity Spiral to identify, assess, develop, test, launch and leverage innovation.
- The RIGT should subsume the existing R&D / Innovation roles and functions of DfT, TSAG and RSSB. There is clearly an opportunity here to drive operational efficiency into the future structure.
- On the assumption that the RVfM work will also recommend the creation of a Rail Systems Authority, we recommend that the RIGT functions could be discharged under its remit and governance. This obviates the need for separate management overheads that would exist should the RIGT be separately established.
- Industry capabilities must be adapted around “platforms” to work; not ‘what could work within the constraints of the current industry’.
- Bespoking of commercially available systems and products to meet implicit though questionable GB rail needs should be reduced to the minimum which is absolutely necessary; this is particularly important with opportunities to ‘lift and drop’ innovations from other sectors into GB rail. Our recommended approach to innovation can only partly address this issue, but it also requires action on safety and standards policies, which lie outside scope.
- A GB Rail Innovation Investment Fund (GBRIIF) should be established to provide and manage joint public and private funding by the industry of collaborative innovation, particularly new system platforms and particularly to de-risk (through matched funding) Technology Readiness Levels 4 - 6.
- The RIGT must be “cognisant of the economic consequences” of its decisions; it must be possible to determine who the winners, who are the losers and how the incentives work. This will be achieved by a market system function, which can provide a sounding board for business case robustness and take a whole-system view to align commercial drivers and build common purpose.
- Testing and evaluation facilities to support innovation can best be met by investment in:
    - Use of existing European testing facilities on a commercial “by the hour” basis.
    - Development of existing GB facilities, including the Network Rail Innovation and Development Centre at High Marnham and the remaining Asfordby Test track facilities.
    - Investment in an engineering development workshop facility, accessible to a wide range of industry stakeholders, in supporting prototyping, development, validation and static testing of novel technology to build confidence in the product before commencing on-track testing.
    - Detailed examination of the case for use synthetic environments as employed by the defence industry for complex interoperable systems. There may be the opportunity for costs to be further reduced by shared resources with, say, automotive, defence or aviation environments.
- The principle of “extensibility” should be re-adopted and once firmly established there exists extensive scope for GB rail derived innovations to have global applicability and generate significant export profits beyond the core GB rail user community or target market. Historically, this was once the case and this capability requires revival and delivery for the benefit of ‘GB plc’. Export success has the potential to lower GB rail’s cost base. GB rail should make choices to focus its attention to developing its capability only where all the following apply:
    - There are large global markets worth billions of pounds per annum.
    - The UK has technical leadership.
    - There is a defensible technology position.

    - There is capacity to anchor a significant part of the value chain from research to manufacture in the UK.
- We have determined that the cost of providing the innovation enablers could be very modest compared to the potential benefits. In terms of the benefits, the export market provides a significant potential which GB rail should explore. If the innovation enablers could perform as well as similar organisations, then large investments should be capable of being channelled, generating substantial levels of returns to the industry. These have the potential to exceed the levels of returns that could be envisaged based on analysis of past projects under the current industry set-up. There is a vast rail innovation world market which GB rail could try to capture, regaining some of the leadership in innovation that was once held and reducing the net cost to taxpayers.
- The outline implementation plan could be initiated within one month of authority and deliver the necessary programme of change within 12 months. There may be opportunities to accelerate. We recommend that this programme is managed, authorised and due governance and budgetary control exercised under the proposed Rail System Authority. This implementation plan is consistent with soft systems implementation good practice.

Note: These recommendations summarise the full conclusions and recommendations stated in sections 2.6 and 8 of this report.

2.1 Description of studies and analysis to date

Previous studies on innovation in the GB rail industry include reports by Arthur D Little (ADL) for the VfM team and the Technical Strategy Advisory Group (TSAG) work on barriers to innovation. Whilst these studies were extremely useful in identifying the source of many of the barriers, in particular the mismatch in commercial drivers between stakeholders, the lack of industry leadership and the lack of collaborative behaviours (with some untypical exceptions) as well as some important examples from other sectors for emulation. However, they did not identify a change programme, financial benefits, or a set of practical, workable solutions in enough detail.

Significantly, although a reasonable basis was constructed on which to calculate the costs of removing barriers to innovation, the benefits arising from removing these barriers were not particularly convincing due to a number of generic assumptions. However, the recommendation to implement a Systems Authority for the industry to resolve conflict and take a system-level view appears both sound and workable. We have attempted to align our thinking and assumptions regarding a Systems Authority with the work being carried out in parallel in RVfM's work package 8.

The TSAG consultation document on the 30-year Rail Technical Strategy was also studied for insight into how innovation can be enabled. Innovation is identified as a key priority for the industry, specifically the building of innovation capability and its embedding into the industry. However, there is little mention of how this might be achieved and innovation is considered in a largely technological sense, whereas best practice would suggest that a systems thinking perspective would embrace other sources of innovation, in particular process, collaboration, operating models, strategic markets, cultural behaviours and the building of an innovation skill-base with a strong element of inventive problem-solving.

2.1.1 Hauser Review

A major source of insights was the Hauser Review, commissioned under the last Government by the Department for Business, Innovation and Skills in order to set the strategic agenda and principles by which innovation should be managed at the level of "UK plc", comparing this with successful examples of how innovation is managed in other economies, in particular through the introduction of a network of Technology Innovation Centres (TICs) as part of what Hauser refers to as a 'translational infrastructure' (i.e. an intermediate interface) designed to provide business-focused support capability that bridges research and technology commercialisation. Other countries, including Germany, France, Taiwan, Japan, South Korea, Denmark and the Netherlands, already benefit from this form of translational infrastructure with the result that their collaborative innovation is in many cases superior to that of the

UK. Our project team carried out further research into some of these infrastructures in order to verify the insights of the Hauser Review and glean best practice for our recommendations.

The principles of the Hauser review have now been bought into at the highest levels of Government as the route for creating the right framework for enterprise and business investment, supporting industries where Britain possesses and can maintain competitive advantage and facilitating the success of innovation at a national level particularly in the area of technology. This approach also highlights the key role of the Technology Strategy Board (TSB) as a primary cross-sector enabler of innovation through its programme of industrial research and its management of knowledge transfer networks and partnerships in multiple key sectors, of which Transport is one.

Further detail on the insight and conclusions we drew from earlier research studies and analysis can be found in section 4.

2.2 Evidence base

The principal reports / documents / sources we used were:

- “Achieving Value for Money in Safety, Standards and Innovation (Rail Value for Money Study – Theme G)” – Arthur D Little (2010)
- “The Current and Future Role of Technology and Innovation Centres in the UK” – Dr. Hermann Hauser (2010)
- “Blueprint for Technology” – Department for Business, Innovation & Skills (2010)
- “Consultation document; Shaping the 30-year Rail Technology Strategy” – Technical Strategy Advisory Group (2010)
- “Annual report” – Fraunhofer-Gesellschaft (2009)
- DfBIS R&D Scoreboards (1990-2010)
- “Innovation Index Project interim report” – NESTA (2009-10)
- The website of the Technology Strategy Board and the _connect collaboration portal
- "Pathways to Innovation Excellence - Results of a Global Study" – Arthur D Little (2010)
- RSSB Strategic Research Document T934 "Enabling technical innovation in the GB rail industry – barriers and solutions" – Arthur D Little (2010)
- "Discussion Paper 2: Innovation, Research & Development in the Rail Industry" – Network Rail
- "Engineering Strategy" – Network Rail (2010)
- "Visit Report – GE Global Research Centre (GRC) Munich" – Network Rail (2010)
- "Innovation Benchmarking Report" – Network Rail (2010)
- "Innovation Benchmarking Guide" – Network Rail (2010)
- "Innovation: Supplier Engagement" – Network Rail (2010)
- "Innovation: Developing a Portfolio Approach" presentation – Network Rail (2010)
- "National Aerospace Technology Strategy – Achievement, Status and Future Direction" – Aerospace Technology Steering Group (2010)
- "UNIFE World Rail Market Study Status quo and outlook 2020" – Boston Consulting Group (2010)

We engaged in stakeholder consultations with Network Rail, DfT, the Technology Strategy Board (TSB), Rail Research UK, RIA, ATOC, Bechtel, Freightliner, Eversholt Trains, East Midlands Trains, the RSSB, Rail Research UK, ERRAC, the Aerospace Knowledge Transfer Network (KTN) and the Energy Generation and Supply KTN. We also consulted with several Atkins internal experts from the Defence, Aerospace, Energy and Rail businesses. Further detail on the evidence base upon which we based our analysis can be found in sections 5.1.6, 5.2, 5.2.2 and 5.2.4 through to 5.8.1.

2.3 Key data for this section of the study

We have engaged with a wide variety of stakeholders from GB rail, academia and government to gain their insights into the previous research as well as their assessment of the state of innovation in the industry and how this might be improved. As well as a participative workshop, a structured questionnaire using qualitative 1-5 scales across 15 different dimensions was used in order to elicit comprehensive understanding of perceptions and insights about innovation and hence to identify perception gaps, conflicts and misaligned commercial and strategic agendas.

Our project team has drawn on our knowledge of the TSB's strategic thinking, tactical best practice and processes for our recommendations, as well as our operational experience working for them on value management frameworks for their transport innovation research portfolio.

The principal analytical frameworks used for this study are known as the Innovation System Structure (ISS) and Innovation Process Maturity Spiral (IPMS). These original open-source frameworks are used to assess systems in holistic terms – in other words, to analyse both what is there and what is not, according to what ought, ideally, to be there. Both can be presented as "spider diagrams" (with different coloured lines representing different entities) and so can be easily used to compare similar systems and identify gaps between them.

ISS is used to analyse the content (organisational or industrial activity) of a system and IPMS is used to analyse the maturity of process activity (analogous to the Technical Readiness Levels progression) that takes place within the journey of innovation from insight to reality, typically via a stage-gate process. The combination of both models thus provides a complete, holistic picture of both the entire innovation lifecycle from idea to commercialisation (including research, development, testing, launch and in-life operation), although they should be deployed and used with care particularly when, as in this engagement, time pressure is an issue.

2.3.1 Concepts

A key concept used in this report is that of a "platform", sometimes referred to as a "capability platform" or "innovation platform". This term denotes a facility, system or capability in which one invests, but does not of itself make money or reduce costs. A platform provides a means by which other services capabilities and systems (or "applications") can be launched in order to actually deliver this value. As they take a long time to build, but are extremely difficult to mimic, Platforms are highly effective when developed by individual organisations.

Platforms that are developed at industry level are particularly rare, as they depend upon the ability to establish an open model of collaboration between multiple stakeholders and constitute a medium-term investment risk until the first set of applications are delivering tangible returns. Nonetheless, when multiple organisations are able to align their skills, staff, processes & capabilities to deliver innovation, the result is highly effective, as seen in the other sectors we have examined. Moreover, when, as in GB rail, the risk associated with delivering innovation affects multiple stakeholders, no one organisation can act effectively in isolation. The result of this is a delivery gap that results in what in GB rail is dubbed the "valley of death".

The proposed solution, a deployment of "innovation enablers", must be able to act to research, investigate, propose and commission the development of innovation by three principal routes:

- Supplier innovation from the traditional value chain ("inside-out")
- Leveraged innovation from other rail industries and indeed other industries ("lift-and-drop" / "outside-in")
- Industry platforms (as described above)

2.3.2 Scale

Industry-level innovation will require funding from the industry, effective systemic decision-making at development stage-gates and a way to align commercial drivers between multiple stakeholders. Industry-level innovation enablers, however, will also provide support to apply the Hauser principles described above to access global markets with targeted, world-beating capabilities developed from selected parts of the industry "value stack". In fact, it can be shown that this approach has been successful within GB rail in the past, let alone other industries at present, enabling organisations to gain further business opportunities which benefits UK plc as a whole. Consequently, we believe that the real benefit from innovation is not from its domestic application, but from its ability to drive a "growth strategy" driven by:

- Large global markets worth billions of pounds per annum.
- Promoting UK technical leadership.
- Obtaining defensible technology positions.

- The capacity to keep significant parts of the value chain in the UK.

The project team also conducted research into the structure and organisation of innovation within two overseas railways, the US and Japanese systems, as well as three other industries, the UK aerospace manufacturing, defence and energy generation and supply industries, assessing the structures, relationships, processes and strategies they use to drive innovation.

Bearing in mind the opportunity for GB rail to potentially benefit from leveraging its products, services, expertise and know-how into global markets, the project team also researched the size of the global innovation market, drawing principally on work done by UNIFE / BCG, DfBIS and NESTA.

Further detail on the inputs we used in our analysis can be found in section 4 and sections 5.4 through to 5.8. The models developed to explore GB rail innovation maturity can be found in section 5.1.

2.4 Barriers to efficiency

Although it is clear that innovation does occur within the GB rail sector, despite much rhetoric, it typically fails the test of value at the procurement stage. There are strong signs (for instance the rollout of the Network Rail innovation management process described below and the ongoing RIA innovation conferences) that a groundswell of support for change is beginning to build. However, there is no real shared framework such as an industry innovation management system, particularly when collaboration between different organisations is at issue. TSAG have outlined a range of useful initiatives regarding innovation but it is still unclear how these initiatives are going to be implemented – and measured / quantified – in practice.

The Hauser review calls for investment in Technology Innovation Centres to deliver a step change in the UK's ability to commercialise its research. If this is to be successful, current roles and responsibilities within the railway governance framework will need to be adjusted and redefined. A number of **innovation enablers** must be developed that enable stakeholders in the industry to engage with innovation more effectively. Some of these have already been identified, like a Systems Authority that could support the management of innovation capabilities and resolve systemic conflicts between stakeholders. Model terms of engagement would also be useful, particularly if they make the Technology Readiness Level visible in order to contribute to consensual and specific measures of innovation performance and value generation.

Innovation is viewed in many cases as being in conflict with the immediate commercial drivers of industry stakeholders. Shared technical priorities as expressed through TSAG / TSLG and the Rail Technical Strategy notwithstanding, the business drivers in the GB rail industry continue to be defined in ways that are contradictory to collaborative innovation. There are some instances of key groups of individuals at senior level exercising leadership and judgement to resolve conflicts and develop solutions, but this is the exception rather than the rule.

Even if consensus can be achieved that a particular innovation will bring overall GB rail system benefits, non-alignment of commercial drivers and an uneven distribution of costs and benefits means that a business case for collaborative investment is difficult to construct. There does not currently appear to be a systematic method of exploiting innovation for the greater good of the industry or (in a global context) for the greater good of the UK economy, as opposed to the commercial drivers of each stakeholder.

This is in contrast to the leadership displayed in past decades by (in most cases) BR Research in sponsoring and developing innovations which delivered significant enhancements to GB rail business and, in turn, delivered increased revenue, decreased operating costs and improved performance. If organisations are able to adapt their decision-making capability to platform thinking, the innovation process is likely to be more dynamic. Innovation in GB rail therefore must be understood in a wider, more systemic context if its potential to add value is to be understood.

The barriers to innovation in GB rail are discussed in more detail in sections 4.1.1 and 5.4.

2.5 Principal issues

There appears to be significant support for the perception that GB rail has a poor innovation capability even compared to itself twenty years ago, although a moderate improvement has been made in the past ten years. However, its capability appears poor by comparison to aerospace manufacturing, energy generation and supply, defence, Japanese and US rail – and certainly when compared to the aspirations of the stakeholders consulted.

There is a wide spectrum of opinion about innovation amongst stakeholders in GB rail, some optimistic with a risk of complacency, and some realistic with a risk of defeatism. The stakeholders were asked to consider the effect of innovation enablers being applied to the industry system, with particular reference to how a Systems Authority might impact on innovation. Broadly speaking, they felt that the introduction of innovation enablers seems to offer benefits that are substantial enough across the board to take GB rail far closer to the innovation performance enjoyed by aerospace manufacturing, energy generation and supply, Japanese rail and defence.

2.5.1 The GB Rail Infrastructure Manager Perspective

The stakeholder with the most bullish view of GB rail innovation system process maturity is Network Rail. This is largely due to the substantial commitment of resources to piloting and rolling out a best-practice management system for innovation that is within their own span of control (which is of course not the same as a comprehensive innovation system for the industry). It is also due to a redesign of their new product approval processes, aimed at improving the rate and quality of new product acceptance and introduction.

Network Rail feels that the substantial effort it has contributed to introducing a robust and workable innovation management system for infrastructure development and maintenance has moved them a significant way towards an ideal final result. We believe that this effort deserves due credit but observe that an innovation system representing one group of stakeholders' priorities may not be wholly aligned with the system needs from the point of view of GB rail as a whole. In other words, an optimal whole-system result requires the commercial alignment of many different stakeholders and this cannot be achieved by the introduction of an idea-to-delivery management system, even if it is based on a robust, best practice approach. Network Rail's efforts thus far, described in detail in the full report, demonstrate the appetite for and willingness to make further progress.

Our experience suggests that, at best, an extremely small number of ideas result in a successful, sustainable launch, even within organisations that do not rely on the cooperation of external stakeholders – all the more so in an industry system. Nonetheless, it would be highly beneficial for the entire industry system if each significant organisation involved was addressing the challenge in at least the same level of detail as Network Rail have.

2.5.2 The GB Rail Train Operator Perspective

Some operators have made significant commitment to their own internal innovation systems, albeit recognising that the success of their own efforts is dependent upon external stakeholder buy-in.

Operators are clearer that innovation will benefit users and customers of the industry. Extremely commercially focused, they are principally concerned with their ability to deliver a good service to their customers at the same time as delivering a good return on investment to their stakeholders. It is thus in their interest to minimise the extent to which they are forced to consider sectoral, environmental and regulatory pressures and allow these to drive innovation. They are far more likely to innovate in areas that are under their direct influence and are adding visible value to their customers, enabling them to enhance the value and profitability of their services.

However, due to the structure of the industry and the non-commercial nature of their relationship with Network Rail, both parties struggle to achieve mutually agreeable results from innovation because their conflicting pressures often result in organisational deadlock, which leads to "gaming" (exploiting idiosyncrasies in the procurement and contracting system through which inter-organisational relationships are commonly mediated). This has resulted in poor value for money for the taxpayer. Moreover, due to the nature of TOC franchises, franchisees cannot be incentivised correctly to deliver superior performance through innovation (the present model often working against private sector innovation to reduce costs, attract passengers and increase revenue). The challenge is to capture the positive aspects of the present system while creating the freedom and incentive for TOCs to drive efficiency, innovation and investment through provision of trains, stations and infrastructure enhancements, both in franchise bidding and in delivery. Passengers and, in the longer term, taxpayers will benefit.

Nonetheless, the biggest gap here remains a cultural one. It is clear that mutual trust is a key enabler of collaborative innovation. When it is not present, poor behaviours can act as an insurmountable barrier. It seems clear that the ability of the industry to show leadership in resolving these and to move forward has not been sufficiently demonstrated and, in this case, the ability to refer the issue to some form of Systems Authority would have significantly assisted an optimal outcome for all parties. Clearly, this affects the ability of operators to maintain competitive advantage if they feel that their ability to execute is hampered by the difficulty in gaining buy-in through the existing industry structures.

2.5.3 The GB Rail Supply Chain Perspective

Although their business models strongly support a commitment to innovation and, with a level playing field, suppliers would be inclined to use innovation to compete, they feel constrained by the current approvals and procurement process. They often feel they must prove themselves in the GB rail market before (or in some cases in spite of) addressing external markets. As a result, they struggle to be able to justify investment in innovation for what is likely to be perceived by the purchaser as having no good purpose.

This inability to achieve end-to-end value creation from the point of view of suppliers is an ongoing problem. Both Atkins and Bechtel, for instance, are certainly aware of a despondency that sets in when the risk of innovation is considered, the perception being that services are purchased on a cost basis alone and that added value is virtually eliminated from the tendering process. Innovation is considered a risky activity and one that suppliers to the industry would rather not be penalised for engaging in. It is therefore of little competitive advantage compared to straightforward cost-cutting.

A lack of ideas is not the problem; fundamental research is at a reasonable state of excellence and the socialisation of new concepts across the industry is comparatively mature. There is an excellent prospect, should an effective industry-level process be achieved, of overall alignment keeping up with the pace of change. Suppliers would therefore view with approval the introduction of an innovation-enabling authority or body that would act in the best interests of GB rail as a whole, rather than in the narrow interests of lowering the cost of procurement on a contract-by-contract basis.

There is an overwhelming feeling that GB rail is turned in upon itself in terms of ideas and sources of innovation. Designers, consultants and product suppliers are most likely to innovate when the global market comes into play. The envisaged introduction of an Innovation and Growth Team would enable the collaborative development of new products and services across the system, rather than the current atmosphere of mistrust that good ideas will simply be thrown open to competitive tender, without any credit given for effort or collaborative thinking around the whole problem at a systemic level. This makes for an environment in which intellectual property is jealously guarded and not shared at all in the interests of being able to submit a more competitive tender at a later stage.

This environment and culture is not one in which open innovation can be achieved and we therefore urge the introduction of a system whereby industry-wide platforms can be developed collaboratively by one set of stakeholder organisations regardless of who ends up delivering the applications to the market based upon these platforms. We propose the introduction of a collaborative investment model to overcome this reluctance.

The current arrangements do not promote cross-system innovation in many cases where stakeholders' individual business aims are not aligned commercially, because no system-level authority exists to drive through the change. GB rail lacks the ability to prepare industry platforms for launch due to the difficulty in achieving commercial alignment between stakeholders as well as the challenge of breaking deadlocks over technical standards and risk management when multiple systems are impacted.

The capability gap is agreed to be between Technology Readiness Levels 4 - 6. However, despite the apparent existence of a certain amount of consensus, the profound differences in opinion once more emerge when the points of view of different groups of stakeholders are broken out from the whole. Designers and consultants feel that capability is greater in the adaptation of workable solutions to real application and, as they operate in a global market in any case, have deep capability in translating their experience of challenging GB conditions into competitive advantage elsewhere in the world.

2.5.4 The Governance and Collaboration Perspective

The RSSB is highly exposed to the shortcomings that result for the misalignment of commercial drivers between different stakeholder groups. It is perceived by some (but by no means all) as a discussion forum which fails to provide leadership for the industry. In some cases, there are areas where RSSB has the capability and expertise to intervene and lead, but the structure of the industry and RSSB's own remit hamstrings them. It is often difficult to reconcile the agendas of powerful stakeholders and given the lack of a suitable process and forum in which to resolve deadlock productively, it is hard to see how RSSB as currently constituted might have acted otherwise.

Clearly, the RSSB contains people with a great deal of technical expertise and it has proven itself able to manage a great deal of research as well as craft a credible technology strategy. Moreover, it devotes significant effort and attention to seeking international collaboration. However, it is in the field of deriving benefit from these influential relationships, as well as putting innovation into practice and driving the strategic innovation agenda, that the gap exists and it seems unrealistic to expect the RSSB (within its defined role) to provide leadership in this area.

GB rail is seen as lacking innovation skills and culturally in conflict with innovation. The culture of GB rail is one of consensus and committees and, whilst this is superficially collaborative and groups such as TSAG function effectively as discussion forums, the structure of the industry makes it difficult to overcome a fundamental lack of clarity about who should be leading innovation at an industry level. This means that the beneficial effects of the professional discussions that do take place are not sufficiently converted into actual application.

The TSB, owing to its view across the whole of UK plc, has a somewhat wider view of innovation system process and it makes criticism of the industry's propensity to over-indulge in bespoking and "gold plating", so every idea is effectively treated as a niche idea and the benefits of capability platform development are overlooked. The TSB's view across UK plc is further borne out when the capability of GB rail as an industry is benchmarked against that of other industries.

2.5.5 The Non-GB Rail Perspective

Japan

Innovation in the Japanese railway business (JR) is highly driven by industry strategy and policy. Culturally speaking, Japan is often considered to be one of the most innovative nations in the world and this principle is successfully embedded into R&D activities conducted by JR Group. Since the formation of the Railway Technical Research Institute (RTRI), innovation has taken a strategic position with a holistic systems view to manage overall railway reliability. Institutions like RTRI, the Railway Technology Promotion Centre (RTPC) and four highly advanced testing facilities play a pivotal role in enabling innovation from basic research through to advance application development and standardisation. A number of public corporations, like the Japanese Association of Rolling Stock Industries and the Japan Railway Technical Service, play a significant role in compiling and enabling data for R&D, conducting market research and encouraging new technologies or improved processes to support operation industry and advance the public interest.

Mainly due to highly innovative technology enabling a high capacity/frequency railway, the number of competing railways and the cooperative nature of Japanese culture, the system is not only largely free of regulation but also free of strong disagreements between operators. This has caused the JR group to be seen as a world leader in terms of delivering safety, punctuality and comfort to its end users, competing companies and other industry stakeholders.

There is significant evidence that the RTRI has developed strong industry relationships and channels through collaboration agreements at national and international levels, in particular with China, Korea, SNCF in France and with the RSSB in the UK. A wide range of activities and collaborative R&D approaches have been taken in the past under each research and co-operation agreement. RTRI also cooperates with domestic rail-related organisations to strengthen relationships with overseas railways.

Research suggests that the role of R&D plays a significant role in delivering value for money; furthermore there are strong indicators that the RTRI has taken increasingly active steps to establish a system to promote Japanese technologies and railway systems in the global export market. For example, Central Japan Railway (JR Central) Company is currently bidding to sell Bullet Train technology in the US rail market. This indicates the value they put in moving technology out of the lab and into application so it can be sold and, ultimately, commercialised. This also underpins the conclusion that the Japanese railway is well adapted to commercialising new innovations and technologies.

USA

Innovation and R&D in the US transportation industry, including the railways, is largely driven by both national and industry strategy and policy and stakeholder needs. However, it has certain limitations, in particular its ability to address inter-modal transport R&D issues and the alignment of modal agencies towards the strategic goals of the US Department of Transportation (DOT).

The US economy is considered by most economic modellers to be the most innovative in the world followed by Germany, UK, Japan and France. It indicates a readiness to respond to challenges linked to its ability to adopt, and benefit from innovative technologies, the science and engineering workforce, scientific knowledge and organisational capabilities. However, initial analysis suggests that this advantage is rapidly eroding due to under investment in R&D by Federal resources.

The extensive freight railroads operate in highly challenging environments to compete with aviation and roadways transportation and, so far, continue to grow market share in challenging economic times. One of the key reasons behind this is technical innovations allowing low costs, high safety records and increased system reliability and the ability to offer transportation services at a very competitive rate. This, in turn, has converted a high volume of its truck industry competitors into long term customers.

Despite the above favourable features, however, the railroad industry has yet to develop the capabilities to offer global technological leadership or catalyse a global trend. The benefits of innovation to the freight customers and stakeholders are clearly visible through the passing of cost reduction savings straight to the end customers. The fuel efficiency of railroads also has a clear advantage over the other modes of transports. However, these innovation benefits are often limited to the freight industry and have yet to be realised for the passenger services particularly in view of a pervasive bias in stakeholder priorities.

The recent innovation initiatives and strategic R&D plans of the DOT and Federal Railroad Authority (FRA) has stimulated dialogue between operators, federal and state governments and industry suppliers, who all seem to be able to integrate together to respond to the industry challenges and maximise their share in the growing market. Thirty four states are participating in the development of a high-speed rail network.

It is envisaged that DOT and FRA-led R&D strategic plan initiatives will have a long-term effect on the US railway system. However, at this stage, many of the projects and programmes are in developmental stage and their full benefits could only be realised in term of the actual return rates and scale of deployment in future. It is anticipated that the programs will begin to show up tangible benefits in earnest after about ten years of implementation.

2.5.6 The Aerospace Industry Perspective

Aerospace manufacturing is a particularly strong sector as far as innovation is concerned. It is highly structured because of the long development cycle and asset life and views its innovation success as coming from an ability to align the market drivers of the various participants. One of the key enablers for this is the importance of taking account of cultural factors at a national level. Industry structure is a huge issue in aerospace manufacturing; it is a highly hierarchical sector, according to not just function but size, from SMEs through to large and very large businesses. Innovation delivery capability is embedded directly into the manufacturing side. The component business relies on tight integration with a complex supply chain, which means that collaboration tends to become more difficult when a part of that supply chain can accelerate innovation to market.

The aerospace manufacturing sector takes a system-level view of value for money from innovation development cycles that can take 15-20 years. Because of past experience in the industry, there is a key focus on technical challenges (and R&D in particular) and awareness that without continuous investment R&D capability degrades over time. Input at early stages is increasingly coming from parallel industries, as well as academia. In fact, the close relationship between aerospace manufacturing and defence (they even share a Knowledge Transfer Network (KTN)) is a key enabler of this kind of transfer, as clearly many aerospace manufacturing platforms are key components of the defence industry system "value stack".

The Aerospace & Defence KTN is seen as a key enabler for keeping the industry from turning in on itself and focusing on the bigger picture, with an ability to provide up-to-date snapshots of industry capability and requirements. The KTN also works in the "network of networks" to bring in influences from other industries and the capabilities of the TSB are fully leveraged. Knowledge is seen as owned by the industry, players complement each other with skills and capabilities, thus the collective requirements for challenge-based competitions are able to take place. This is in full accordance with the Hauser principles and the introduction of the new Technology Innovation Centres will also be aligned going forward. Surface transport has its own KTN and its new steering board (as of December 2010) now includes senior stakeholders from Network Rail and RIA who provide a link into Rail via the TLSG, although the KTN itself was only formed in April 2010 and is still in its formative stages, having only just appointed a permanent director.

Industry platforms (described as "systems" and "subsystems") are specified by the industry only when it is clear that the industry will be open to collaboration. The standard practice is for complementary stakeholders to come together for, say, five different platforms and, although the investment in each platform is not shared, but rather made individually by each stakeholder, the resulting value is shared across all stakeholders at industry level. Finding the common drivers for complementary stakeholders is key. Despite the bulk of investment spend coming as expected at Technology Readiness Levels 4 - 6 (as in rail), public funding is largely unnecessary for civil platforms as the platform developers are prepared to put up the money and therefore manage the risk. What enables them to do so is the visibility of their interest in the downstream market.

Where this differs from GB rail is that the income stream is visible over the long term and not subject to constant pressure from competitive procurement. Similarly, the market has global volume, as envisaged by the Hauser principles, ensuring continuity of use for platform development capability and hence steady building of industry capability and contingent steadiness in employment. High variability over short timescales causes difficulty because development capability has to be flexed up and down, negatively impacting on value for money. Investment in platform capability is enabled by "lean"-style reduction of variation and a constant flow of the development process. The lack of vertical integration in GB rail, by contrast, combined with the procurement environment and short-term focus, prevents the development of this kind of constant flow.

The greatest challenge observed over time in platform-building is that of achieving accuracy in development costs based on clear understanding of the market. Platforms always take longer to deliver and cost more to develop than anticipated. What keeps the industry focused is the clear understanding that there is substantial downstream revenue over several decades. Where the payback period is too long the business case is far less convincing and collaborative stakeholder participation can be difficult to achieve.

The development of the National Aerospace Technical Strategy (NATS) has driven a highly coherent industry-level strategic approach. The NATS acts as a visioning platform to identify the enablers that UK plc should be investing in to support the aerospace manufacturing industry innovation system. The NATS it is not just a technology strategy, but an industry-level innovation framework, supported by the following explicitly enumerated enablers:

- Improved skillsets.
- A skilled research base.
- High-performance computing capability.
- Strategic facilities and infrastructure.

- Interdependent partnerships between government, academia and industry.
- Alignment with the wider economic and social environment.

It has led to clarity for the industry about precisely where growth is coming from globally, thus enabling innovation to be aligned to meet these goals and long-term economic objectives for UK plc. Compared to the NATS, the GB rail equivalent, the Rail Technical Strategy, developed by TSAG/TSLG, is more clearly a technology strategy which concentrates on identifying the key technologies of the coming decades and does not explicitly link the development of the components of the technology strategy to clear, tangible and substantial benefits for the economy, or attractive and buoyant global markets, justifying the investment of public money.

Driven by the NATS, aerospace manufacturing can demonstrate a clear example of successful integration of the Hauser principles for a distinct industry sector – select a part of the industry "value stack" and concentrate on building world-class capability platforms in that area.

GB rail's vision, by contrast, is far narrower, far more technically focused and far too concerned with the challenge to the existing stakeholders of delivering the service in the home market, rather than looking to global markets as an engine of growth and a deliverer of inward investment which can refresh GB rail itself.

2.5.7 The Energy Industry Perspective

The energy generation and supply (abbreviated to EGS below) innovation system is less balanced than aerospace. This sector is strikingly focused on innovation drivers based on value for money and cashflow, pressure from regulators and internal competition. Compared to GB rail, the EGS innovation system is far more certain of the value for money from innovation and this is probably because the areas for innovation are so clear and incentivised by substantial regulatory penalties. The penalty for not innovating is clear, present and serious and, as a result, stakeholders are able to take action to align their priorities far more, although there is no particular industry-level strategy pushing them to do so as a group.

Similarly, without value for money from innovation, the cost of energy would have increased significantly. Innovation is seen as helping to maintain the freedom of end-user supply for energy products and services. Players in the EGS industry have understood the principle that building unique, hard-to-emulate industry capability creates barriers to entry and this has led them to invest in strategic innovation platforms.

Competition within the industry is extremely fierce and lack of differentiated platforms would be a substantial risk. Innovation is seen as a source of competitive advantage despite the challenges it poses to EGS industry culture, skillset and structure. This may be because the competitive disadvantage for not innovating is so clear. Innovation is still highly challenging for the relationships in the industry, which are not aligned commercially for collaborative development of industry platforms.

By comparison, there is no real commercial penalty for GB rail from not innovating, as it is obscured by the issue of overall cost, which is so large that crisis management is perceived to make it difficult to justify investing time in what is perceived to be a source of additional risk, except ultimately in terms of the encroachment of other modes in both passenger and freight.

EGS appreciates the value of innovation platforms, but the lack of cross-system dependencies and standards (by contrast with GB rail) means that the industry has been able to embed strategic best practice and consequently the industry as a whole is able to be sufficiently reactive to regulatory, environmental or cost pressures. Rather than having a strategy for the industry as a whole, strategy appears to have been devolved down to platform level, so individual platforms are developed in response to strategic challenges with supporting technology roadmaps by industry interest groups.

Specific organisations available to the industry to promote collaboration, functioning specifically as innovation enablers, include the Energy Technologies Institute (ETI) and the UK Energy Research Centre (UKERC), as well as the EGS KTN and the subsector trade associations. Once more, the gap between rail and EGS is obvious in the "valley of death" between Technology Readiness Levels 4 - 6. There is a high level of engagement from the EGS KTN and UKERC which provide enabling facilitation and collaboration capability, contrasting strongly with lower engagement between GB rail and the Transport KTN.

The ETI is particularly interesting as it sits squarely in the "Valley of Death", covering Technology Readiness Levels from 3 - 7 and has an ability to carry out demonstration projects and support technology roll-outs. It is recognised, however, that has underperformed despite the strategic rationale. Confidential inquiries reveal that this is likely to be a result of a poor intellectual property collaboration model despite substantial funding.

Innovation pull-through is well calibrated within EGS through its capacity to build and launch industry platforms. EGS shows particular ability to transfer its innovation across industry boundaries, particularly into built environment and automotive applications.

To summarise, the EGS industry innovation system is noticeably more advanced than the GB rail industry innovation system but less so than that of aerospace manufacturing. The regulatory impact is also similar, in that large sections of the value chain are highly regulated or highly taxed, resulting in high levels of government intervention. In railways, regulation shows as levels of subsidy rather than tax, but there are still strong economic levers in the hand of the government which determine the success or failure of investment strategy.

It is important to consider the validity of sectoral comparisons. It might not be as correct to compare rail with EGS as it would be to compare it with modes of EGS, electricity for example, Other modes of EGS can also satisfy the need for energy so it could be argued that EGS is more properly compared with transport as a whole. EGS modes also have the same issues as transport modes concerning modal shift (oil and gas to renewables for example) in comparison to automotive to rail.

2.5.8 The Defence Industry Perspective

A comparison between the innovation systems of GB rail and defence reveals large gaps in industry culture, skillset and competitiveness. Innovation is not the primary driver of strategy, but remains a strong enabler. Due to the network of UK military alliances, the defence industry is a leading proponent of the global market. They are already deploying a version of the Hauser principles, but strategy is also highly influenced by the need to respond to emerging threats and whether or not sovereign capability (i.e. without help from other states) is required.

The defence industry is unfazed by technical aspects of innovation, but this can lead to problems at "system of systems" level. When too many innovative approaches are crammed into a new system, this in itself can end up leading to systemic technical risks. The sector is notable for its commitment to the people-facing, skill-based aspects of innovation; it is typical for organisations to make training available in different ways of brainstorming and harnessing creativity. The sector nonetheless considers itself risk-averse in terms of the cost of innovation, despite its clarity about the benefits of innovative capability.

As in rail, innovation efforts pale next to that focused on immediate operational needs, especially since the advent of the recent high-profile and highly critical Gray report into defence overspends and inefficiencies. Nevertheless, the industry itself has been successful in building an impressively mature collaborative innovation process. The sector has already integrated TIC-type "Innovation Centres" into the process but, rather than focusing on technology capabilities, they are focused on the end-user communities. Longer-term innovative responses raise challenges as it continues to be difficult to adapt long-standing industry platforms for new strategic realities.

One area of innovation in which the defence sector excels is that of capability transfer, e.g. using resources from the video-gaming industry for synthetic environments. Transformational "inside-out" innovation is extremely prevalent and transfer paths are well established to motor sport and thence to the automotive retail market. The most interesting aspect of the defence industry innovation system, however, is the response to recognition that there was not enough engagement between government, the forces and industry, in part as a result of highly protective attitudes to IPR, especially where intellectual property was held by multiple stakeholders for a shared platform.

The highly successful Niteworks partnership approach was established to resolve these IPR issues and other facilitate of collaboration. Participants contribute their IPR as "background" and then typically balance the risk of their investment in innovation platforms with the benefit they can expect to receive from launched applications via a sharing agreement covering the “foreground” IPR that is developed as a result of collaboration or funding arrangements. Typically, this foreground IPR is retained collaboratively so as to build deep, long-term and open partner engagement. This model would appear at this stage to be worth further investigation for GB rail. Output-based specifications are routine, as are long contracts of 15-20 years.

It is also worthwhile looking at the testing facilities available to the sector, particularly with regard to interoperability testing, which benefits from regular industry events e.g. Coalition Warfighter Interoperability Demonstration (CWID). Lessons for GB rail might well be learned from this focus on interoperability and we recommend the further investigation of a case for this type of capability as a priority for the proposed innovation management system. Synthetic environments are also an excellent tool for evaluating the interactions between systems and people and there is an expanding role for them in the rail industry, particularly in staff training and in ‘human factors’ aspects of equipment design. However, the opportunities for their use in place of physical testing of safety critical equipment and systems are limited at present. The rail industry should continue to monitor developments in the field, with a view to potential future applications of synthetic environment technology.

It is also worth looking closely at the role and approach of the TSB as the government agency tasked with improving innovation across UK plc, as well as its track record of success, contributing to the enhancement of its position subsequent to the recent reorganisation of government agencies. The TSB, as an agency of the Department for Business, Innovation and Skills (BIS), takes a view across the entire breadth of UK plc, with a view to obtaining the best value for money from investing in innovation. At early Technology Readiness Levels, it deploys a highly successful collaborative research model called the Small Business Research Initiative (SBRI) for public procurement of solutions to bounded problems posed as challenges. The TSB poses the problem and then offers 100% funding for small R&D contracts (typically £30-50k) to be carried out by organisations who think they can solve the problem. The prospect for participants is the sale of a successful solution to the government albeit, significantly, retention of the IPR by the SME.

The experiences of Niteworks, the ETI and SBRI are all useful lessons for GB rail in terms of the proposed innovation management framework. It is critically important to be aware of the perception from the point of view of SMEs and non-traditional participants in GB rail. Prospective small equity investors in the development of innovative solutions will be put off by the loss of IPR and will not be attracted by the prospect of what amounts to contract research work. As in the defence R&D world, Crown use of rights for 100% funded projects could be used as a way to avoid the risk of critical national infrastructure depending on the IPR of SMEs. Consequently, it will be important to establish the optimal percentage splits in IPR to attract collaborators of all sizes and types. For industry-level innovation to succeed as an open model in rail, key organisations will have to adjust to these concepts.

2.5.9 Comparison Conclusions

In conclusion, other sectors and industries which form part of critical national infrastructure such as defence, energy, aerospace and rail manage innovation as a ‘structured innovation management system’, being a coordinated and collaborative (including participation from SMEs, OEMs, academia and government) approach to channelling new methods, ideas, products and products services into their industry. A successful industry innovation management system relies upon both formal and informal roles and responsibilities that define the scope of innovation and innovation performance. Other sectors have realised the need to collaborate in order to materialise additional value.

Innovation, defined here as the development of new methods, products, services, systems and capabilities – and the bringing of change based upon them – is, in some sectors and wider economies, seen as fundamental to support the means by which industries and hence economies can develop and grow. Industry sectors and whole economies have developed effective mechanisms for managing innovation so they can measure their performance and position on a global basis and this is the basis of Hauser’s view, supported at the most senior levels of UK government. This is borne out by the experience of other industries and other countries’ rail industries, that in order to grow the UK economy and place the UK in a leading global position the UK must capture and exploit innovation to the fullest potential before other economies do so. Also, as our financial analysis and research into global markets bears out, we believe that the benefits from adopting an approach that recognises and can bring substantially greater benefits to the industry and the country as a whole are greater than the solely domestic benefits of innovation within the industry.

Inputs and comparators are assessed in detail in sections 5.5 and 5.6. The approach to benefits quantification is described in more detail in section 6.2.1.

2.6 Recommendations – for Cost Reduction, Increased Efficiency and Increased Revenue

The following recommendations for cost reduction, increased efficiency and increased revenue are identified:

- Innovation enablers must be able to act to research, investigate, propose and commission the development of innovation through:
  - Supplier innovation from the traditional value chain ("inside-out")
  - Leveraged innovation from other rail industries and indeed other industries ("lift-and-drop" / "outside-in")
  - Industry platforms (as described above)
- A **Rail Innovation & Growth Team (RIGT)** should be established, following the best practice of the long-established Aerospace and Automotive teams and the Niteworks partnership from the Defence sector.
- The RIGT should emulate best practice from aerospace manufacturing and automotive and develop an industry vision for innovation (as opposed to technology) similar to that outlined in the National Aerospace Technology Strategy (NATS).
- The RIGT's remit should cover the entire TRL cycle and enable the alignment of people, processes, structure and culture around the IPMS to identify, assess, develop, test, launch and leverage innovation.
- Existing explicit and implicit R&D/ Innovation roles and functions of DfT, TSAG and RSSB should be subsumed into the RIGT.
- On the assumption that the RVfM work will recommend the creation of a Rail Systems Authority, we recommend that the RIGT functions could largely be discharged under its remit.
- The RIGT should fulfil the "systems intelligence function" which will look at opportunities and challenges, covering futures and horizon scanning, legislative change, franchise renewal, major projects, new methods and RUSs.
- The RIGT should be tasked with the identification of transferable innovation from external sources as well as reporting on it to the industry. If a piece of innovation is deemed applicable, then its porting and development into GB rail can be commissioned as a platform as described in IPMS.
- The RIGT must make a comprehensive assessment of existing industry initiatives for inclusion in its programme to avoid the risk of "orphaning" activities that are already being catered for within the existing structure.
- The regulatory function of RIGT, via the interface between the RIGT and the ORR, should take the guardianship role in terms of incentivising the industry to meet these insertion points and ensuring compliance with a stated and clear requirement to innovate.
- Best practice guidelines for systemic and systematic innovation decision support must be developed for the industry as a matter of urgency – these should include investigating the scalability and industry-level application of the Network Rail innovation management system.
- The location of the systems authority should be independent both from Network Rail, operators and RSSB as they are at present, but directly accountable to the regulator and the taxpayer (via ORR and DfT).
- Based on the Hauser report, the successful set-up of the Technology and Strategy Board and the planned set-up of the Systems Authority, the Government should fund the set-up cost of the RIGT and other enablers.
- Based on the level of involvement and the successful example of existing organisations such as TSB, the Government should fund the operating cost of the RIGT and other enablers, with a small subscription fee charged to NR, ATOC, RFOA and RIA.
- The RIGT must provide adequate interfaces to keep civil servants informed and appropriately involved in the industry's research and innovation agenda.
- The technical capability of the RIGT could be drawn in part from the established TSAG / TSLG, but the RIGT must be able to make an informed assessment in terms of not only technical issues, but all ten dimensions of innovation system structure as described in ISS.

- The technical capabilities of the RIGT must go far beyond core rail technical skill-sets, to cover, for example, validation for software controls.
- The RIGT should be responsible for setting (via output-driven specifications) and managing the response to industry-level innovation challenges as well as functioning as a systems authority to make stage-gate decisions on behalf of the industry concerning collaborative investment funding.
- The RIGT should also act as a referral body for difficult-to-resolve systemic innovation issues down to component level.
- A matrix of insertion points should be created to enable the agendas of industry stakeholders to be linked to technical road-mapping.
- Membership of RIGT functions be periodically refreshed, on a 2-3 year basis.
- The industry should seek to develop innovation leaders that are capable of effective participation in any one of the RIGT's functions, so innovation skills should be explicitly included in GB rail's new National Skills Academy programme.
- To address the issue of funding and support open IPR models, a **GB Rail Innovation Investment Fund (GBRIIF)**, should be established, jointly funded by industry and government, to support collaborative investment in innovation, using suitable IPR models.
- The unequal distribution of development investment against launch revenue streams in the industry must be addressed by the development of collaborative investment models like a Value-Added Reimbursable Launch Investment (VARLI) vehicle.
- Project- and platform-level innovation investment should be shared between the public and private sectors via the GBRIIF with the exact split and the mechanism for transactions considered on a project-by-project basis using VARLI or a similar process.
- Draft partnership and collaboration agreements must be developed which align the profit drivers of the various stakeholders and provide safeguards to prevent undue pressure being brought to bear by the more powerful stakeholders.
- A "strategic market" function should be developed for the RIGT in order to drive a global growth strategy for GB rail to capture world innovation market share?
- The RIGT should develop an informed and detailed understanding of the world rail innovation market, GB rail's competitive position (both current and potential, by product sector and region) and construct a relevant set of market entry and exploitation strategies to drive the industry vision.
- The RIGT must define and establish clear and straightforward procedures for interacting and collaborating with other innovation enablers such as "Clerk Maxwell Centres"/TICs, in particular if one is established for Transport, as well as the Transport KTN and other industry IGTs. We consider that the interface between RIGT and the TIC will enable GB rail to bring industry-level strategic clarity about its innovation priorities to the TIC so that the industry will be able to commit to developing and delivering everything from innovative offerings from the supply chain to new industry capability platforms and we expect the TIC to be an active participant in the agenda and functioning of the GBRIIF.

2.6.1 Further research and study required

The following areas are suggested for further investigation:

- Detailed study into the functioning of both Aerospace and Automotive IGTs and the defence industry's Niteworks partnership as well as other innovation enablers like the NHS Innovation & Improvement Agency should be carried out to ensure the RIGT is a best-of-breed model.
- Network Rail and the TSB consider that GB rail has world-class capability in the area of rail research and the early stages of innovation, pointing in particular to understanding of the wheel-rail interface. This diverges with the views of the academic stakeholders consulted (and at least one of the consultancies) so a more in-depth analysis of the academic and early stage capabilities should be undertaken in order to test this hypothesis.
- The industry, through the RIGT, should engage with UK Trade & Industry (UKTI) with a view to developing GB rail global markets as British overseas trade opportunities.
- As significant learning is needed to develop optimal models for collaborative investment, more detailed work should carried out to assess and develop Value-Added Reimbursable Launch Investment (VARLI) with a view to gaining stakeholder buy-in and learning the lessons from other industries, particularly that of aerospace manufacturing and the ETI.
- As a recommendation of the best model for IPR collaboration for GB rail stakeholders to produce an optimal result at system level is beyond the scope of this report, more in-depth study should be carried out to assess and select the best of these for adoption by the RIGT and other innovation enablers. Instructive perspectives on optimal systemic IPR models to underpin collaborative

industry-level innovation and provide clear lessons both in what to do and what to avoid are likely to come from ETI, SBRI, Niteworks, the TSB, TICs (domestic and overseas), Imperial Innovations, Oxford University's "ISIS" hub and the pharmaceutical industry.

- Lessons for GB rail might well be learned from this focus on interoperability and we therefore recommend the further investigation of a case for this type of capability as a priority for the proposed innovation management system.
- Further work for the provision of cost-effective rail industry test facilities in the UK should include discussions with representatives from key industry stakeholders including ROSCOs, TOCs and test facility operators, investigation of the potential for upgrading the two UK test track facilities to meet current and future industry needs and benchmarking of rail test facilities with those in related industries, particularly defence and aerospace.

The model that was developed to model the domestic benefits from innovation is described in section 6.2 and the global opportunities for increased revenue are described in detail in section 6.3. Detailed recommendations for establishing appropriate cost-effective testing facilities can be found in section 6.1.5.

2.7 Potential for and Timings of Cost Savings

This section summarises the potential gains based on our analysis. This report has found that the cost of providing the innovation enablers could be very modest compared to the potential benefits. In terms of the benefits, the export market provides a significant potential which GB rail should explore. If the innovation enablers could perform as well as similar organisations, then large sums of investments should be capable of being channelled, generating substantial levels of returns to the industry, exceeding the levels of returns that could be envisaged based on analysis of past projects under the current industry set-up.

It is estimated that the one-off set up cost of the RIGT is likely to be no more than £3.3m, with an annual operating cost at no more than £2m depending on staffing level. It is recommended that the public sector is best placed to provide most of these costs, with small contribution from the private sector.

Past innovation projects have been reviewed based on usable high-level data provided by GB rail organisations up to 20th January 2011. It is estimated that the innovation enablers could bring a contribution of approximately £280m per annum by addressing some of the key issues faced by the industry.

It should be noted that under a new industry set-up, with innovation enablers in place, different projects could be initiated compared to the type that have so far been considered under the current industry set-up, and indeed new levels of cost and return potentials could be achievable. Depending on the level of resourcing, if the innovation enablers could manage project investments of up to £140m a year and if a return-on-investment of 5 : 1 could be achieved at a portfolio level, then the net return from these investment could be up to £560m a year. The funding structure at the project level should be determined on a case-by-case level, aligning costs to foreseeable beneficiaries and depending on the level of technology readiness. Different transaction routes should be explored, depending on the project, including reimbursement models.

Of course, there is a range of potential levels of returns and these are discussed in greater detail in the main report. However, it is sufficient to say that with an adequate level of staffing and organisational effectiveness, the innovation enablers could address existing problems and stimulate new initiatives, with the potential for hundreds of millions of pounds' worth of net benefits to GB rail.

The above analysis is primarily focused on the UK market. There is a vast world market for rail innovation which GB rail could and should try to capture. It is estimated that the market size related to innovation is in the region of €14bn a year in mature and emerging markets. If GB rail could capture 5% of this, then this would be €700m. Of course GB rail could target less promising markets if it has inherent advantages compared to its competitors and, hence, the potential market could be greater than €14bn a year. The extent to which GB rail could capture this world market (and the identity of the key product markets that GB rail should focus on) is beyond the scope of this report but should be subject to further investigation.

A summary of the overall costs and benefits over time from innovation, both internally and from accessing global markets, is shown below:

	CP4						CP5					
Rail year	2009/10	2010/11	2011/12	2012/13	2013/14	CP4	2014/15	2015/16	2016/17	2017/18	2018/19	CP5
Set up & operating costs		£0.0	-£4.1	-£2.6	-£2.6	-£9.3	-£2.6	-£2.6	-£2.6	-£2.6	-£2.6	-£13.0
Central investment		£0	-£29	-£39	-£49	-£118	-£49	-£49	-£49	-£49	-£49	-£245
Industry investment				-£29	-£49	-£78	-£49	-£49	-£49	-£49	-£49	-£245
Total costs		**£0**	**-£34**	**-£71**	-£101	**-£205**	**-£101**	**-£101**	**-£101**	**-£101**	**-£101**	**-£503**
Internal benefit		£0	£0	£175	£263	£438	£350	£350	£350	£350	£350	£1,752
Growth rate		2.5%										
€ Addressable global innovation market		14,000	14,350	14,709	15,076	58,135	15,453	15,840	16,236	16,642	17,058	81,228
Exchange rate		0.86										
£ Addressable global market		£12,040	£12,341	£12,650	£12,966	£49,996	£13,290	£13,622	£13,963	£14,312	£14,670	£69,856
Penetration			0%	0.5%	1%		2%	3%	4%	5%	5%	
Revenue from global markets		£0	£0	£63	£130	£193	£266	£409	£559	£716	£733	£2,682
Total benefit		**£0**	**£0**	**£238**	**£393**	**£631**	**£616**	**£759**	**£909**	**£1,066**	**£1,084**	**£4,434**
Net benefit		**£0**	**-£34**	**£167**	**£292**	**£426**	**£516**	**£659**	**£808**	**£965**	**£983**	**£3,931**
Cumulative net benefit		**£0**	**-£34**	**£134**	**£426**		**£516**	**£1,174**	**£1,983**	**£2,948**	**£3,931**	
Annual BCR			1.0	-2.3	-2.9		-5.1	-6.5	-8.0	-9.6	-9.8	

Naturally, it would be beneficial to have a clearer insight as to how the costs and benefits would fall amongst the various industry members. However, to pre-judge this before the RIGT has determined priorities would be premature. We believe that while the potential size of the costs and benefits can be established at a "rail network/ rail industry" level, decomposing these and attributing them to individual stakeholder areas reinforces the sort of internecine behaviours that currently hamper systemic innovation. The sub-division of costs and benefits in this way has been nugatory for the last 15+ years, destroying the system-wide approach that the RIGT should drive forward and begin to establish.

A further level of detail would essentially translate into the content of the entire collective innovation portfolio of the industry and would require a shared view at industry level of what all stakeholders were engaged in. Because of commercial sensitivities, the only stakeholders that have been completely forthcoming about their actual portfolio content have been Network Rail and the RSSB and, even so, some of the detail is hard to ascertain. With other stakeholders, it would have to be assumed that they would first and foremost innovate in their core areas, so one would have to assume a proportional spend of about 14% of turnover (according to the NESTA figure) and a roughly 3:1 benefit to start with assuming the industry remains structured the same way and that the project data shared with ourselves is representative. This would be combined with whatever the industry decided to commission at industry level via the RIGT, again to a roughly 3:1 benefit to start with. But the industry has only made quite high-level decisions about what technology they think is important at the moment (via the Rail Technical Strategy) and this is subject to change over time.

Each of the elements in the Technical Strategy, if translated into an RIGT programme, would require its own detailed business case in order to value it more tangibly. Similarly, the allocation of benefits and costs between stakeholders is exactly what the industry is unable to agree consistently and effectively at this point, so it would be presumptuous of this report to attempt to decide for them before an RIGT is even in place. Innovation has to be dependent on industry strategy, which is not clear at this point much beyond the "4 C" stretch target. To produce a more robust picture of the associated costs and benefits to support the vision for innovation would be the first order of business for the RIGT. More detail on how cost savings and other domestic benefits may be achieved through the implementation of an industry innovation management system can be found in section 6.2.2 and indicative timings can be found in Appendix D.

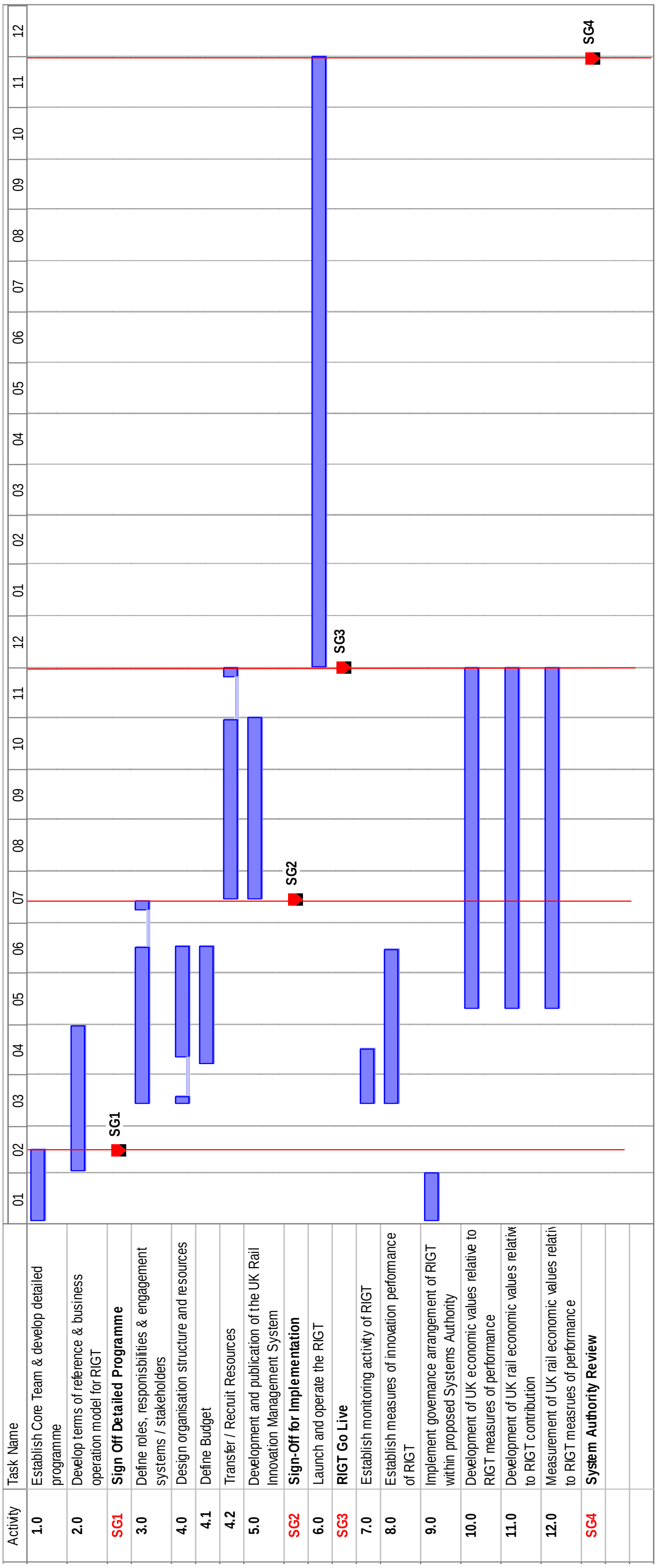
2.8 Implementation Plan

The implementation plan for the industry innovation management system can be summarised as follows:

- Establish core team and develop detailed programme.
- Develop terms of reference and business operation model for RIGT.
- Define roles and responsibilities and engagement systems / stakeholder engagement.
- Design organisation structure and resources.
- Define budget.
- Transfer / recruit resources.
- Development and publication of the GB rail innovation management system.
- Launch and operate the RIGT.
- Establish monitoring activity of RIGT.
- Establishing measures of innovation performance of RIGT.
- Implementation of authority to intervene with the operation and organisation of RIGT.
- Development of GB rail economic values relative to RIGT measures of performance.
- Development of GB rail economic values relative to RIGT contribution.
- The measurement of GB rail economic values relative to RIGT measures of performance.
- Intervention of the organisation of the UK sector (not shown on the plan).

This indicative plan shows the timeline for implementing the industry innovation management system solution described (and is also shown in Appendix D for clarity).

More detail on the implementation plan can be found in sections 7.1 and 7.2.


Activity
Task Name
01
02
03
04
05
06
07
08
09
10
11
12
01
02
03
04
05
06
07
08
09
10
11
12
1.0
Establish Core Team & develop detailed programme
2.0
Develop terms of reference & business operation model for RIGT
SG1
Sign Off Detailed Programme
3.0
Define roles, responsibilities & engagement systems / stakeholders
4.0
Design organisation structure and resources
4.1
Define Budget
4.2
Transfer / Recruit Resources
5.0
Development and publication of the UK Rail Innovation Management System
SG2
Sign-Off for Implementation
6.0
Launch and operate the RIGT
SG3
RIGT Go Live
7.0
Establish monitoring activity of RIGT
8.0
Establish measures of innovation performance of RIGT
9.0
Implement governance arrangement of RIGT within proposed Systems Authority
10.0
Development of UK economic values relative to RIGT measures of performance
11.0
Development of UK rail economic values relative to RIGT contribution
12.0
Measurement of UK rail economic values relativ to RIGT measrues of performance
SG4
System Authority Review
SG1
SG2
SG3
SG4

2.9 Risk Management

The following key risks have been identified and in each case suitable mitigations have been proposed:

Risk	Consequences	Mitigation
Failure to achieve common understanding of how innovation works in GB rail industry	• Insufficient understanding of industry interfaces to manage innovation systematically. • Continuation of status quo, and loosing GB rail's competitive capability to other countries and sectors.	Defining innovation management system, strategy and clear rules of engagement for realising, prioritising, funding and delivering innovation and its benefits to the industry and stakeholders. See section 7.
Boundaries of innovation are not clearly defined as relative to the industry	• Unclear ownership and accountability, discouraging right values and collaborative approach. • Insufficient transparency in incentivisation and stakeholder engagement rules and terms of reference.	Establishing decision-making leadership with clear objectives. Defining scope of works, roles and responsibilities of regulators, beneficiaries and stakeholders.
Non-uniform or random incentivisation of industry stakeholders and suppliers	• Lack of trust in industry system, discouraging private sector funding. • Increased reliance on public funding and government involvement. • Complex industry relationships and inability to challenge the status quo.	Use of platform conception to exploitation approach for sharing benefits.
Lack of private sector investment to stimulate innovation and R&D activities	• Scarcity of resources to operate the industry innovation system. • Inability to harness the scientific workforce and knowledge embedded in private sector industries.	Application of Hauser principles in encouraging private sector investment. Using Value added reimbursable launch investment. See section 7.
The GB rail innovation dependencies on other sectors and stakeholders are not recognised and addressed	• Delivery of benefits to wider UK economy are not fully realised and valued. • Limits the GB rail industry's capability to exploit the global market benefits.	Enable a consistent and transparent approach for speedy and uniform return of benefits to the contributors.
Ineffective development, implementation and exploitation of new platforms	• Non uniform stakeholder incentivisation . • Lack of strategic objectives and goals to drive innovation supply chain.	Enable effective development and implementation of new platforms.
Failure to embrace supplier-led and lift-and-drop innovation approach	• Excessive capital investment in state-of-art technologies. • Affecting cross-sector R&D and blocking baseline data for further development.	Executing tasks of Innovation Management System for successful R&D and innovation. See section 7.1.1. Enabling data and information sharing for common R&D goals.
Failure to establish innovation management system and develop detailed programme	• Reduced or complex decision making / executive capability. • Ineffective development plan. • Insufficient scope of works.	Executing tasks of Innovation Management System for successful R&D and innovation. See section 7.1.1.
Failure to develop terms of reference and business	• Non systematic innovation management.	As above.

Risk	Consequences	Mitigation
models innovation management system	• Complex business terms of references and unclear operations roles. • Inability to project values for innovation platforms to industry.	
Failure to define roles and responsibilities and engagement model for innovation management system	• Lack of visibility to innovation process. • Complex approval process and longer execution time.	As above.
Failure to design organisation structure and resources for innovation management system	• Misaligned industry directives, insufficient transparency. • Ineffective stakeholder engagement and lack of collaboration and accountability. • Complex processes and lengthy time delays. • Difficulty in identifying 'winners and losers' of innovation strategy implementation.	As above.
Failure to define and provide sufficient capital and operational budget for innovation management system	• Insufficient funds leading to lack of operational capability. • Reduced rate of overall return due to under investment.	As above.
Failure to recruit sufficient workforce for the innovation management system.	• Reduced or ineffective terms of reference or business model. • Lack of suitably experience staff capable for running RIGT.	As above.
No or ineffective publication system for GB rail innovation system	• Blockage to innovation management system interface visibility, discouraging new party involvement and industry collaboration.	As above.
Inability or lack of resources to launch and operate the innovation management system.	• Continue status-quo, with ineffective capability to recognise, prioritise, invest and deliver innovation to the industry.	As above.
Failure to establish provisions to monitor performance of innovation management system	• Innovation is not valued and managed uniformly in all segments of the industry. • Misleading regulatory and strategic guidance without historic performances. • Inability to assess success and industry capability to address innovation challenges.	As above.
Inability to design a measure for innovation performance in GB rail industry	• Non-integrated and dysfunctional innovation strategy and goals. • Quantification of benefits and returns on strategic R&D investments.	As above.
Misalignment of innovation management system with regulators and regulated community.	• Inability to strategically steer the innovation approach. • Inability to adapt and respond to emerging issues and innovation trends.	As above.
Loss of GB rail's competitive advantage over other railways and sectors.	• Reduced market share in the global market. • Inability to effectively contribute to the economy and high reliance on public subsidy.	As above.

Risk	Consequences	Mitigation
Inability of GB rail industry to stimulate economic growth through commercialisation of advance technologies, processes and best practises	• Increased public subsidy and government interventions. • Reliance on other countries and sectors to meet GB rail industry challenges.	As above.

More detail on the implementation plan can be found in sections 7.1 and 7.2 and in Appendix D.

Part Three

3 Part Three – Main Report Introduction

3.1 Overview

The value for money study of GB rail industry, under the independent chairmanship of Sir Roy McNulty, aims to examine the current railway business and make recommendations to improve its value for money, in order to build a financially and organisationally sustainable platform for future growth. The study is jointly sponsored by the Department for Transport (DfT) and the Office of Rail Regulation (ORR) and is broadly segregated in three major phases, with little overlap between them.

Phase 2a – Problem analysis and evidence gathering
Phase 2b – Solution identification and selection
Phase 2c – Option and business case development

On 22nd November 2010, Atkins was commissioned by Rail Value for Money (RVfM) team to undertake part of Phase 2b study, **'Achieving Value for Money from improving the management and delivery of innovation in the GB rail industry.'**

This work is focussed on gathering evidence, identifying barriers to improvement and improving the analysis of how to achieve cost-efficient value for money from the improvement of the management and delivery of innovation in the GB rail industry. It considers the innovation challenges identified during Phase 2a of this study, in particular Arthur D Little's (ADL) report for the rail industry's Technical Strategy Advisory Group (TSAG); this suggests that the gap in the product development cycle between concept and de-risked large-scale demonstration is widely acknowledged and solutions needed to be identified, developed and implemented to overcome GB rail innovation barriers.

3.2 Scope of Work

The remit for the scope of work is to:

- Review the conclusions of the work that TSAG commissioned from Arthur D Little (ADL) and ADL report on Safety, Standards and Innovation for the value for money (VfM) study and build on additional relevant work carried out by TSAG, DfT and other industry parties.
- Confirm the suggestions made in this work as well as highlighting any alternatives or challenges to these for discussion and resolution
- Build on the previous work by identifying practical means of incentivising the industry to focus on carrying out research, encouraging development and undertaking affordable testing.
- Produce a study on the best approach, applying our knowledge and experience of the development and implementation of innovation systems to improve the speed and effectiveness and minimise the cost of the introduction of innovation into GB rail industry.

3.3 Inputs, Assumptions and Dependencies

- The work draws on the input documents from TSAG and VfM studies mentioned in the previous section.
- The project team has engaged with industry stakeholders including those suggested by the VfM team, as well as internal experts and cross-sector external experts.
- The quantitative benefits analysis is dependent on the timely co-operation and goodwill of industry stakeholders in providing project and programme-level data.
- The project team assumes that a Systems Authority is being implemented and can play a suitable part in this process and also that other industries can provide instructive examples of best practice and has attempted to align outputs with the team carrying out that work.

4 Examination and Analysis of Previous Research

4.1 Safety, Standards and Innovation Study (ADL Report and other input documents)

Within the context of developing the 'UK Rail innovation management system', a review was carried out of the outcome of previous research. In particular, close attention was given to the following publications and research areas:

- Achieving Value for Money in Safety, Standards and Innovation (Rail Value for Money Study – Theme G); Arthur D Little.[3]

In summary, this report provides a detailed and comprehensive review of improvements that could potentially be made within the UK Rail industry. These improvements are presented at a tactical level including a reasonable basis on which to calculate the costs of making these improvements. However, the basis on which the benefits of innovation are calculated are not particularly convincing and rest on somewhat generic assumptions.

Innovation in the context of GB rail
There is no one definition of innovation, but it is used in this report to mean the development of new methods, products, services, systems and capabilities and the bringing of change based upon them. It is often reduced to the development of new technology, but in fact touches every part of business systems, embracing people, process, structure and culture.

- The Current and Future Role of Technology and Innovation Centres in the UK; Dr. Hermann Hauser[4]

In summary, the report presents a view of how innovation is managed (and should be managed) within the UK and compares this with the success of how innovation is managed in other economies. A number of important recommendations are made for improvements for, and the development of the 'UK innovation management system', in particular the introduction to the UK of Technology Innovation Centres. A member of the project team was also fortunate enough to have the opportunity to meet Dr Hauser and the Department for Business, Innovation and Skills' (BIS) Director General of Innovation & Enterprise at a conference where they were setting out in more detail the principles by which innovation should be managed at the level of "UK plc", which have been highly influential in the recent flagship publication by the Department for BIS, committing to Technology Innovation Centres, which was launched by the Prime Minister:

Technology Innovation Centres (TICs)
TICs are part of a 'translational infrastructure' designed to provide a business-focused capacity and capability that bridges research and technology commercialisation. Other countries benefit from this form of translational infrastructure – for example, the Fraunhofer-Gesellschaft in Germany, ITRI in Taiwan, ETRI in South Korea, the Carnot Institutes in France, GST in Denmark, AIST in Japan and TNO in the Netherlands. The Department for Business, Innovation and Skills is in the process of establishing a network of TICs for the UK, branded 'Clerk Maxwell Centres'. TICs are envisaged as covering TRLs 3-8. TICs are fully described in the Hauser Review carried out by BIS under the previous government.

- "Blueprint for Technology"; Department for Business, Innovation & Skills[5]

This document sets out the investment and policy agenda for the Government at a national level in seeking to create the right framework for enterprise and business investment, support industries where Britain possesses and has the clear potential to maintain competitive advantage and facilitating

[3] Ref: Confidential document shared by the VfM team with the project team
[4] Ref: http://www.bis.gov.uk/assets/biscore/innovation/docs/10-843-role-of-technology-innovation-centres-hauser-review
[5] Ref: http://www.bis.gov.uk/assets/biscore/innovation/docs/b/10-1234-blueprint-for-technology

the success of innovation, particularly in the area of technology. It is notable for underlying the importance of the Technology Strategy Board (TSB) as a "key channel" for this strategic agenda. The project team engaged in some detail with the TSB, drawing on our knowledge of their strategic thinking, tactical best practice and operational processes in terms of innovation management thinking, gained as part of our ongoing work managing their transport innovation platforms and research portfolio and benefiting from their insight into cross-sectoral approaches to innovation.

- Consultation document; Shaping the 30-year Rail Technology Strategy; Technical Strategy Advisory Group[6].

In summary, the report presents a range of technical development themes which will be important research areas to develop the performance of GB rail and, in particular, highlights the importance of developing a more effective approach to innovation within the industry. The project team also carried out research into how innovation at industry and cross-sector level is managed, implemented and facilitated by government in European Member States:

- In Germany, the Fraunhofer-Gesellschaft,[7]
- In France, the Carnot Institutes,[8]
- In Denmark, the GTS Network.

In summary, each of these member states has a comprehensive and integrated management system for managing systemic innovation (as opposed to straightforward supplier-led innovation or technology transfer) from idea through to delivery, as well as a commitment to and a largely successful track record in leveraging world-class capabilities from their national rail industries into global markets, with the result that they retained healthy rail supply systems.

Fraunhofer –Gesellschaft (Institutes)
The Fraunhofer-Gesellschaft (FHG) is a network of independent research institutes funded by German government and industry. It carries out application-oriented fundamental research and innovative development projects, acting as a research and development partner to industry to open up new opportunities for businesses in tomorrow's markets. The FHG is responsible for conceiving and implementing "innovation clusters", collaborative ventures used to pool the strengths of a region and activate them to solve demanding tasks. In addition to industry and universities, the networks include local non-academic research institutes that can make important contributions in relevant thematic areas, facilitated by regional partnerships between private companies, research institutes and universities. The FHG has more than 80 research units, including 59 Fraunhofer Institutes in Germany.
It is the key model on which the introduction of Technology Innovation Centres (TICs) to the UK is based.

The project team also conducted research into the structure and organisation of innovation within two overseas railways, the US and Japanese systems, as well as three other industries, the UK aerospace manufacturing, defence and energy generation and supply industries, engaging with the Aerospace Innovation and Growth Team, the Aerospace and Energy KTNs[9], the UK Energy Research Centre[10] and numerous internal experts on these industries within Atkins. Bearing in mind the opportunity for GB rail to potentially benefit from leveraging its products, services, expertise and know-how into global markets, the project team also researched the size of the global innovation market, drawing principally on work done by UNIFE / BCG, DfBIS and NESTA:

- UNIFE World Rail Market Study: Status Quo and Outlook 2020[11]
- DfBIS R&D Scoreboards 1990-2010[12]
- NESTA Innovation Index Project[13]

4.1.1 General conclusions drawn from previous research

Our research provided the following general conclusions:

6 Ref: http://www.futurerailway.org/Pages/consultation.aspx
7 Ref: http://www.fraunhofer.de/en/
8 Ref: http://www.instituts-carnot.eu/en/instituts-carnot
9 Refs: http://www.innovateuk.org/deliveringinnovation/knowledgetransfernetworks.ashx
10 http://www.ukerc.ac.uk
11 Executive summary can be seen at http://www.bcg.com/documents/file60454.pdf
12 http://www.innovation.gov.uk/rd_scoreboard/
13 http://www.nesta.org.uk/areas_of_work/economic_growth/the_innovation_index

Other sectors and industries which form part of critical national infrastructure such as defence, energy, aerospace and rail manage innovation as a 'structured innovation management system', being a coordinated and collaborative (including participation from SMEs, OEMs, academia and government) approach to channelling new methods, ideas, products and services into their industry. For example, the UK Aerospace industry is represented by the Aerospace Innovation and Growth Team (AeIGT) and the automotive industry is represented by the Automotive Innovation and Growth Team (AIGT). In numerous instances innovation is managed on an economic (country) level, for example with the operation of the Fraunhofer Institutes.

Successful industry innovation management system relies upon both formal and informal roles and responsibilities that define the scope of innovation and innovation performance. Other sectors have realised the need to collaborate in order to materialise additional value. For example, Hauser points out that inputs to the innovation process complement one another so that the total is worth more than the sum of its parts. Any weakness in the innovation system disproportionally affects the performance of the whole system. A successful innovation approach at industry level has to rely upon an approach that pursues excellence across all key innovation capabilities. An 'innovation management system' manages the value and interactions of innovation across the sector.

There are a range of innovation enablers that have been established both within GB rail and outside it which enable stakeholders to invest and engage at the most appropriate Technology Readiness Level (TRL). TSAG have already identified a range of themes for innovation. The innovation management system needs to consider these themes, understand their value and provide the necessary support to coordinate TRLs through to innovation implementation.

Technology Readiness Level (TRL)
TRLs (individually specified in Appendix B: Technical Readiness Levels (TRLs) are widely used across many different industries to describe the process by which an insight or scientific breakthrough becomes a real-world operational system. They are principally used for technology

In some sectors the outcome of innovation is supported in many cases by dedicated research facilities, primarily used to share the cost and reduce risk of testing amongst the stakeholder group. For example, the AeIGT share a common research and development centre at the Manufacturing Technology Centre at Ansty. This is supported by major players in the aerospace sector as well as strategic SMEs who have expertise in specific technologies.

The resources, inputs and outputs that support the innovation management system are clearly defined; for example, types of research, types of technology, types of organisations, types of partnerships. Typically, a question arises as to whether innovation development should be primarily defined by the applicable sector[s] or the technology concerned. This is resolved in a variety of ways – for example, the Fraunhofer Institutes address specific sectors whilst referencing technologies in seven groups shown in the figure below:

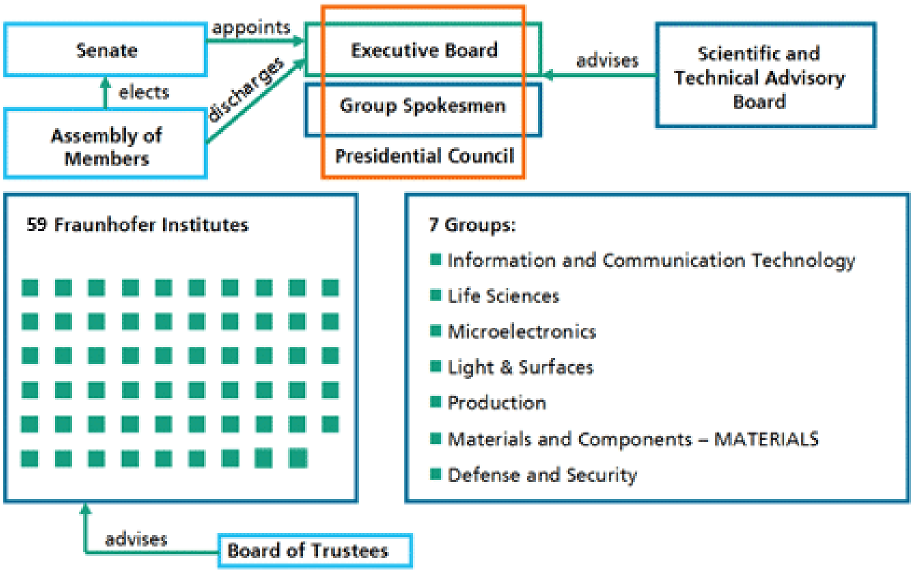


Figure 1: Organisation of the Fraunhofer institutes showing seven technology groups

Importantly, industries tend to adapt around capabilities to work rather than focusing on what could work within the constraints of the current industry. Consequently, it should be seen and expected that the industry is continually adapting to streamline the delivery of the **capability** via functions that are typically enabled by technology and not the other way around. Hauser points out that government funding cycles have not supported longer term investment for longer term innovation to work. In some instances, longer-term funding, beyond two years, is not legally guaranteed. Hence effort is placed by management to secure additional funding by other means which obviously becomes a major distraction to the benefits of the project.

It is recognised that the existing organisations within the UK Rail sector provide the currently defined governance framework for railway operation and it is clear that innovation is being carried out in various places within the sector. However, innovation does not appear to be valued or managed as part of the front-end improvement process for the UK Rail sector, although there are strong signs (for instance, the rollout of the Network Rail innovation management process described below and the ongoing RIA innovation conferences) that a groundswell of support for change is beginning to build. However, within the context of an 'innovation management system' there is no shared framework for understanding or positioning the role or value that different organisations bring to innovation. For example, the recent output from TSAG outlines a range of useful initiatives regarding innovation, but it is difficult to understand how these initiatives are going to materialise and what value they will bring to the industry and wider economy.

Hauser, by contrast, identifies that there is no formal process or oversight, coordination, promotion and prioritisation of investment in TICs at a national level to ensure alignment with national technologies and strengths. Hauser calls for new approaches to investments in TICs to deliver a step change in the UK's ability to commercialise its research. To ensure the success of innovation-enabling change, the current roles and responsibilities within the railway governance framework will need to be adjusted and new / additional responsibilities need to be defined.

A number of enablers need to be developed that enable stakeholders in the industry to engage with innovation more effectively. Some of these have already been identified, although they need to be put into context within a 'railway innovation management system'. For example, it has been recognised that a 'Systems Authority' would support the management and scoping of innovation capabilities and technologies enabling 'business pull'. In addition, model terms of engagement could be defined, enabling visibility of the innovation TRL so that testing facilities are used purposefully with specific measures of performance and value contributing to the management of the innovation.

Metrics (benefits) are not clearly defined as to the value of improvements relative to the whole railway system, although it is recognised that the improvements are valuable and need to be defined, but only in a tactical and technical context. The improvements are not particularly valued in relation to the railway system or railway industry and are viewed in many cases as being in conflict with the immediate commercial drivers of industry stakeholders.

There does not currently appear to be a systematic method of exploiting development work for the greater good of the GB rail sector (or the GB rail sector in a global context for the greater good of the UK economy), as opposed to the greater good of the commercial interests of the individual stakeholders. This is in contrast to the situation in the 1970s and 1980s when BR (in most but not all cases BR Research) sponsored and developed for implementation innovations which delivered significant enhancements to the rail business (and in turn delivered increased revenue, decreased operating costs and improved performance). Examples include the development and production implementation of:

- The Class 253/254 High Speed Train which revolutionised InterCity Rail travel
- High Speed Freight Bogies which permitted much faster freight transits
- The world's first Solid State Interlocking (SSI)* which allowed more efficient signalling control
- Pacer low-cost DMUs for rural and urban routes* which provided cheap capacity
- AC traction drive systems, allowing faster acceleration and finer efficient control of energy
- Track condition monitoring- allowing risk-based track maintenance to be prioritise
- Radio Electronic Token Block (RETB) delivering low cost signalling for rural routes

Examples asterisked * above were even developed in partnerships with private sector companies including in some cases, new entrants to rail. It is instructive to note what could be achieved then by a nationalised industry despite, or perhaps spurred on by a tight era for funding, but also in some cases achieved through development partnerships with non-rail industries (aerospace, automotive, power).

Currently, the non-integrated multiple stakeholder structure of GB rail sector does not demonstrate "the kind of drive to focus on innovation for overall system benefits that was clearly shown in BR days" (as one stakeholder described it. Even if consensus can be achieved that a particular innovation will bring overall "GB rail system" benefits, the contractual interfaces and considerations of cost and benefits mean that a business case for investment is difficult to construct – consider the illustrative case study example at right.

The decision-making process within the GB rail sector is now dependent upon consensus. Organisations should ideally adapt their decision-making capability to platform thinking, which requires new insight, responsibilities, skills and capabilities if the decision-making process is to be more dynamic. Some of these shortcomings have already been identified, for example the change in standards to 'output requirements specifications'. The way in which these are defined and managed will require a role change, involving a higher degree of engagement and responsibility for some of the organisations in the industry. It is likely also that a resurrection of a "leadership role" of the kind shown by BR Research will catalyse better performance, though perhaps not in the way designed for the 1970 / 80s railway.

Case study: A better rolling stock bogie

1980s rolling stock could be sensibly life-extended providing affordable capacity without new build. Manufacturers might use this opportunity to provide new bogie designs which ride and curve better doing less track damage (lower whole- life costs, safer), as well be being more comfortable for passengers (attracts custom).

All these benefits are clear at a system level.

However, who invests in the development? Almost certainly the manufacturer, but from whom do they obtain their return? Network Rail benefit but may not charge lower track access fees, the TOCs benefit but will resist higher leasing fees from the ROSCO. There is the risk of the opportunity not being realised at all, since the costs and benefits fall unevenly.

4.1.2 Understanding the problem situation

Following focussed research, it is clear that a large number of GB rail industry improvements have already been identified which, if addressed, *could and would* improve the way in which GB rail operates and, in particular, offer benefits in terms of enhancement of capacity, efficiency or other tangible benefits to customers and taxpayers. However, it is recognised that it is difficult to understand how effective these improvements will be and to specifically quantify the benefits these improvements will bring.

Part of the problem is seen to be generating ‘business pull’; the means by which GB rail business drivers are defined and then the realisation of how these drivers are met. Shared technical priorities as expressed through TSAG / TSLG and the Rail Technical Strategy notwithstanding, the business drivers in the GB rail industry continue to be defined in ways that are contradictory to collaborative innovation – Network Rail being focused on infrastructure development, operators being focused on delivering the franchise, for example. This means that the way in which GB rail is organised means that the primary focus is internal for each type of stakeholder’s sphere of influence and objectives and that their objectives and structure are not aligned to deliver overall benefit for the UK taxpayer. Costs and benefits therefore fall unevenly between stakeholders with a consequent lack of shared objectives. Innovation in GB rail therefore must be understood in a wider, more systemic context if its potential to add value is to be understood.

Innovation, defined here as the **development of new methods, products, services, systems and capabilities – and the bringing of change based upon them** – is, in some sectors and wider economies, seen as fundamental to support the means by which industries and hence economies can develop and grow. Industry sectors and whole economies have developed effective mechanisms for managing innovation so they can measure their performance and position on a global basis.

Significantly, Hauser identifies that the strengths of competing global economies is influenced by the exploitation of research and development through innovation. In order to grow the UK economy and place the UK in a leading global position the UK must capture and exploit innovation to the fullest potential before other economies do so and, as our financial analysis and research into global markets bears out, we believe that the benefits from adopting an approach that recognises can bring substantially greater benefits to the industry and the country as a whole than the solely domestic benefits of innovation within the industry.

5 Analysis of GB Rail industry innovation system

> **The Innovation System Structure (ISS) and Innovation Process Maturity Spiral (IPMS)**
> The ISS and IPMS frameworks are used to assess systems in holistic terms – in other words, to analyse both what is there and what is not, according to what ought, ideally, to be there. Because both can be presented as "spider diagrams" (with different coloured lines representing different instances) they can be easily used to compare similar systems and identify gaps between them. ISS is used to analyse the content of a system and IPMS is used to analyse the process that takes place within the system from inception to ultimate goal.

5.1 Innovation models and frameworks used in analysis

The project team were tasked with creating a model using measures to assess the effectiveness of innovation and, having defined innovation as it relates to the GB rail industry, using examples to validate where the GB rail industry sits in comparison with other organisations The model used would have to be capable of measuring innovation so as to estimate where the industry would move to if all the initiatives and changes are fully accepted.

The team defined a measure of the effectiveness of Research, Development, Testing and Innovation, capable of identifying trends over time and suitable for benchmarking & analysis of other industry innovation systems. The base content was two existing "open-source" best-practice structural and process maturity analytical and diagnostic frameworks:

- **the Innovation System Structure (ISS) and**
- **the Innovation Process Maturity Spiral (IPMS)**

These were configured to align with the boundaries of the GB rail innovation system. Whilst the explanatory box above describes these, a fuller explanation is given in the next section.

5.1.1 Innovation System Structure framework

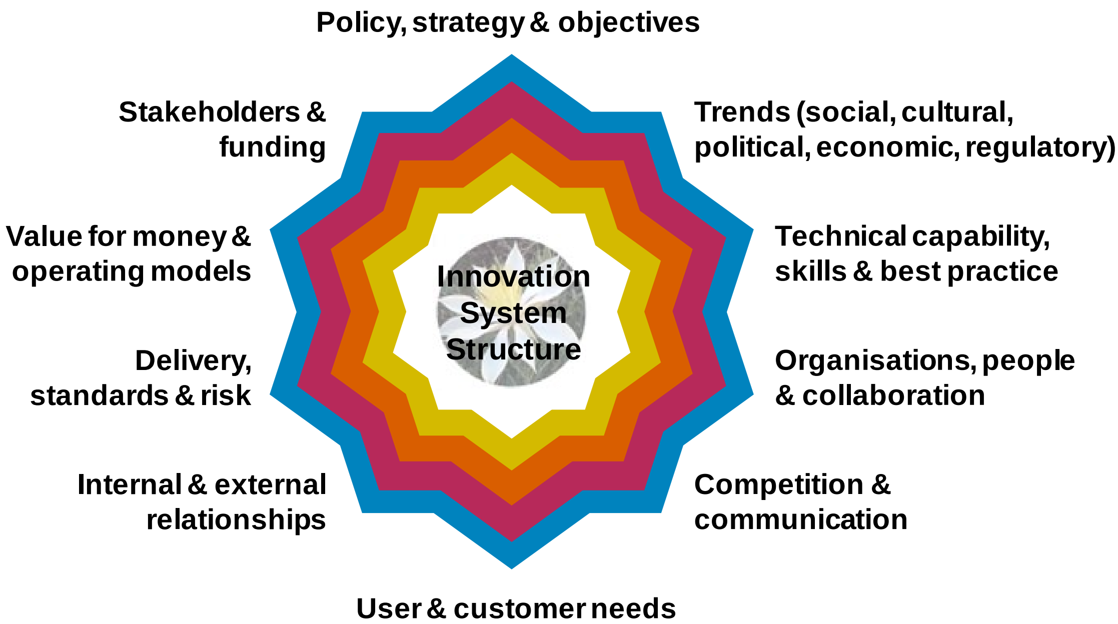


Figure 2: Innovation System Structure model configured for the GB rail innovation system

The Innovation System Structure model (ISS) displays a system-level view of organisational or industrial activity. It is based upon an "idealised design" holistic systems approach where the aim of the system is to maintain productive dynamic tension (for more detail on what this means, see Appendix E, with no subsystem exerting undue influence, carrying undue risk or distorting the overall aim of the system. Based on a long-term analysis of organisational structures and subsystems relating to innovation in numerous industry sectors, including IT, payments, professional services, fast-moving consumer goods, healthcare and latterly engineering and transport, all innovation activities can be broken down into the following ten categories ("dimensions") and related to an archetypal idealised design of the content of the system:

Dimension	Related innovation activities & subsystems
Policy, strategy & objectives	Strategy formulation, goal-setting, visioning, leadership, clarity of purpose
Trends (social, cultural, political, economic, regulatory)	Opportunity and market identification arising from knowledge strategy, environmental and regulatory considerations, horizon scanning, trend-watching, creativity and innovation theory, undirected research
Stakeholders & funding	Prioritisation, budgeting, resource allocation, investment strategy, sources of funding
Technical capability, skills & best practice	Technical / technological investigation, prototyping, experimentation, directed research, proof of concept, Intellectual Property (IP) generation
Value for money & operating models	Financial scenario modelling, cost-benefit analysis, investment return, breakeven analysis, sensitivity analysis, business case development, IPR modelling
Organisations, people & collaboration	Integration activities, change management, facilitation, internal / external collaboration and partnering, knowledge-sharing, organisational learning, skills development
Competition & communication	Proposition development, market research and market communications, branding, competitive differentiation, unique selling points
Delivery, standards & risk	Testing, project management, delivery process efficiency, cost control, risk management, quality and safety, supply chain management
Internal & external relationships	Channel strategy, route to market, purchasing / procurement interface, contracting
User & customer needs	User experience modelling, customer journey analysis, user insight testing

Table 1: Dimensions of ISS and related innovation activities and subsystems

Successful innovation requires that activities take place across all ten dimensions of ISS to a greater or lesser degree. The absence of activity on any one of these dimensions constitutes a risk to innovation delivery:

Dimension	Critical success factor
Policy, strategy & objectives	Innovation needs strategic commitment, purposeful leadership and objective-setting from the very top.
Trends (social, cultural, political, economic, regulatory)	Innovation that ignores the insight that can be gained from proper consideration of the environment in which it is expected to take place, in particular external factors acting upon the innovation space (such as legislation) does so at its peril.
Stakeholders & funding	Without support and prioritisation from key controllers of organisational resources and adequate and sufficient funding models innovation will be stifled.
Technical capability, skills & best practice	Deep technical competence and the ability to experiment and pursue lines of possibility are both indispensable if insights are to be valid and viable.
Value for money & operating models	Too many constraints make innovation mechanical and unadventurous; too little means not enough caution; lack of attention to modelling the benefits of innovation, or inappropriate expectations of return on investment are lethal.
Organisations, people & collaboration	Perspectives focusing on investment criteria, technical feasibility or user / customer need must be integrated from an early stage, which means

Dimension	Critical success factor
	overcoming significant cultural barriers, not to mention organisational behaviours.
Competition & communication	Innovation is no use to users and customers if they are unaware of it, can't get access to it or it doesn't better the competition – or if there is no reason to believe that it fulfils a need or performs appropriately.
Delivery, standards & risk	If the promise of innovation cannot be delivered in an effectively controlled and repeatable manner, or if barriers to challenging the status quo exist is withheld, execution will be poor – if it happens at all.
Internal & external relationships	Innovation requires absolute clarity over who owns responsibility for engagement with the customer, how the customer is engaged and clear lines of responsibility over how the relationship is managed, to avoid confusion, mixed messages and barriers to effective delivery.
User & customer needs	Innovation requires a profound level of understanding of both implicit user and customer needs as well as explicitly stated requirements – failure to gain this is inevitably fatal.

Table 2: Critical success factors for innovation expressed in terms of ISS

ISS can be used to assess the effectiveness of an innovation system by means of qualitative anchored scales, producing a holistic view of its structural integrity. The assessment framework used with stakeholders for this project is shown below:

	1	2	3	4	5
To what extent is innovation driven by industry strategy & policy?	No strategic relevance or contravenes strategy / policy	Low strategic / policy priority	On-strategy, clearly aligned	Priority growth area	"Burning platform" strategic imperative
To what extent does innovation align with sectoral, environmental & regulatory trends?	Challenges standards, may be unacceptable to external world	Some issues which can be overcome with careful planning & application	Reasonably straightforward & acceptable to regulators	Demonstrates not only compliance but best practice	Challenges limits of best practice, reveals systemic shortcomings
To what extent does innovation present a technical challenge for the industry?	Hard to see how it could be done even if strongly supported	Challenging but feasible with right commitment of resource	Clearly achievable within definite timescale if appropriately resourced	Straightforward , demonstrable previous track record	Technical components readily available internally or off-the-shelf
To what extent is innovation compatible with industry culture, skillset & structure?	Required culture, skillset & structure in conflict with significant inertia	Requires substantial commitment to bringing in new skillsets or structure	Moderate change required but mostly straightforward	Some adjustments required to support weaker capabilities	Strong industrial capability, highly motivated staff
To what extent does innovation affect industry competitiveness?	Reduces competitiveness of the industry	Neither improves nor worsens, incremental change	Contains some industry-differentiating elements	Significant, hard-to-match differentiation	Unique, "blue ocean" offer, no alternative
To what extent does innovation deliver benefits for users & customers?	Less utility for users & customers	Commoditise d market, no additional utility	Marginal utility for users & customers	Significant utility for users & customers	Unique ability to fulfil desired function
To what extent does innovation impact industry relationships & channels?	Implementation causes significant pain to industry relationships &	Channels & relationship managers not aligned or convinced of	Some alignment of channels & relationship managers	Channels & relationship managers already aligned & keen	Huge demand from channels & relationship managers prepared to

	1	2	3	4	5
	channels	utility	necessary		invest
To what extent does innovation challenge industry supply & delivery capability or appetite for risk?	Capability hard to come by without significant pain & risk	Tough challenge for existing delivery capability	Requires some change & investment in capability	Straightforward achievability	Capability already exists
To what extent does innovation deliver cashflow and value for money?	Poor RoI, not worth investing in compared to other potential projects	Marginal RoI but still worth doing if resources permit	RoI meets internal criteria for positive decision	Good RoI, either large or speedy, to justify funding	Significant & / or speedy RoI, attractive to external investors
To what extent does innovation meet the needs of industry stakeholders?	Politically difficult, may compromise core capabilities	Less of a priority than competing calls on resources	As important as other projects & initiatives but not more than all	More of a priority than competing calls on resources	Critical enough to warrant redeployment of key resources

Table 3: ISS anchored scale for assessing the structural integrity of an innovation system

Innovation Process Maturity Spiral framework

Whilst the ISS is used to assess the various types of content and action within the system, the Innovation Process Maturity Spiral (IPMS) is used to assess the maturity of activity through the system, Like the ISS, the IPMS is an idealised design approach which takes the journey of innovation from insight to reality, which is typically institutionalised within both organisations and industrial systems as a stage-gate process:

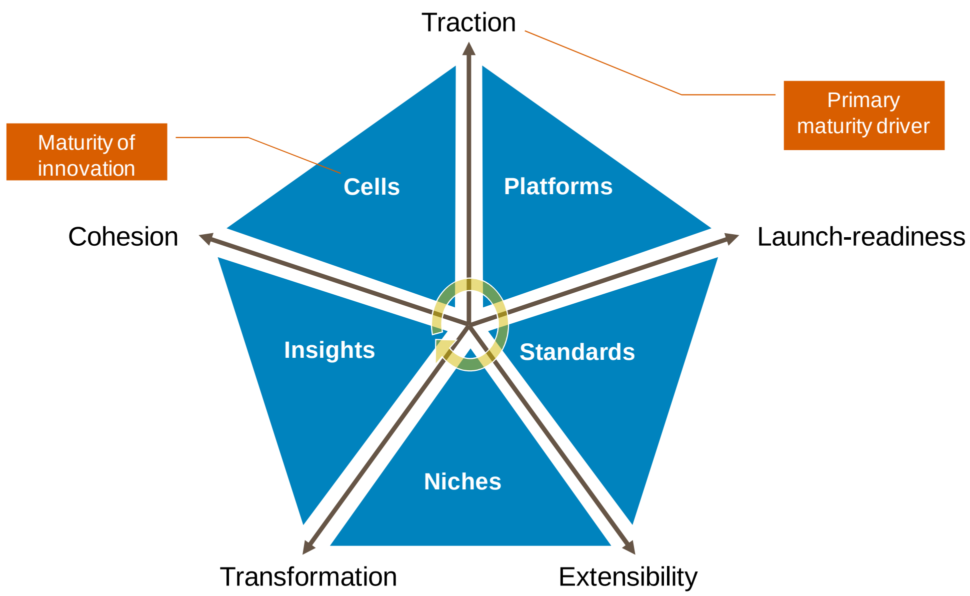


Figure 3: Innovation Process Maturity Spiral (IPMS) model showing stages of maturity and primary maturity drivers to reach the next stage.

Maturity level		Primary maturity driver	
Insight	A "germ", someone's bright idea, not fully thought through but worth exploring further with specific expertise	**Cohesion**	"Well-formedness", creativity, validity, degree to which it captures potential sponsors' imaginations
Cell	Limited exposure beyond a small circle who evangelise and build in an effort to engage key stakeholders	**Traction**	Believable viability to meet an identifiable need or proposition which can be verified via prototyping, testing and user research
Platform	Potential recognised by stakeholders and approval sought to invest in a launchable build	**Launch readiness**	Appropriate market conditions, available resourcing, compelling value proposition and clear delivery channel and user utility, mitigated risk profile
Standard	Clear, straightforward, scalable attractiveness to the target market and wide potential for growth	**Extensibility**	Scope for global applicability and significant profits or cost savings beyond the core user community or target market once firmly established
Niche	A particular application with strong adaptability to a limited market but limited potential beyond marginal growth	**Transformation**	Crossing boundaries, finding new applications which can disrupt established markets elsewhere or fulfil a previously unrelated function or user need

Table 4: Different stages of innovation process maturity and the drivers of maturity at each stage

5.1.2 Innovation Platforms Approach

It is important to emphasise the importance of the term "platform" (as understood in IPMS and in innovation good practice) which denotes a capability, asset or system which enables the speedy execution and wide extension of multiple market applications:

- Platforms facilitate and sustain long-term value;
- Platforms take time to build, but are extremely difficult for competitors to mimic;
- Platform development is a managed risk involving the investment of time and resources;
- Value is created throughout development, but tangible returns only appear when applications are launched.

Platform
A facility, system or capability in which one invests, but does not of itself make money or reduce costs. A platform provides a means by which other services capabilities and systems can be based and which do deliver value of this kind. An example in GB Rail could be ERTMS / GSM-R provided that sufficient thought is given the wider applications that can be "hung" from it. As is shown below the collaborative development of SSI is a successful GB rail platform.

Platforms are highly effective when developed by individual organisations and numerous examples from multiple industries are available. However, platforms that are developed by industries are rarer due to the difficulty of establishing an open innovation model at industry level along the line envisaged by ISS / IPMS. Platforms at industry-level require industry-level leadership, collaboration and investment, together with commercial driver alignment across organisational boundaries and, as will become clear, this does not exist within GB rail.

As shown in the IPMS model, the innovation process is also a cyclical spiral in which value increases over time with launch-readiness marking the point of greatest increase in value generation from the platform. As the number of applications diminishes over time and the limits of extensibility are reached, it is these limits that spur a new lease of life by disrupting or creating entirely new spirals.

It is evident from an analysis of the maturity stages of IPMS and the key drivers at each stage, that the skills, structures, processes and decisions required for successful innovation are very different at each. In complex industrial innovation systems, no one entity / organisation has all of the skills, staff, processes & capabilities necessary to effect change & drive activity across the entire innovation spiral. For innovation to succeed across organisational boundaries, integration across the spiral stage interfaces is critical.

Case study: Platforms

The GSM-R network may be considered a "Platform" in the GB rail context. It provides the means to carry modern digital communications data and the number of potential applications and uses is not yet exploited fully. For example, it might be perfectly possible to permit use of the GSM-R network to :

- deliver high quality data services to train passengers
- stream TV and advertising to trains
- transmit train telemetry to transmit vehicle health data to home depots and allow balanced rolling stock maintenance to be optimised in real time
- transmission of controls and commands to signalling field objects obviating the need for lineside cabling and permitting low-cost signalling.
- undertake remote monitoring of crowding or crime incidents

The risk is that the concept may have been too tightly specified to permit these applications- all of which save cost or generate income to be "hung" from the platform – a missed opportunity.

The principal cause of integration failure is most commonly the lack of understanding of platforms – both people and organisations focus on their locus of [apparent] control and those closes to their immediate or personal priorities. As a result, they tend to ignore the considerations of other stakeholders and try and effect control over the entire spiral in order to gain sole benefit. This behaviour results in a characteristic pattern of trying to go anti-clockwise straight from idea to niche, which results in a poor idea-to-delivery hit rate which one piece of PhD research into idea management estimated to be as low as 0.34%.

Another unique aspect of the IPMS model is its inclusion of the effects of innovation in one system upon another: as the number of applications of a launched platform diminishes over time and the limits of extensibility are reached, it is these limits that spur a new lease of life by jumping the curve, in many cases transforming completely different sectors. A further key to the understanding of the IPMS framework is the idea that what an innovation process actually does is to manage **investment risk** over **time** with the object of creating value to users and / or customers. The source of this risk is most easily visualised by considering the behaviour of different types of value-creating stakeholders in an industry with regard to intellectual property.

Ideally, commercial organisations want their innovation IP for free, without taking the risk of investing in it over the "mountain of uncertainty". There is reluctance to get involved at the early stages, before the value has been created, but, obviously, this is subject to contingent pricing later in the process. Conversely, universities are intensely involved in the creation of IP from fundamental research but frequently lack the means to enter the market on their own without commercial partnerships. Moreover, academics are less concerned with results as long as funding remains available. The result is an uncertainty gap between where universities' drive peters out and where the drive for commercialisation begins in earnest.

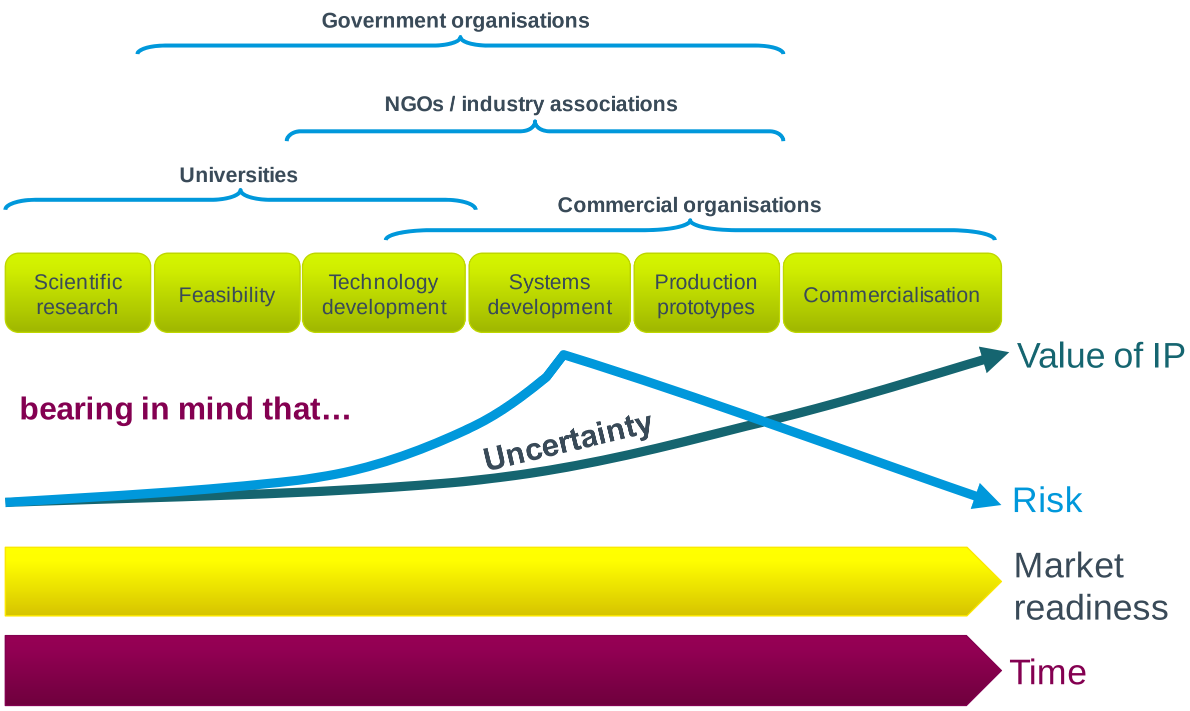


Figure 4: Innovation risk & value over time in a complex industrial system

Case study: High Speed Train (HST) versus Advanced Passenger Train (APT)

Considering these two competing technical innovations in the 1970s illustrates why the “Mountain of Uncertainty” is a crucial issue to address. HST harvested known (but state-of-the-art) technologies and integrated them into a train prototype just as BMW do for all new models of their automobile ranges. Put through exhaustive trial and evaluation, it was optimised for fleet production and successful commercial deployment – the smaller ‘mountain of uncertainty’ was crossed more easily through thorough testing

APT was at the cutting edge, employing untried technologies and in a new application and the mountain of uncertainty was, therefore, proportionately large. Business pressures forced premature “freeze” for commercial entry into service with poor results and project cancellation. Unfortunately non-GB manufacturers picked up the concepts and persisted, such that modern tilting trains are based on successful evolutions from the ATP concept – a missed opportunity for GB rail supply industry to take a 15-year lead on technical rolling stock solutions in widespread demand.

In complex industrial systems which are a public good, such as the railway, it is that gap that governmental organisations like the Technology Strategy Board or industry associations often provide bridging support and funding. However, when, as in GB rail, the risk associated with delivering innovation affects multiple stakeholders, no one organisation, even Network Rail, can truly act in isolation. This is the gap that results in what in GB rail is known as the “valley of death” – this is where innovation generally runs into its biggest problems.
As with ISS, IPMS can also be used to assess the effectiveness of an innovation system by means of qualitative anchored scales, producing a holistic view of its process maturity and optimal behaviours at each stage. The assessment framework used with stakeholders for this project is shown below:

Process stage / driver	1	2	3	4	5
Cohesion	Few insights, low quality research, not well structured or coherent, lots of "not-invented-here"	Small number of insights, deficient evidence base, incremental, not focused	Enough insights, moderate quality, reasonable evidence base, not linked to industry goals	No shortage of insights, well evidenced, linked to strategic industry goals	"Ideas are not the problem", whether sustaining, radical or disruptive, focused on both present & future, grounded in high-quality data
Traction	No forum in which to share insights, convince or collaborate, industry disincentives	Some forums exist but industry behaviours do not allow collaboration	Established forums for collaboration but few incentives to gain end-to-end industry buy-in	Established mechanisms for socialisation & collaboration, limited to industry boundaries	Open & clear collaboration process , strong networks crossing industry boundaries, clustering, leveraging & building industry platforms
Launch-readiness	Significant barriers to certification of system-worthiness , difficult to access test-beds	Some barriers to certification, shortage of test facilities, difficult to get sign-off	Clear route to certification & adequate provision for testing, some issues with sign-off	Established, clear processes for testing, sign-off & launch, transparency of stakeholder oversight	New launches are "business as usual", open access to affordable test-beds & certification process, other industries follow best practice
Extensibility	Capability is actively prevented from extension to adjacent applications within the industry	Silos or lack of knowledge sharing prevent extension beyond core	Launch of occasional niche applications, but little leverage of benefits into marginal revenues	Clear path to creation of niche applications & extensions, some marginal revenues	Industry constantly launches new extensions & variant applications, meeting niche requirements & generating significant marginal revenues
Transformation	Innovation is unfit for transfer to other sectors due to low quality or restrictive industry practices	Occasional external adoption of tried-&-tested incremental improvements	Moderate external adoption of innovation & re-use of some approaches & technology	Regular lift-and-drop, some radical external interventions & transfers of best practice	Constant flow of disruption into other industries, sourcing of research capability, large demand for technology transfer programmes

Table 5: IPMS anchored scale for assessing the process maturity of an innovation system

IPMS can be easily aligned with another standard framework used in multiple industries, namely Technical Readiness Levels (TRLs):

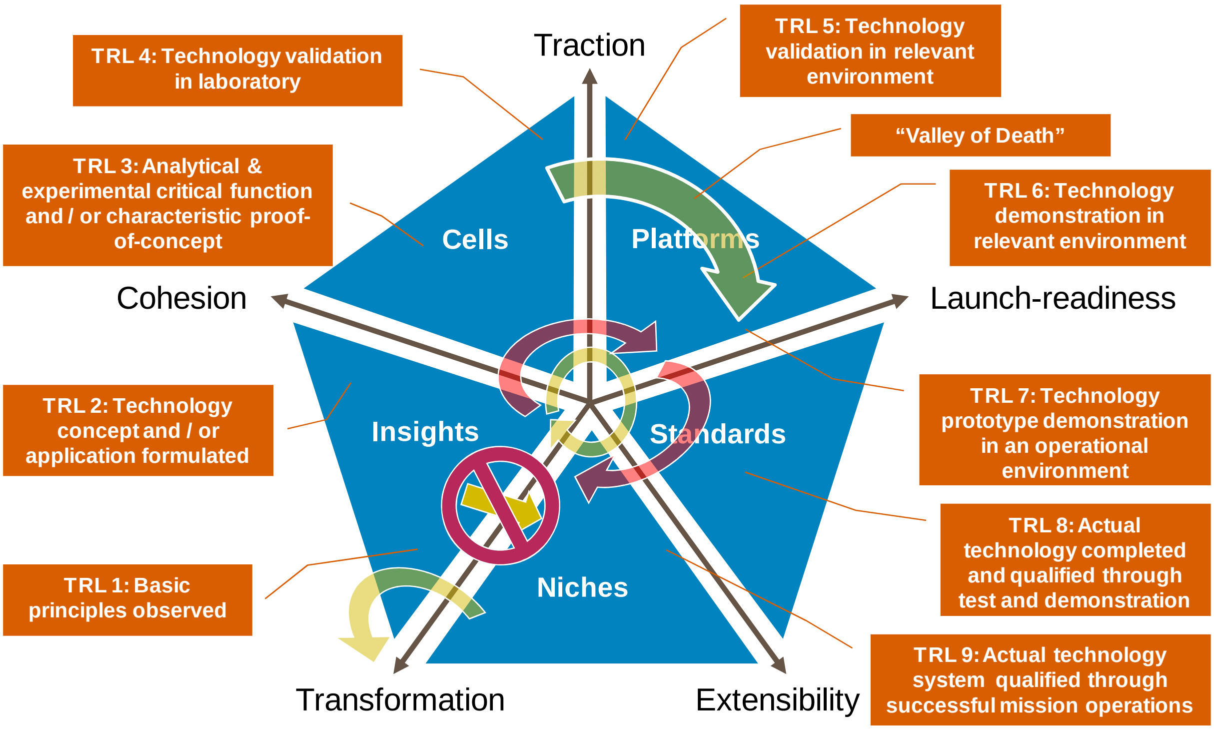


Figure 5: IPMS model showing mapping to Technical Readiness Levels framework

The "mountain of uncertainty" / "valley of death" described above is situated between TRLs 4-6 and is overwhelmingly associated with the challenges of platform building.

5.1.3 How ISS and IPMS combine to model whole-system capability

Whilst the ISS looks at the structures across an industry system, the IPMS is designed to analyse industry capability across innovation-led change processes. However, the combination of the two gives an extremely rich picture of both the structure of an industry and the system's maturity as far as innovation is concerned, analysed in terms of its subsystem areas and structural tensions. This approach, combining both structural and process analysis at a system-wide level in two holistic and interdependent frameworks, enables specific interventions and portfolio management systems to be designed which directly address any capability gaps or systemic weaknesses to create end-to-end holistic integration:

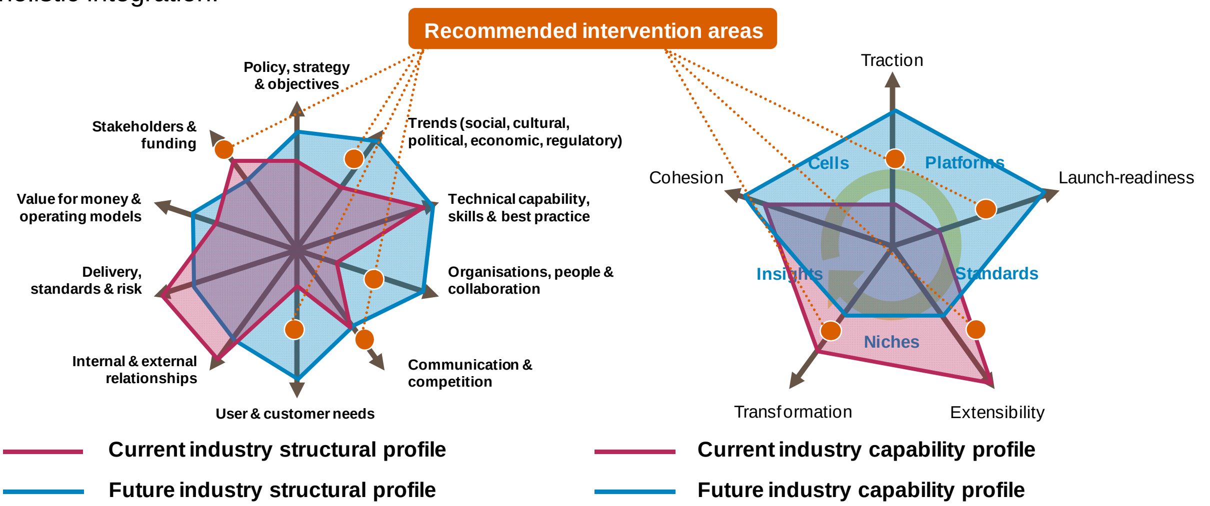


Figure 6: Combination of ISS & IPMS models showing indicative areas for targeted intervention

As described above, recommendations for systemic interventions can be scored based on a configurable balanced scorecard approach, enabling ongoing monitoring and review. The combination of both frameworks also demonstrates the capabilities that are needed across the system at each stage of the process:

	Cohesion	Traction	Launch-readiness	Extensibility	Transformation
Strategy, policy & leadership	Purpose definition & scoping	Strategic maturity & urgency	Mandate for launch	Mandate for growth	Permission to challenge status quo
Sectoral & theoretical trends, regulatory & environmental changes	Secondary research, evidencing of insights	Directed research & investigation	Scenario planning & competitive analysis	Responsiveness & "early warning" network	Data sourcing, trend analysis, sector scanning
Organisational structure & stakeholder relationships	Identification of key resources	Prioritisation of resources, silo-busting	Alignment of initial go-to-market structure	Scalability of execution structure	Challenge and reorganisation
Technical excellence, creative insight, R&D	Structured idea generation, clustering	Technical deep-dive, proof of concept	Prototyping, testing, dry running	In-service testing, category management	Data mining, lift-and-drop opportunities
Systems, processes & operating models	Initial assessment criteria, quick scanning	Business case & process development	Go / No-go "hard" decision-making	Standardisation and scaling processes	Inventive problem-solving, disruption
Cross-functional integration: culture, people, teamwork, synergies & skillbase	Casual conversations, workshops & cells	Upskilling, partnering, cross-functional links	Defined go-to-market or execution team	High-performance teaming, OTJ training	Porous borders & synergy identification
Delivery, quality & risk management	Challenge, feasibility, risk workshopping	Risk mitigation & quality measurement	Performance reliability & process stability	Continual "lean" process improvement	Systems thinking, fundamental limits
Marketing, communications, reputation, competitive threats	Market identification, value definition, core message	Value proposition development, channel identification	Competitive positioning, channel access planning	Channel management, defence of core value proposition	Pro-active offensive activity against tomorrow's competition
Relationship management, channels, suppliers & partners	Customer utility identification & characterisation	Partnering, target segment piloting, strategic procurement	Launch strategy, key segment planning, commercial decisions	Point-of-sale promotion & account management	"Your best users / partners / customers may be your worst"
Users & customers	Customer journey / experience analysis	Beta testing, key user groups, influencing	Key adopters, first-movers, power-brokers	Key account development	Tomorrow's biggest user / customer

Table 6: Combined IPMS / ISS matrix showing capabilities required within an innovation system at each stage of process maturity

This capability perspective demonstrates precisely what the right skills are in each area and stage of the innovation system. Having right skills means that people need to have an understanding of appropriate innovation techniques, the ability to build business case arguments, to manage innovation programmes and the many other competencies described in the above table.

The combination of both models thus provides a complete, holistic picture of both the entire innovation lifecycle from idea to commercialisation (including research, development, testing, launch and in-life operation) and the content of the innovation system (thus enabling the identification of structural trends over time). They also demonstrate how innovation systems run beyond organisational boundaries; even a discrete project may stretch beyond to a consortium or even an industry.

It is also worth making clear that people, process and technology are inherently part of and embedded in every subsystem of both frameworks and, at a greater level of analytical granularity (i.e. decomposing each ISS subsystem into a lower-order "innovation subsystem structure", each plays a part in the ability of this subsystem to contribute to the delivery of the required capability. The IPMS also reveals the importance of the platform-building stage of innovation, which is particularly challenging, as capability platforms cost money to build, but generate no value and save no money until applications that use the capability are actually launched.

The five different quadrants of the IPMS demonstrate the challenge of managing innovation across the entire process as well as the need to balance the needs of the present against the needs of the future. The skills, structures, processes, knowledge and decisions at each stage of the spiral are very different and different organisations have different strengths and capabilities which allow them to act most effectively in specific areas around the spiral. The capabilities are enabled by behaviours which are proxies for the people demonstrating these behaviours. This structural perspective can be analysed using the ISS, which in combination with the IPMS proves to be a powerful and effective systematic approach to understanding the management of innovation in complex and ambiguous spaces, making it possible to identify shortfalls, weaknesses and gaps even at industry system level.

5.1.4 Caveats in using ISS / IPMS

ISS/IPMS are tools which are best used for systematic analysis and assessment of all relevant aspects of innovation systems structural integrity and process maturity. They quickly enable the user to draw out deep insights about the relationships of subsystems and system actors, they reveal tensions, lacunae and both strength and weakness. It is these qualitative aspects that affect system integrity and process maturity. Anchored scales are intended to separate out levels of maturity, not show quantitative measures of value. A score of 4 in an ISS/IPMS assessment is not, for instance, twice as good as a score of 2. ISS/IPMS scoring is most effective when used to identify differences and gaps, to draw comparisons and spot how an innovation system falls short of the ideal, similar to the use of a Pugh matrix[14] for facilitating option selection, a "value curve"[15] for characterising differences between market propositions, or an "evolutionary maturity plot"[16]. This implies the development of consensus from stakeholders in the system of what precisely constitutes the ideal design of the system in their view. This idealised design approach allows the identification of "what ought to be" from an examination of "what actually is" by virtue of its inclusion into consideration of all possible elements of the system.

[14] Matrix-based method for determining the most optimal selection from a number of options, widely used in engineering. More information is available at: http://www.thequalityportal.com/q_pugh.htm
[15] "Blue Ocean Strategy" – see the book by Kim & Mauborgne (2006) or the website http://www.blueoceanstrategy.com
[16] For an example of how this is used, see http://www.osaka-gu.ac.jp/php/nakagawa/TRIZ/eTRIZ/epapers/e2003Papers/eMannDeWulf0303/eMannPatentAnal030316.html

The effectiveness of the ISS/IPMS approach is particularly demonstrable from its use in assessing an innovation system on the basis of the insights of a small number of well-informed stakeholders. It could in theory be used to create a statistically valid survey, but this would require a far greater number of participants, which is beyond the scope of the current work. The assumption driving the assessment in this report is that the opinions of a small number of sufficiently well-informed (and senior) stakeholders are of more value than the opinions of a greater number of less experienced survey respondents. Naturally, this means that the risk of non-inclusion of a particularly influential point of view is correspondingly greater.

ISS/IPMS should be used to draw conclusions only with considerable care. Ideally, both should be used to draw out hypotheses, contradictions and areas for further detailed investigation, as it relies on the accuracy and well-informedness, goodwill and honesty of contributors to a given instance of the models. Similarly, a great deal of care should also be taken in the configuration of the models and anchored assessment scales, the precise characterisation of its dimensions in terms of the reality with which stakeholders are familiar and the phrasing of the questions that seek to draw out their insights. It will always remain possible to disagree with the configuration of a model or precisely whether a particular subsystem or system interface should be included in one or other dimension or quadrant.

5.1.5 Analytical methodology for this study

The structural and process integrity of various innovation systems was analysed to provide a whole-industry innovation risk profile based on the combination of the ISS and IPMS, modelling both how the industry is structured, how it balances present needs with future needs and how it introduces new technology and working practices from conception to maturity.

For convenience and simplicity, the constituent elements of the risk profile models thus created was combined into a numeric “Innovation Index” that is both meaningful, useful and suitable for cross-industry comparisons of “like with like” performance. Data for the profiling and benchmarking of the innovation systems was obtained by conducting an analysis of the systems of GB rail (past and present), three other industries and two overseas railways, to analyse how new products, services, technologies, processes and working practices are introduced.

The analysis consisted of a series of structured interviews of participant organisations in the industries in question (except overseas railways which were conducted by desk research), driven by questions based around the ISS and IPMS. Structured interviews were conducted paying particular attention to culture and collaboration across the industry as part of the ISS and IPMS analysis. The current state of the GB rail industrial innovation system was then benchmarked along the dimensions of time and sector, thus permitting comparison with previous system states (up to 20 years previously) and alternative industrial sectors and transport modes at the present time.

5.2 Defining innovation success

Innovation Index
A means of ranking innovation performance, to benchmark GB rail innovative capability against comparable sectors or similar railways.

5.2.1 Primary considerations for GB rail in creating an industry-level innovation management system

Previous work within the VfM workstream by Arthur D Little has identified the need for some form of System Authority to deal with system-level issues of safety, standards and technical and the project team has considered the validity and viability of this proposal in the light of how it might act as an enabler for innovation within the industry. We have assumed that one of the outputs of the RVfM work will be a System Authority with a remit and locus to enable greater innovation in GB rail.

This proposal must consider **three different routes** by which innovation is delivered to the GB rail industry:

1. **Supplier innovation** from the traditional value chain (“inside-out”)

Suppliers to GB rail can be relied upon, both individually and as a group, to be driven by their commercial considerations to innovate their products and services for profit. They will naturally develop, test and launch new products and services in line with their appetite for investment risk in innovation activities, the pull and attractiveness of the GB and international rail market and their abilities to engage in technical innovation.

Hauser Principles.
Guiding principles of UK plc's national innovation-led growth approach to the exploitation of global markets potentially worth billions of pounds per annum, where the UK has truly world-leading research capability, or potential business capability and absorptive capacity to make use of increased investment to capture a significant share of high value activity, using TICs to attract and anchor the knowledge-intensive activities of global mobile companies and secure sustainable wealth creation for the UK.

Supplier innovation follows a comparatively straightforward and clear route to market, albeit one that has been identified as historically complicated and bureaucratic by numerous stakeholders. Nonetheless, NR are in the process of improving their product approval process (see the case study below in section 5.3) and if approvals and compliance with standards can be improved enough to facilitate the introduction of innovative products and services, this does not require a Systems Authority – unless, as is not uncommon, the approvals and standards affect multiple systems or affect system interfaces (train-track or Railway Undertaking to Infrastructure Manager).

In such a case, an appropriate decision could be made by a group of about 3-5 stakeholders having a sufficient level of technical understanding but not limited to technical competence. The system authority must also be able to take an informed decision in terms of not only value for money but all ten dimensions of innovation system structure as described in ISS.

The principal points at which the systems decision should be made during the industry innovation process are between TRLs 4-6 and consequently the specific ISS capabilities required at those points must be available to the decision-making body (see section 7.2 below)

Platform
A facility, system or capability in which one invests, but does not of itself make money or reduce costs. A platform provides a means by which other services capabilities and systems can be based and which do deliver value of this kind. An example in GB Rail could be ERTMS / GSM-R provided that sufficient thought is given the wider applications that can be "hung" from it. As is shown below the collaborative development of SSI is a successful GB rail platform.

2. **Leveraged innovation** from other rail industries and indeed other industries ("lift-and-drop" / "outside-in")

GB rail also needs to be able to cater effectively for the introduction of tried-and-tested innovation imported or more correctly 'lifted and dropped' from other rail industries. Similarly, some way of appropriately assessing and adapting technology, processes and insights, not only from adjacent sectors in transport but also from other industries entirely is also required.

3. **Industry platforms**

The proposed industry innovation management framework must be able to act to research, investigate, propose and commission the development of industry platforms as defined above and discussed in IPMS. These platforms will require funding from the industry, effective systemic decision making (as discussed above) at development stage-gates and a way to align commercial drivers.

The importance of global growth and world-beating capabilities

Effective application of the Hauser principles (see section 5.2.2) requires recognition that GB rail operates in a global market. If GB rail is to manage innovation effectively at industry level, there must be clarity of focus as to which parts of the industry "value stack" should be developed into world-beating capabilities.

This strategy is naturally available to all participants in the industry and indeed members of RIA, RFOA and other suppliers, or any organisation that operates in global markets like participants in the Energy Generation & Supply and Aerospace Manufacturing industries, for example EDF or Rolls-Royce.

However, the industry as a whole is likely to benefit substantially from an ability to launch platforms developed for GB rail into global markets and has in fact done so successfully in the past – an instructive example is the introduction by British Rail of Solid State Interlockings (SSIs) in the 1980s – the world's first Solid-State signalling interlocking, and though mature technology now, it enjoyed considerable export success:

- The three principal partners, BR, Westinghouse and GEC came to an arrangement whereby the two industry partners were given free access to the network to test the new system and then received royalties from any offshore sales. Although the size of the royalty was small, over 1,500 contracts were received as a result.
- Commercial incentives were aligned to the degree that IP and even circuit boards were shared.
- The collaborative relationship was not disrupted by the demands of procurement, as no OJEU process was undertaken once the design had been stabilised.
- The net result was that 10-12 times the number of contracts for SSI equipment was sold to the overseas market.

All the stakeholders thus far consulted, including Network Rail, view this proposed development as a welcome one, as they recognise that revenue from overseas growth can be used to subsidise the cost of GB rail. It is worth noting that other countries have already successfully adopted this strategy by leveraging the world-class capabilities in selected parts of the value stack of their rail industries, notably Germany, via Siemens and Deutsche Bahn; France (Alstom, Systra and SNCF/RFF); the US (GE); Italy (Ansaldo) and Japan, (organisations like JARTS and suppliers like Hitachi and MHI).

In Japan, unconstrained by European rules on procurement, there is an even more integrated approach, via organisations such as JARTS and RTRI working hand-in glove with academia and with suppliers such as Hitachi and MHII. Our discussions with some of these organisations have revealed that they looked at the BR research model (for the establishment of the RTRI) as a means to facilitate innovation. They look to harvest technologies from outside Japan, such as use of fuel cells and Lithium-Ion batteries in rail and indeed in Friction-Stir welding, developed in partnership with TWI.

Case study: Friction-Stir Welding

Friction-stir welding of aluminium rail vehicles offers significant opportunities for light-weighting and stronger fabrication of carbodies. This technology was developed by TWI, but investment and co-operation from Hitachi enables them to reap the benefits and provides an example of GB rail largely missing out on the export potential of an innovation which offers a keen rival an advantage; and, ironically one aided by Britain.

We therefore suggest that a sustainable solution depends upon the industry which recognises that GB rail innovation needs to drive global revenue growth and further suggest that the proposed industry innovation management solution engage with UK Trade & Industry (UKTI), the body tasked with developing British overseas trade opportunities and with the Rail Industry Association (RIA), the trade body specifically focussed on UK-based rail suppliers. This model should position GB rail systems suppliers to gain further business opportunities which benefits UK plc as a whole, in a similar way to the countries cited above.

Network Rail believe that there is potential to build international alliances to facilitate access for GB rail to the global market, pointing in particular to AAR/TTCI as a channel to the US market. NR also mention the TWI (Welding Institute), another independent research and technology organisation based in Cambridge, as a potential channel partner, particularly for software, as it is currently chaired by NR's Engineering Director and already functions along Fraunhofer principles.

It is widely recognised that whilst the UK science and research capability is second only to the US, the UK falls short in translating scientific leads into leading positions in new industries. It is clear that the leisurely translation of scientific discoveries into new industries and new capabilities has been replaced by a race between nations to take advantage of these discoveries and translate these discoveries into economic success stories before others do so.

In the wider context, therefore, the UK Rail sector should make choices to focus its attention to developing its capability only where:

- There are large global markets worth billions of pounds per annum
- The UK has technical leadership
- There is a defensible technology position; and,
- There is capacity to anchor a significant part of the value chain from research to manufacture in the UK

These are seen as the *primary business drivers* for the UK Rail industry (or any UK industry sector) and provide clarity and focus for managing the process of innovation so it can be exploited into economic success and these are encapsulated in the "Hauser Principles".

5.2.2 The UK plc considerations for industry-level innovation systems: understanding and disseminating the "Hauser Principles"

The scientist and entrepreneur Dr Hermann Hauser, author of the "Hauser Review"[17] commissioned for the Department for Business, Innovation and Skills (BIS) under the previous government establishes straightforward and practical principles for what contributes to a perfect environment for long term growth and sustainable innovation at industry and national level. These include:

- **Funding** from the taxpayer to an "intermediate institution" (i.e. which can bear risk and apply procedural rigour)
- Indicators of **excellence** in R&D: not just the amount of research, but the amount of "quality" research papers and spin-offs resulting from research
- The ability to take advantage of this combination of research excellence, spin-offs and funding via appropriate **industry interfaces**

Hauser considers that historically, there exists a poor relationship between setting of policy and UK business and his work to improve this relationship has driven the recent flagship publication "Blueprint for Technology", launched by the Prime Minister, in which one of the key industry interfaces, Technology Strategy Board (TSB) is identified as "a key channel through which we will incentivise business-led technology innovation".

The launch of "Blueprint for Technology" coincides with the investment of £200m into "Technology Innovation Centres" along the lines of the Fraunhofer Institutes described in Appendix C. The Hauser principles envisage a situation where industry innovation systems at national level sustain themselves within the context of multibillion-dollar global markets; numerous examples of this in overseas rail industries, for example those of Germany and Japan and other transport sectors, for example aerospace and automotive, are in evidence.

The TICs are explicitly intended to act as drivers of future economic growth. The centres are designed to make advanced technology available at an industry level, where individual companies cannot afford to invest in them on their own. TICs are particularly being considered where there will be a significant, coordinated, long-term return investment and this can bolster competition in an industry element to ensure that the centres remain relevant and valued by industry long into the future. Initial priority areas are likely to be:

- High Value Manufacturing
- Energy and Resource Efficiency
- **Transport**
- Healthcare
- Information and Communications Technology (ICT)
- Electronics, Photonics and Electrical Systems

[17] Ref: http://www.bis.gov.uk/assets/biscore/innovation/docs/10-843-role-of-technology-innovation-centres-hauser-review

TICs are aimed at bolstering the introduction of new technologies through the provision of organisational infrastructure and facilities which is targeted at the gap between research and technology commercialisation (particularly at TRLs 4-6) in areas where the UK has the potential to gain substantial economic benefit. They are also explicitly intended to integrate with the overall UK innovation system, including the innovation platforms, collaborative R&D support, Knowledge Transfer Networks, Knowledge Transfer Partnerships and the Small Business Research Initiative (SBRI) operated by the TSB (The TIC oversight committee will report to the TSB's governing board), not to mention interfacing with EU innovation programmes. The new Centres are also intended to complement other types of centre which operate at different points in the research and development cycle, from Research Council Institutes, through Innovation and Knowledge Centres to contract research organisations, consultancies and virtual centres.

In the context of the national agenda to position the UK at the front of the field as far as innovation is concerned, the Hauser principles point to a very clear route to success based on clarity of focus about which part of the industry "value stack" to fight for as a country. We believe that these principles are entirely applicable to GB rail and consistent with the aims of the VfM study. This view has been echoed by the stakeholders, who believe that the "UK technology brand" is very strong across the world, pointing to expertise particularly in R&D and at early TRLs. An appropriate solution must provide the industry interface for determining and this growth strategy and an industry investment fund as a vehicle to pursue this growth strategy are therefore in alignment with the best practice of the Hauser principles and should also provide adequate separation for the global growth strategy from the ongoing business of delivering a cost effective GB railway.

Hauser Principles
Guiding principles of UK plc's national innovation-led growth approach to the exploitation of global markets potentially worth billions of pounds per annum, where the UK has truly world-leading research capability, or potential business capability and absorptive capacity to make use of increased investment to capture a significant share of high value activity, using TICs to attract and anchor the knowledge-intensive activities of global mobile companies and secure sustainable wealth creation for the UK.

5.2.3 Proposed Framework for developing the innovation management system

The innovation management system for the industry should be able to act as the eyes and ears across sectors and the innovation support mechanism / 'voice' both into and out of the Rail Sector. Its proposed remit should cover:

- Setting up, gathering data for and monitoring an 'innovation index that includes measurement of the performance and value of innovation intervention to the UK Rail sector;
- Supporting the development of platform capabilities from cradle through to 'platform sign off' by the systems authority, supported by a suitable model for managing intellectual property rights and collaborative investment mechanism. Monitoring the status of the platform up to sign-off;
- Facilitating (by virtue of the ability to take a cross-sector view) the focus on research organisations to support research that would enable platforms, by, for example, developing a range of funded research programmes to support stages through the lifecycle of the platform.
- Facilitating the development of strategy for centres of excellence based around platform delivery (across sectors) feeding and sourcing from organisations involved in early TRLs, including the Transport KTN (established in April 2010 and including rail, automotive and maritime modes) and Rail Research UK.
- Providing platform support (for example, NR or other facility owner's support for testing and evaluation would be a key enabler)

Knowledge Transfer Network (KTN)
A KTN is a national network in a specific field of technology or business application which brings together people from businesses, universities, research, finance and technology organisations to stimulate innovation through knowledge transfer. KTNs have been set up to drive the flow of knowledge within, in and out of specific communities.
KTNs have been established and are funded by government (through the Technology Strategy Board), industry and academia. They bring together diverse organisations and provide activities and initiatives that promote the exchange of knowledge and the stimulation of innovation in these communities.
There are currently 24 KTNs, including one for transport, hosted on _connect, a web-based networking platform.

- Bringing in other sector ideas and concepts that have worked elsewhere ('Lift and drop').
- Working with the collaborative investment mechanism to managing cross-sector IPR issues so IPR can be exploited into and out of the rail sector.
- Providing advice and support with model commercial agreements to enable the rail industry to engage the supply chain (sourced from across sectors)
- Interfacing with sector economies / government to support area / sector growth around regional bases e.g. the West Country for Aerospace
- Interfacing across economies where partnerships need to be established where GB rail doesn't have (or want) the capability
- Monitoring of sector influence on local/regional economies

Methodology for implementing the innovation management system

The team was asked to develop a clear and simple implementation plan for the innovation management system to succeed and be effective. We developed this plan based on Soft Systems Methodology[18] (SSM) because this approach results in the production of recognisable components which clearly reveal the base functions required for management systems to work. Functional requirements for an effective innovation management system based on a generic management system profile are as follows:

Activity #	Functional requirement of management system	Level of function
A	Appreciating the work to be undertaken	Innovation system (content)
B	Decide the scope of work to be undertaken	Innovation system (content)
C	Decide the actions to take	Innovation system (content)
D	Obtain instructions and resources	Innovation system (content)
E	Carry out the work	Innovation system (content)
F	Define measures of performance	Innovation management system
G	Monitor innovation system activities	Innovation management system
H	Take control action	Innovation management system
I	Appreciate actions for the system	External influential factors
J	Define measures of performance effectiveness	External influential factors
K	Monitor innovation management system activities	External influential factors
L	Take control action	External influential factors

Table 7: Functional requirements for an effective innovation management system based on a generic management system profile

Their relationship in terms of system content, operation and externalities is shown below:

[18] Checkland, P., Scholes, J., (1999). '*Soft Systems Methodology in Action'*, John Wiley & Sons Ltd.

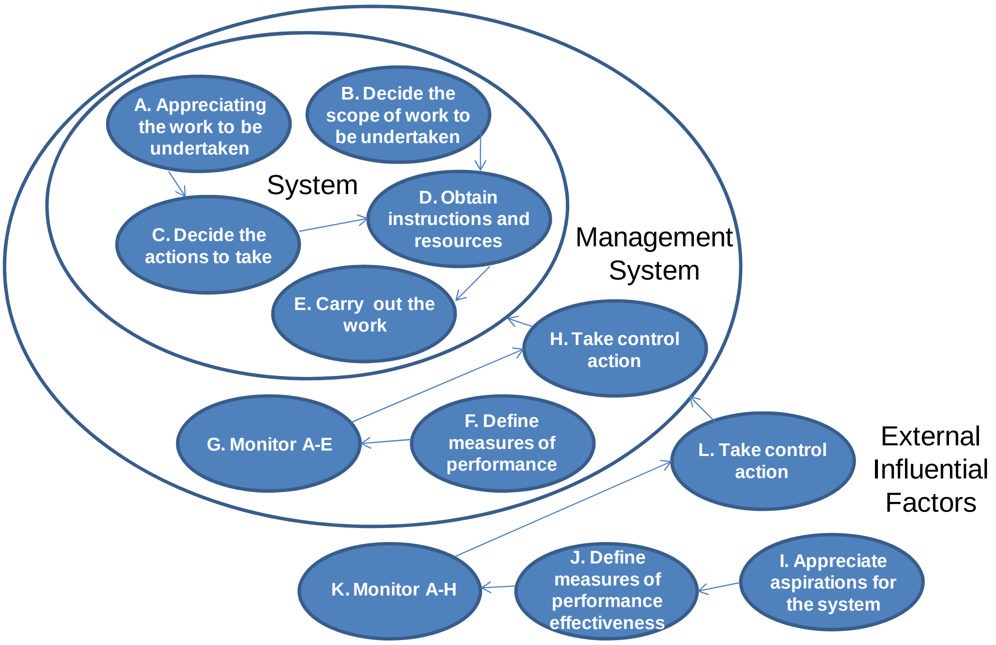


Figure 7: Functional requirements for an effective innovation management system

Using SSM, the implementation plan described in section 7.1 below considers the development of each one of these requirements in context of the innovation management system and then interprets the management system requirements into a series of actions required for the implementation plan for the innovation management system. A high level programme is provided to indicate the sequence of tasks and timeline.

A successful industry solution should take specific care to avoid bespoking and the elimination of what is known in some circles as the "Treasure Island Effect", where UK implementations of tried and tested technology are alleged by some stakeholders to cost significantly more when GB differentiation, widely considered as unnecessary, is factored into the development cycle. One example of costly bespoking that is mentioned by numerous stakeholders is the "yellow button" added at the insistence of the operators that is alleged to have added 25% extra costs to the implementation of GSM–R when GSM was already established as a tried-and-tested standard. Another example is the degree of changes that were required to be made to customise non-UK computer-based interlockings to suit GB application, as well as the additional engineering work which added weight and complexity to the innovative Class 395 Javelin Trains:

Case study: Javelin Class 395
GB Railway Group Standards requirements added significantly to the weight and cost of the Javelin Class 395 High-Speed train, when a more progressive approach would have been to look at the "whole-train" design and accept that its bogie performance, its robust construction and operation mainly on fully ATP-protected routes offered an acceptable solution and the degree of 'bespoking' could be reduced.

In situations like this where stakeholders are at loggerheads, the decision is ideally referred to an effective senior body. Bechtel cite the example of the Hong Kong Government's "AdsCom" (Advisory Committee of Government) that operated as a systems authority during the first tranche of major rail projects in the 1990s, worth £15bn over seven years. It was not seen as desirable for a problem to end up being referred to AdsCom, there was, rather, a strong political incentive to avoid such referrals and resolve issues at an operational level in real time. Such incentivisation does not present a difficulty if data on the number of referrals over time is collected and analysed according to proper statistical principles to see that it does not display anything other than common cause variation.

Case study: The AdsCom model- Hong Kong Rail development
AdsCom met fortnightly on a Saturday morning in order to handle problems and issues that could not be resolved through existing decision-making bodies but if not resolved, would add delays and costs to these projects. The crucial point here is that AdsCom did not act as another layer of authorisation ('blocker'), but rather as a source of leadership in challenging circumstances (an 'unblocker').

5.2.4 An ideal vision for the future of innovation in GB rail

Currently, any weakness in the innovation system has a disproportionate affect on the performance of the whole system. There is no formal process or oversight, coordination, promotion and prioritisation in investment in TICs at a national level to ensure alignment with national rail technologies or strengths.

We have not yet established the basis of the evidence that points to the rationale for investment in TICs (comparator within the Rail sector). We understand that discussions on this subject are ongoing with RIA among others to define a broader programme of work with strategic intervention and support from the TSB. Therefore it is difficult to understand the adequacy of the level of integration between the organisations in the rail sector, although there is evidence of disparate activities and potential duplication.

5.2.5 Ideal Final Result

Ideal Final Result
In this context, this is the unconstrained ideal innovation capability and performance that GB rail aspires to attain.

As part of the stakeholder consultation exercise, we undertook an exercise to define an "ideal final result" in terms of ISS and IPMS. An ideal final result is the system in a state that would be in place given no constraints of money, time, skills or resources – it is by definition 'Ideal'.

There was a strong degree of consensus amongst stakeholders for either, which enabled us to establish a baseline against which the effectiveness of the proposed innovation enablers could be judged. Figures 8 and 9 below characterise the ideal final result for GB rail innovation.

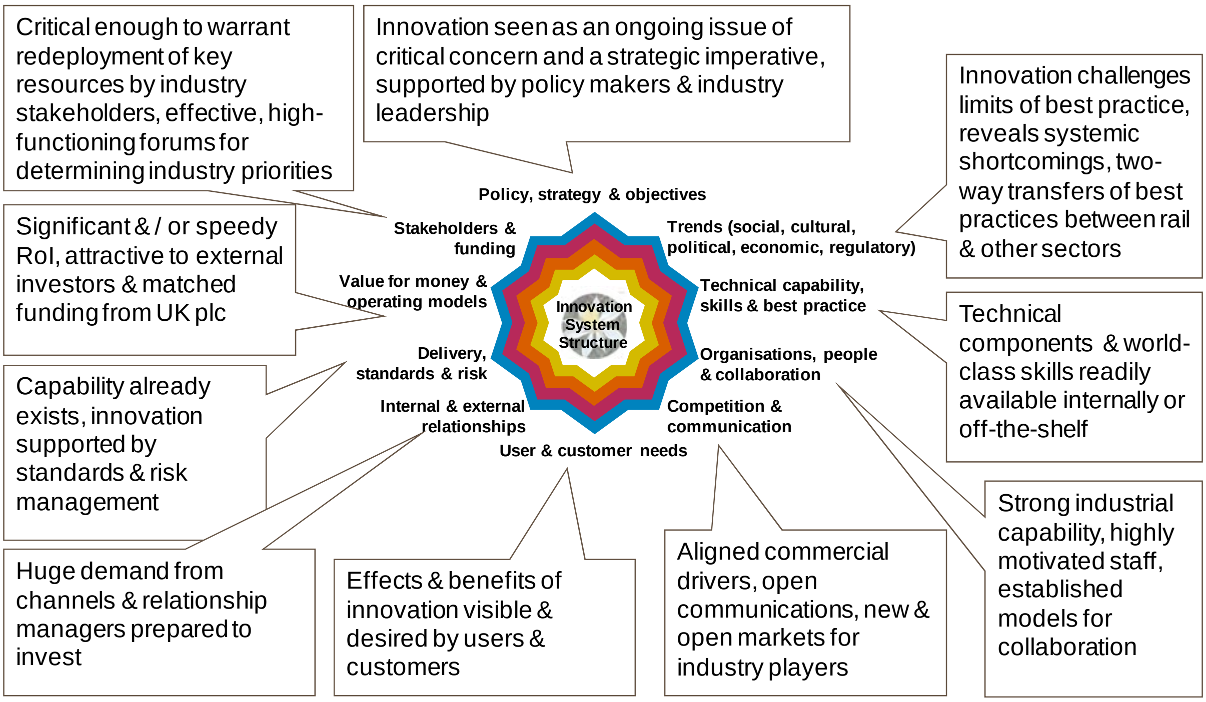


Figure 8: Stakeholder consensus of an "ideal final result" for innovation system structural integrity

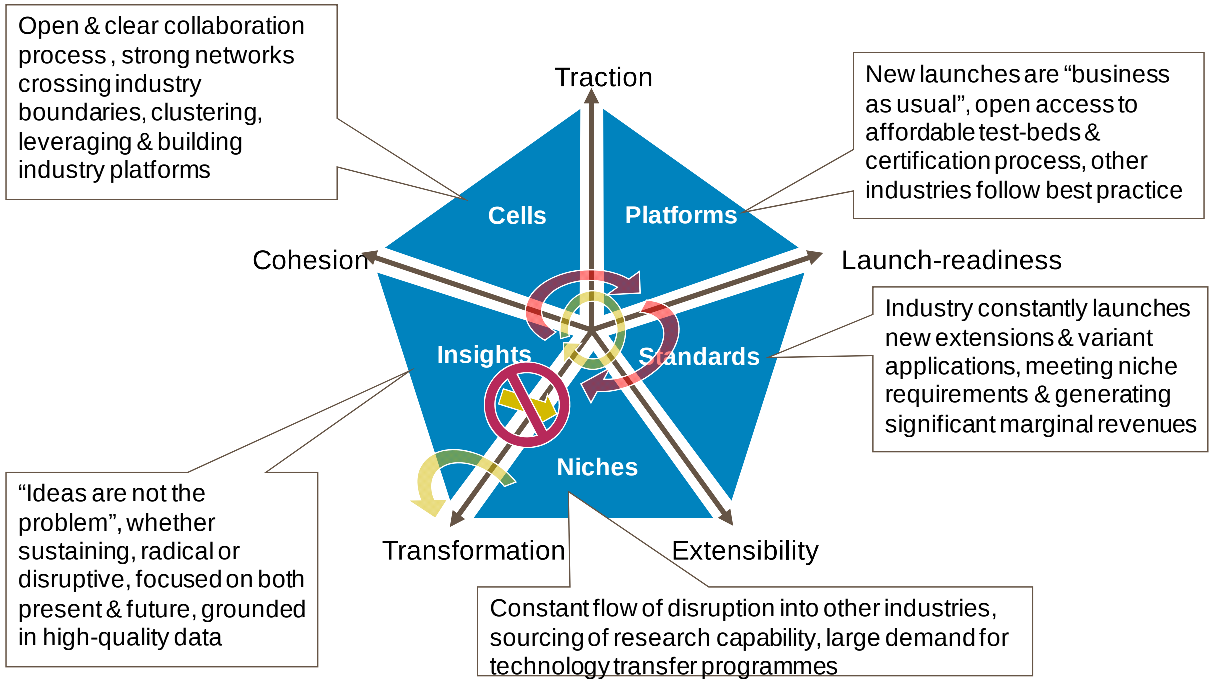


Figure 9: Stakeholder consensus of an "ideal final result" for innovation system process maturity

5.3 Defining an Innovation Index

The team were requested to define a measure, drawing on academic research where appropriate, of the effectiveness of Research, Development, Testing and Innovation (an Innovation Index), capable of identifying trends over the last 20 years.

As requested, we have produced an index built from a stacked version the risk profiles produced by the ISS and IPMS models which can easily be used to visualise and benchmark innovation capability within the industry. Two previous approaches to defining innovation indices were considered by the team in the design of the innovation index. The DTI R&D scoreboard, maintained on an ongoing basis for ten years, but which has been discontinued from 2010, assembled a data set from published company accounts (thus "ex post") combined with a value-added scoreboard, which enabled moderately successful comparison between sectors. The DTI, now BIS observed some sharp sectoral differences in terms of "innovative" against "non-innovative" sectors, also attempting to benchmark the UK against the rest of the world. However, this approach focused overly on technical, R&D-enabled innovation via measurable investment and its relation to turnover in particular.

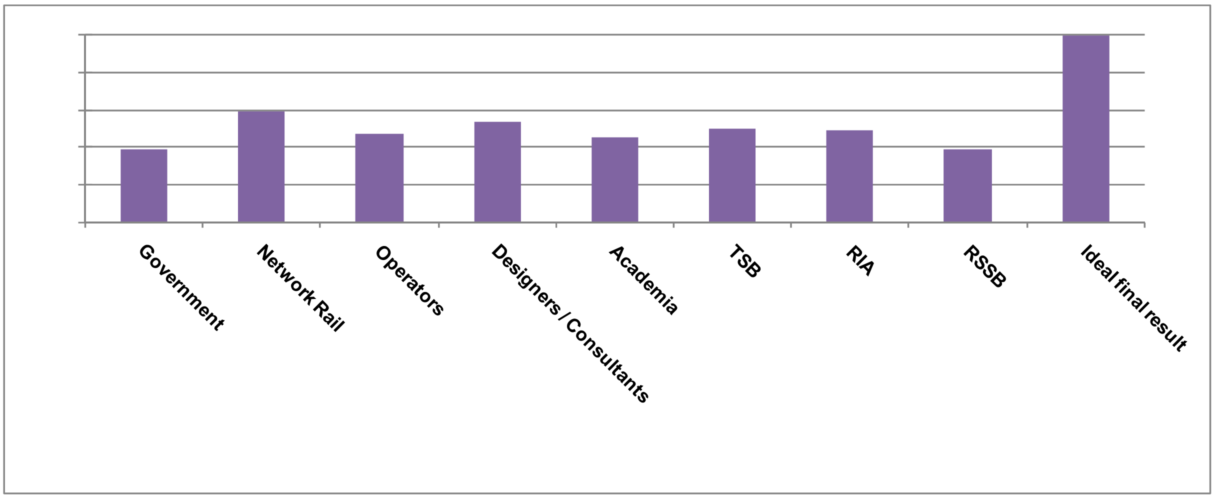
Innovation Index
A means of ranking innovation performance to benchmark GB rail innovative capability against comparable sectors or similar railways.

It is important to sound a note of caution in relation to the definition of R&D, as figures in company accounts are highly affected by powerful incentives such as the HMRC R&D tax credit. The existence of this credit, currently equivalent to an 8.5% discount on the cost of R&D mediated through the reduction of corporation tax, biases R&D towards the sort of R&D that qualifies for the tax credit, as well as biasing the data collected. Moreover, there are many things that might qualify as R&D which are excluded. Consequently, the skewing of innovation measures towards R&D, by contrast to a systemic view, overlooks other forms of innovative improvement in processes, management systems, collaborative working and intangibles. It was these shortcomings that appear to have driven the second interesting approach, that of the National Endowment for Science, Technology and the Arts (NESTA).

NESTA's ongoing work on an "innovation index for the UK", viewable online but as yet only delivered in draft form, takes a far more systemic and well-structured view of the nature of innovation and how it might contribute to the performance of a particular sector, with a view to making the UK's business environment as favourable as possible to innovation (as opposed to science and R&D, given the services bias of the UK economy as a whole). Such factors are readily identifiable in terms of technology / R&D-led innovation, such as the average level of PhDs in the sectoral workforce, or in terms of import-export performance in global markets.

Whilst some helpful baseline data has emerged from this work to date (for example, the interim conclusion that the grand total of innovation investment was 14% of GDP, of which R&D was only 1.8%) the approach as a whole, whilst impressive in scope, systemic in terms of its inputs and mathematically and statistically robust, is predicated upon an econometric approach which is both highly esoteric and difficult to draw practical lessons from. In short, its theoretical complexity makes it somewhat impractical to use as a basis for clarity of analysis for anyone other than skilled econometric modellers and there is a clear gap between the data that emerges from the model and the sort of clear and straightforward guidance that is required by GB rail. Nonetheless, it makes some excellent progress towards the identification of enablers for the innovation at industry level, which we have factored into our implementation plan.

We have, nevertheless, produced an index designed for clear, simple and straightforward industry comparisons, although caution on the use of such things without the proper contextual background should immediately be advised. The figure below shows a simplified version of the absolute index based upon responses to a survey-enabled consultation whether, in the perception of industry stakeholders the innovation system for GB rail is currently fit for purpose.

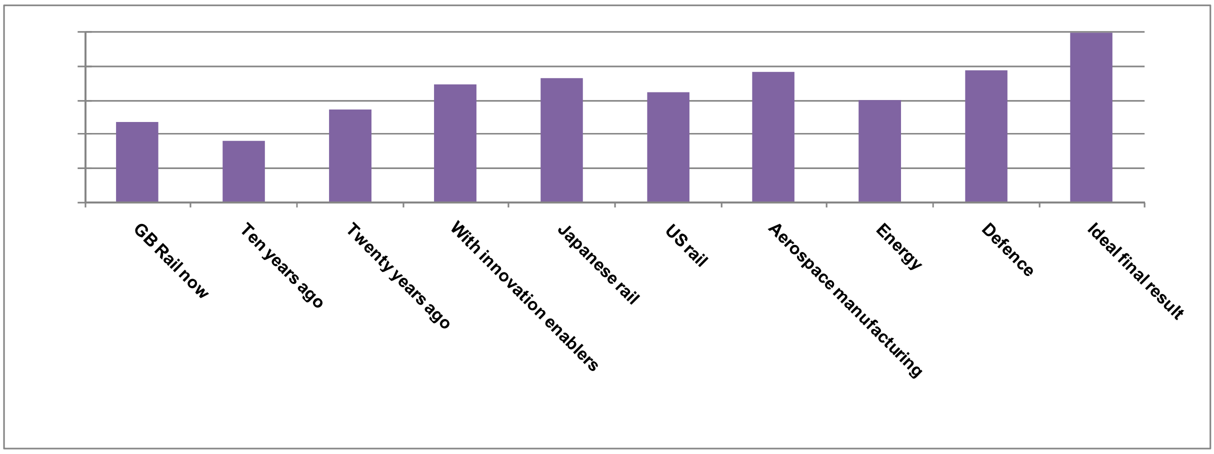


	Government	Network Rail	Operators	Designers / Consultants	Academia	TSB	RIA	RSSB	Ideal final result
Total index	39	59	47	54	45.5	50	49	39.25	100

Figure 10: Simplified innovation index for GB rail showing "whether, in the perception of stakeholders, the industry innovation system is fit for purpose"

The index is configured against a notional "ideal final result", which can be characterised as "the perfect system that would be in place were there no constraints of time, money, resources, risk, culture or skills", scoring 100/100; the characteristics of this ideal final result are described in section 5.2.7, Figure 9 and Figure 10.

The project team were also asked to produce an index which can be used to benchmark the GB rail industry as it is now against other industries and railways, in particular aerospace manufacturing (AM) and energy generation and supply (EGS), as well as against the situation in GB rail ten and twenty years ago. We have also included the defence industry, for reasons outlined in the comparator section 5.5.3.



	Now	Ten years ago	Twenty years ago	With innovation enablers	Japanese rail	US rail	Aerospace manufacturing	Energy	Defence	Ideal final result
Total index	47.1	36.0	54.9	69.7	73.5	65.0	77.0	60.5	78.0	100

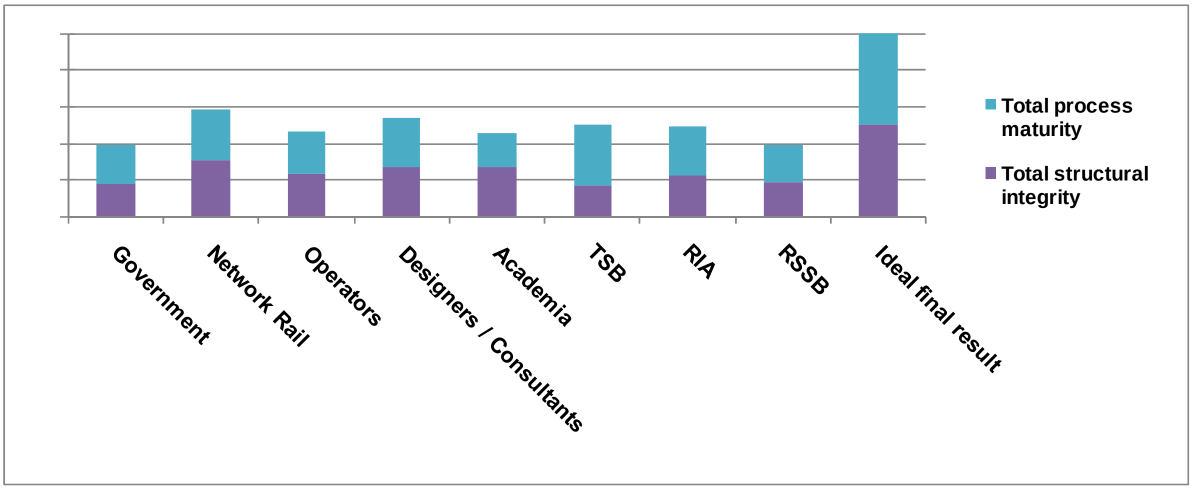
Figure 11: Simplified innovation index benchmarking GB rail against other industries and in previous states, showing "whether, in the perception of stakeholders, the industry innovation system is fit for purpose"

The index, based on the input of stakeholder groups including Atkins internal experts from the Defence, Aerospace, Energy and Rail businesses, Network Rail, DfT, the Technology Strategy Board (TSB), Rail Research UK, RIA, ATOC, Bechtel, Freightliner, Eversholt Trains, East Midlands Trains, the RSSB, the Aerospace Knowledge Transfer Network (KTN) and the Energy Generation and Supply KTN, indicates that there appears to be significant support for the perception that GB rail has a poor innovation capability even compared to itself twenty years ago, although a moderate improvement has been made since ten years ago. However, its capability appears poor by comparison to the robust index scores for AM, EGS, Defence, Japanese and US rail and certainly when compared to the ideal final result.

The stakeholders were also asked to consider the effect of innovation enablers being applied to the industry system, with particular reference to how the introduction of a set of innovation enablers including an undefined "Systems Authority" (the scope and constitution of which is being undertaken by a parallel work package for the VfM team) for safety, standards and technical excellence might impact on innovation.

The simplified index combines both the industry innovation process maturity and the industry innovation structural integrity. "Process maturity" denotes the process by which innovation is introduced to the industry and "structural integrity" denotes the components which must be present and correctly aligned in order for innovation to be successful; the critical success factors without which innovation is distorted to meet the requirements of particular subsystems and considerations, resulting in sub-optimal delivery and high levels of risk to value creation. An example might be innovation that is too concerned with the size of attractive markets at the expense of technical viability, or too concerned with short term payback at the expense of user / customer needs or industry culture.

Splitting out the industry innovation system process maturity and structural integrity components (each worth 50% of the total index score) reveals the following:

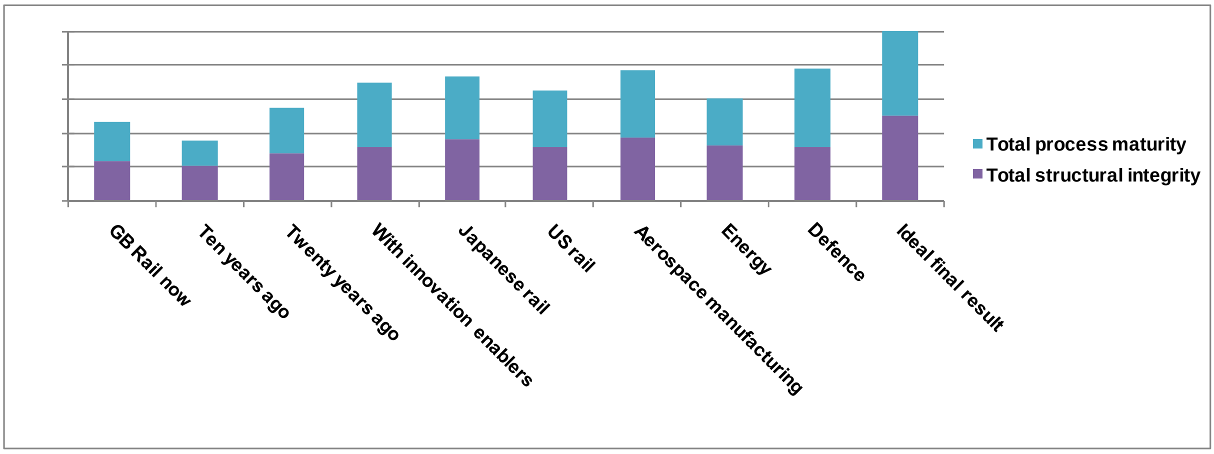


	Government	Network Rail	Operators	Designers / Consultants	Academia	TSB	RIA	RSSB	Ideal final result
Total structural integrity	18	31	24	27	27.5	17	23	19.25	50
Total process maturity	21	28	23	27	18	33	26	20	50
Total index	**39**	**59**	**47**	**54**	**45.5**	**50**	**49**	**39.25**	**100**

Figure 12: Level 2 innovation index for GB rail showing "whether, in the perception of stakeholders, the industry innovation system is fit for purpose"

The "Level 2" index reveals that in the perception of nearly all the stakeholder groups consulted, the challenge for the industry is more or less equally split between process maturity and structural integrity. Two notable exceptions are the academic stakeholders and the TSB, both of whose perceptions will be discussed in more detail later.

A "Level 2" comparison between GB rail and other industries and railways, splitting out process maturity and structural integrity, reveals the following:



	Now	Ten years ago	Twenty years ago	With innovation enablers	Japanese rail	US rail	Aerospace manufacturing	Energy	Defence	Ideal final result
Total structural integrity	23.5	20.9	28.4	32.3	36.5	32.0	37.3	33.0	32	50
Total process maturity	23.6	15.1	26.5	37.4	37.0	33.0	39.7	27.5	46	50
Total index	47.1	36.0	54.9	69.7	73.5	65.0	77.0	60.5	78	100

Figure 13: Level 2 innovation index benchmarking GB rail against other industries and in previous states, showing "whether, in the perception of stakeholders, the industry innovation system is fit for purpose"

The "Level 2" index would suggest that both structural integrity and process maturity are only now approaching the levels of twenty years ago from a low point ten years ago. Process maturity took a particular dive. Fortunately, the introduction of innovation enablers such as a Systems Authority, to be described below, seem to offer benefits that are substantial enough across the board to take GB rail far closer to the levels of innovation structural integrity and process maturity enjoyed by AM, EGS, Japanese rail and Defence.

When structural integrity and process maturity are each considered on their own, a more nuanced picture emerges. The concept of a "platform" in the context of IPMS is defined in section 5.1.2 above. The IPMS analysis of GB rail stakeholders follows the profile below:

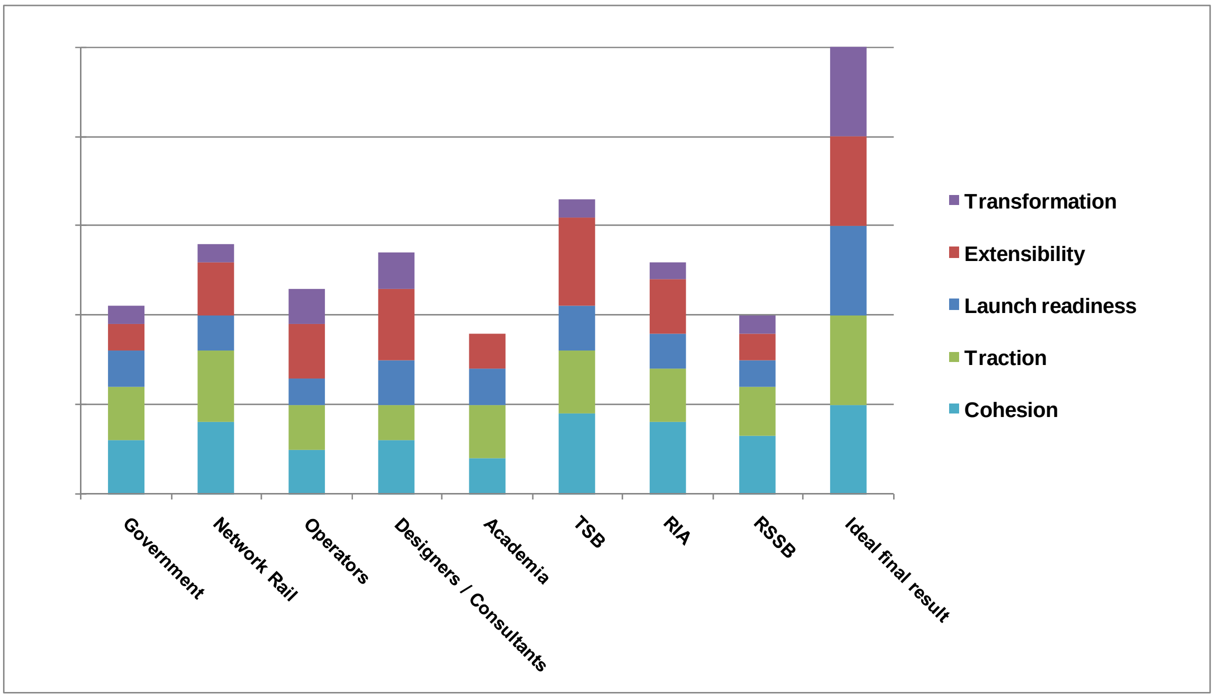


Figure 14: IPMS benchmarking of stakeholder group perception of GB rail industry innovation system process maturity

On first glance, it would appear that the TSB believes that on the whole GB rail scores comparatively highly for process maturity, a closer look reveals that despite the high scores for early TRLs and the production of innovative ideas, these are not linked to industry goals (the ISS score for strategic alignment is extremely low). Process scores relating to innovation traction (despite the plethora of organisations available to the industry in the "cell" quadrant of IPMS) and launch-readiness are commensurately low, illustrating that the industry as a whole is not following a robust platform-building innovation process, but is rather attempting to follow short-term goals by moving straight to launched applications, thus dramatically increasing delivery risk. The industry is, in the TSB's view, rather too comfortable adapting applications to market, resulting in ubiquitous bespoking and "gold-plating", hence a high score in the "extensibility" quadrant – essentially, all developments are quickly niched.

The stakeholder with the most bullish view of GB rail innovation system process maturity is Network Rail (NR). This can be attributed to (a) NR's large size and dominant role in GB rail and (b) NR's commitment of resources, under the leadership of Steve Yianni, to implementing a best-practice management system for the innovation that is within their own span of control (which is of course not the same as a comprehensive innovation system for the industry), combined with a redesign of their new product approval processes, aimed at improving the rate and quality of new product acceptance and introduction. They are keen to draw attention to the considerable time, effort and investment undertaken and a closer look at their experience enables some valuable lessons to be drawn. They also consider that the Network Rail innovation management system is scalable to industry-level application and this should be investigated during the implementation of an industry-level solution.

Case study: Network Rail Innovation Management System

Innovation was identified as a strategic priority in the internal 2009 report "Innovation in Action", with engineering as the catalyst for innovation, although NR recognise explicitly that it touches every part of the system. Initially, a survey-based approach informed by the work of Boston Consulting Group[19] to do comprehensive benchmarking recognised that they were displaying the two most prevalent characteristic organisational barriers to innovation – a risk-averse culture and lengthy development times.

The new process, which is considered a big success internally and is due to be unveiled shortly, follows a generic best-practice trajectory: "Think" – "Explore" – "Prove" – "Do". Their research identified that they had difficulty filtering ideas appropriately and lacked practicality in their approach compared to the companies they were benchmarking against. In particular, more priority was needed for practical testing capability and more robust decision-making / sign-off.

A particularly encouraging aspect of the system concerns collaboration and early engagement with other stakeholders: the stated aim is to be more inclusive rather than dominating by means of size and weight, whereas the existing project approval process is criticised for being primarily geared to NR requirements, benefits and timescale. There is a quid pro quo: if NR are to be expected to take more account of supplier priorities and less proprietary, they are expecting some measure of innovation risk to be borne by suppliers. At industry level this collaborative investment risk would require a robust and flexible approach to be successful (this should be addressed by the proposed solution in section 6.1.2).

A priority for NR has been improvements to financial investment governance, especially clarity about which innovation projects should be kept going and which should be stopped, as well as the learning to be gleaned. Early-stage investigations follow the model of making seed funding of up to £50k per project available against specific research opportunities, a typical amount being £20k. If the early stage stuff succeeds, a formal investment process can begin.

Internal prioritisation is intended to be achieved through the deployment of dedicated innovation management staff to reduce conflict with "business as usual" (innovation will in most cases be deprioritised if this occurs) as well as maintain ongoing accountability for the progress of innovation activities. NR are attempting to reduce this conflict by increasing innovation management capacity by delegating authority. Success is partial; delegation does not solve the problem in every discipline (e.g. track), although it does in telecoms and signalling. Delegated authority notwithstanding, product acceptance remains ultimately with the Professional Head concerned.

NR claim strong internal support for the improvement of Product Approval Processes; apparently there is internal frustration with the slow pace of change. Consequently, they have been working to

[19] BCG Senior Executive Innovation Surveys 2007-9

produce a steady reduction in the backlog of product approvals, which come in at about 40-50 a month, by introducing category management and internal sponsors – if one cannot be found then the product approval is considered not consistent with business needs. (NB: It would make sense if there was an interface to refer such product suggestions up to an industry-level innovation management system as outlined in section 6.1 if they have potential system-level owners rather than a sole focus on infrastructure). Major systemic innovations such as a totally new signalling system still require a full-blown system review panel (which would have inherent industry-level implications and consequently require a suitable interface).

NR have aimed to address specific criticisms and provide consistent messages to current and prospective suppliers. They aim to introduce a more "market-pull" approach to innovation, aligning new technology introductions to specific and clear requirements and consider that reduction of the end-to-end process down to 6-7 months would be a considerable improvement. Responding to criticisms that their system is opaque and closed to external stakeholders, they have begun to focus on building collaborative internal behaviours and breaking down silo walls – a particular focus has been given to the important interface between category / procurement managers and technology managers to address the concern that still remains concerning mutuality of behaviour. NR are also attempting to link their innovation resource into the procurement and contracting process for major projects, although they recognise that gaps still remain between innovation functions and the functions concerned with the actual procurement and writing of contracts for design projects. NR is exploring options for opening their models to IPR management. They recognise that they have to be able to cope with different models and behaviours and, furthermore, that the object of IPR is not to own all IP in every single case. For this to succeed, they need to focus on embedding partnership behaviours at all levels internally and externally. The operating words are "open up" – NR are trying to get the message across to prospective suppliers "we don't want to steal your IP, we want open engagement and diffusion". (NB: this would be considerably assisted by framework collaboration agreements as used in other sectors – see the Niteworks example from defence).

One particular flagship initiative to assist in this is the prospective launch of a web-based interface to manage the front end of open collaboration. This is not intended to be a "suggestion box" approach, where prospective suppliers drop their ideas and wait with baited breath for a response. Rather, the intention is that prospective partners – and, explicitly, new suppliers – should be able to choose to declare as much or as little information as they wish about innovation proposals, with a view to beginning and raising engagement, rather than submitting ideas. The front end will aim at publicising to the supplier base what the top NR agenda items are for long-term technical priorities (e.g. increasing safety at level crossings) and increase granularity of supplier contacts.

The focus internally is a lot more like the traditional "idea management" suggestion box which, unfortunately, has a history of under-delivery at most organisations, with some innovation experts claiming only 0.34% success[20]. Based on their experience consulting with GE and Deutsche Bahn, NR expect, based upon 5% of workforce participation, about 1,500 ideas a year, working out to approximately 30 a week. Assuming that resource is available to assess these ideas, which has been identified and allocated, the first best practice filter of 12%[21] should result in four ideas to investigate further weekly, which they nonetheless believe is manageable. The ideas sought are not for products alone, but also for processes. They are also exploring challenge-led innovation (set in terms of "Problem X costs NR £Ym/year – how can it be solved?") and solutions are sought both internally and externally. Assessment criteria are aimed at meeting not only technical but also user / customer and cost considerations and use balanced scorecards for decision-making.

Technology exploitation and diffusion routes are being highlighted by the introduction of "technology days" aimed at engaging with internal stakeholders to show what types of technology are being worked on around the organisation. Although these have been piloted internally they are envisaged to include partners going forward. NR have also begun to participate extensively in various forums for sectoral knowledge-sharing, including the Transport KTN, along with their ongoing involvement in TSAG/TSLG and are presently building links with the TSB's lead technologists for the various transport and energy modes with a view to learning from other sectors, as well as participating in organisations like the Welding Institute (TWI) which work cross-

[20] PhD research by a head of innovation at a major high-street bank
[21] Ibid., typical filters are 12%, 25%, 25%, 50%, for 100% delivery success

sector. They are also attempting explicitly to leverage knowledge from other sectors – a good example of this type of learning is the knowledge transfer from the forestry sector which has enabled NR to reduce reliance on chainsaws for vegetation management across their large land holdings, with the concomitant safety issues.

NR also believe that the introduction of TICs by the TSB investing £200m over the next four years is "the biggest issue" facing the sector in terms of innovation, which they see as a valuable resource to begin addressing the lack of facilities and industry capability to progress innovation, particularly over what they too recognise as the "valley of death" in TRLs 4-6. The project team also spoke to individual innovation managers within NR, who recognise that there is a considerable learning curve in terms of understanding the practicalities of innovation, particularly in regard to the clear statement of problems from internal customers. A primary driver of innovation is a clear understanding of the business objectives, for example how much a given problem costs per year to fix, as well as clarity about the internal sponsor and agreement of success criteria. The stage-gate and funnel process then allows them to add assessment rigour that previously has not been available. An example from the track discipline is that of the opportunity from introducing slab track rather than balance. Research by the innovation project manager into worldwide methodologies of using this technology has led to better understanding of the technologies used elsewhere, but it was concluded that the customer for this innovation had unrealistic expectations with regard to the potential of this innovation in aspiring to use slab track as the de-facto standard. However, even unsuccessful projects are regarded as a useful learning exercise for the organisation.

A more successful project has been the cable management sleeper developed for Thameslink, in which feeder cables between sleepers were identified as leading to maintenance difficulties and using steel sleepers were impractical from the point of view of conductivity. A concrete solution was developed for which the customer, in this case Thameslink, was willing to pay; a 90% cost reduction was achieved.

On other projects, particularly those where the benefits are largely in terms of safety and maintenance, the benefits are regarded as hard to quantify, although some effort is made to link them through to customer benefit – for example, working with Corus to introduce harder premium steels, which reduces contact fatigue, which of course would otherwise feed through into highly visible customer delays.

Although NR believe their programme is scaleable enough to form the basis of an industry-level solution, it must be emphasised that the success of an innovation project management stage-gate process depends upon the structural integrity of the innovation management system that supports it, as IPMS depends upon ISS.

NR considers the insight / cohesion stage within the industry to be healthy. They point to their request for a "Technology Watch" service and their strategic alliances with three major centres of rail research expertise. They consider that GB rail has an extremely strong academic base.

NR's own process has to sustain a situation where any industry participant can send in a Product Acceptance Application to them and they are obliged to process it. They maintain an internal sponsor filter and have lowered approval levels for catalogue management level items such as a change from a 100m cable down to 50m. However, they do concede that their approvals process has been slow and bureaucratic but insist that the backlog is reducing. At an industry level, they recognise a gap at the platform-building/launch readiness stage (between TRLs 4-6) which suffers from a lack of strategic vision and leadership from the industry. The view from NR is that innovation occurs in many ways "despite the system".

The NR innovation programme comprises some 30-40 different projects, aligned to an extent with the Technical Strategy outlined by the RSSB Technical Strategy Advisory Group (TSAG). It should be noted that this is a new programme and is not absolutely comprehensive of the total number of innovation projects in progress within Network Rail. They believe that they are in a position, if permitted, to make a substantial contribution to exporting world-class innovation, particularly in the area of wheel-rail interface knowledge through VT-SIC, or via productising systems such as the VTISM procurement tool or Track-Ex, a tool to help track engineers plan how tracks should be designed, which predicts stress locations where track will wear out. The VTISM tool needs a PhD running it to function effectively.

For NR, an innovation-led growth strategy would rely on leveraging world-class technical knowledge from TRLs 1-4. This requires a strategy of constructive engagement with participants with these capabilities, including the upstream sustaining of material science with an appropriate mental model. NR have already laid the groundwork for such an engagement with their recent announcement of a strategic alliance with three leading universities engaged in rail research and they claim furthermore that all their innovation projects consider this eventuality. They also appear to support the concept of using the revenue from innovation leveraged for global markets in order to support the delivery of innovation in GB rail.

Technical Strategy and the Technical Strategy Advisory Group (TSAG)
TSAG, now known as the Technical Strategy Leadership Group, was established in October 2007 as the cross-industry client group for strategic research. to support the development, challenge, communication and delivery of the Rail Technical Strategy and support it over a 30-year horizon.

Independent confirmation of this view of an innovation-led growth strategy can be drawn from opinion of senior advisors at the TSB, who also point to the consultancy skills in the UK market as a means to leverage GB rail knowhow, much as existing consulting businesses such as Atkins already attempt to do globally; they believe that NR should consider re-engagement in this market, although not as a part of their core business, as it would be a distraction from their public service delivery objectives, but rather in collaboration with the significant resource available from GB rail consultancies.

An instructive lesson can be drawn here from the sale of Transmark, BR's one-time consultancy arm to the consultancy Halcrow or indeed the dispersal of the various elements of the former BR Research organisation as part of the privatisation of GB rail in the 1980s / 90s. A view of the value of collegiate research as an enabler of innovation which could benefit the "whole rail system" was prioritised below the overriding objectives of introducing private sector funding and private sector thinking.

Productive future collaboration will require a strategy of engagement which is in accordance with the requirements of all participants. Care should therefore be taken to develop appropriate models for collaboration and open innovation with a view to the participative sharing of IPR, which for the current culture in GB rail will be a considerable challenge and one which has all too often been stymied in the past by overly controlling and tactical attitudes, especially from large stakeholders. Here the example of the defence industry's "Niteworks" (described in section 5.5.3) can provide some excellent guiding principles.

Analysing innovation system integrity using ISS (Innovation System Structure)

The ISS analysis of GB rail stakeholders follows the profile below:

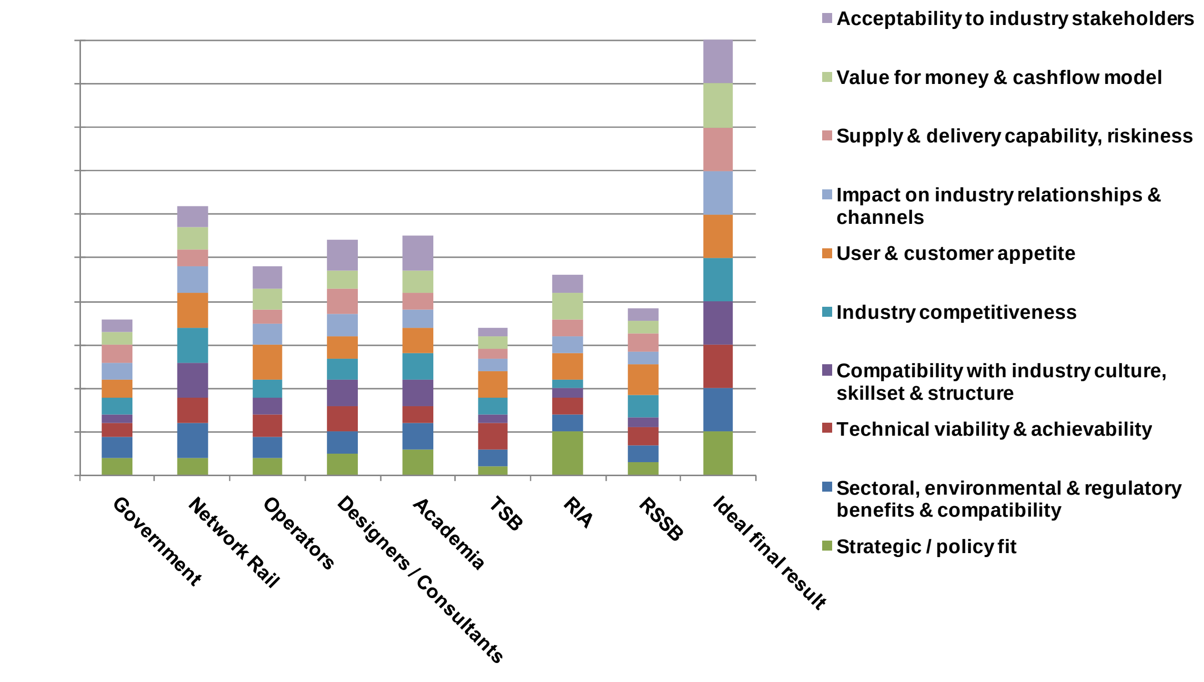


Figure 15: ISS benchmarking of stakeholder group perception of GB rail industry innovation system structural integrity

NR is reluctant to accept sole responsibility for system-level barriers to introduction, with some justification, although they do concede that where authority is unclear, the approval system is not working well. They hold up the lack of introduction of the 380 "fly-by-wire" trains, which they consider due to a lack of agreement between the ToC and Transport for Scotland, as a particular instance of this type of problem.

A particular technical gap relates to software controls and validation – in NR's opinion, operators do not have the resources and resist using NR's, even though they are free, preferring to spend considerable sums on external consultants.

NR give a robust response to the charge that their standards prevent innovation, pointing to a survey requesting input as to which are unfit for purpose, but received only three responses. However, they concede that standards could be more user-friendly, including far more pictures and improved recommendation behaviours.

Requirements need to be based on function and NR would welcome a move to a more innovation-friendly commercial output-based specification regime. NR readily agree that over-specification is a huge disabler of innovation, given egregious examples such as the specification of a set number of cycle hoops per platform in a recent tender document (which was, in fact, not an NR tender) seen by Atkins. An innovation-friendly specification would rather have required improved facilitation of modal interchange between cycle and rail at the stations concerned, with a view to reducing short-range car travel; this would have been far more likely to result in innovative design solutions.

Innovation cutting across system boundaries, for which responsibility is requires the assent of more than one stakeholder is particularly problematic. NR point to the example of salt on platforms during icy conditions, which affects the life of the asset, as it causes corrosion, deterioration of the platform and then knocks out the track circuits when it dissolves and washes onto the tracks. They consider this a systems issue which could be resolved by the provision of a systemic authority.

For systemic approvals, the current provision of Notified Bodies (NoBos) results in a challenging environment for any decision that is not "black and white". An outstanding example is a regular problem commonly occurring at Euston Station when Class 378 rolling stock causes electromagnetic interference with other trains' systems. In such a situation it is typical for respective operators to trade blame with no system authority available to cut through the ambiguity. If GB rail is ever to support the EU aspiration for operators to be able to decide where they run their trains, this issue must be addressed. A similar issue occurs when old trains are taken out of service from their original operating environment; it is a far from straightforward transfer process owing to the fragmented nature of the infrastructure. NR believes that in such ambiguous situations, a Systems Authority should be able to broker a deal and point to an excellent example of just this type of project-level system authority model emerging informally:

Case study: Improving overhead line reliability

Following a spate of OHL failures on the WCML after the introduction of a new table and a 40% increase in traffic, a group of four senior stakeholders from Virgin (as the affected operator) NR (as the infrastructure maintainer), Alstom (as the train manufacturer) and Serco (as the contractor who would be carrying out rectification works) came together to find a way forward to solve what was clearly a systemic problem and not one that rested clearly in any one stakeholder's exclusive purview. The typical approach would have been for responsibility to have been disputed between the parties, but when the key group agreed to work together to look at the whole system, they were able to discover that the source of the problem was the need to reduce chipping on the carbon on the train pantograph head, which was resulting in too many replacements. They kicked off a £150k development project to find a workable solution and, nine months later, this is now in successful operation with a drastic reduction in OHL dewirements and resulting lost customer hours. No formal partnership was used, only informal agreements for how IPR should be managed – in the end, it was agreed that one party would provide the funding and take on the risk, retaining the IP for the application in the UK, whereas another party would retain the rights to subsequent worldwide sales of the technology. (an excellent illustration of exploiting world-beating capability using the Hauser model).

Attitude and willingness of the people involved to find a real solution was a key factor of success It is not considered by NR that this model should be rigidly followed, but that it was the best solution in this case – it is flexibility regarding IPR, risk and exploitation that should be the basis of collaboration for tactical challenge-led innovation, based on the desire from all parties to make it work.

It is clear that mutual trust is a key enabler of collaborative innovation. When it is not present, poor behaviours can act as an insurmountable barrier: NR point to the example of commissioning new designs for a particular variety of on-track equipment to satisfy an underlying safety consideration which resulted in protests that this would make the current supply chain and designs obsolete. The underlying consideration was the size of the window of opportunity for the next “insertion point” for procurement of this equipment. NR believes that the supply chain lacks visibility of the approach vector to the insertion point at which this equipment can be procured and introduced and will consequently end up missing the window and, as a result, NR expects to end up by buying the equipment from outside the existing supply chain.

5.4 Discussion with GB rail industry, other railway administrations and other industries

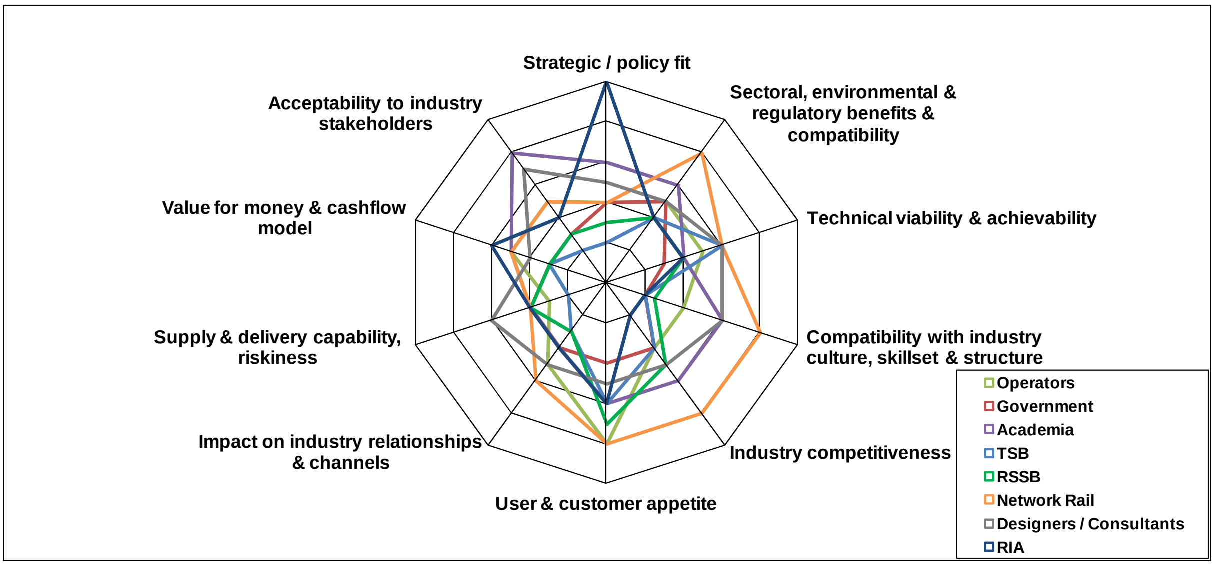


Figure 16: Views of innovation system structural integrity from different stakeholder groups within GB rail

There is a wide spectrum of opinion about the innovation system's structural integrity amongst stakeholders in GB rail, some optimistic with a risk of complacency and some realistic with a risk of defeatism. It is most instructive, however, to point out the major gaps in perception between major stakeholder types.

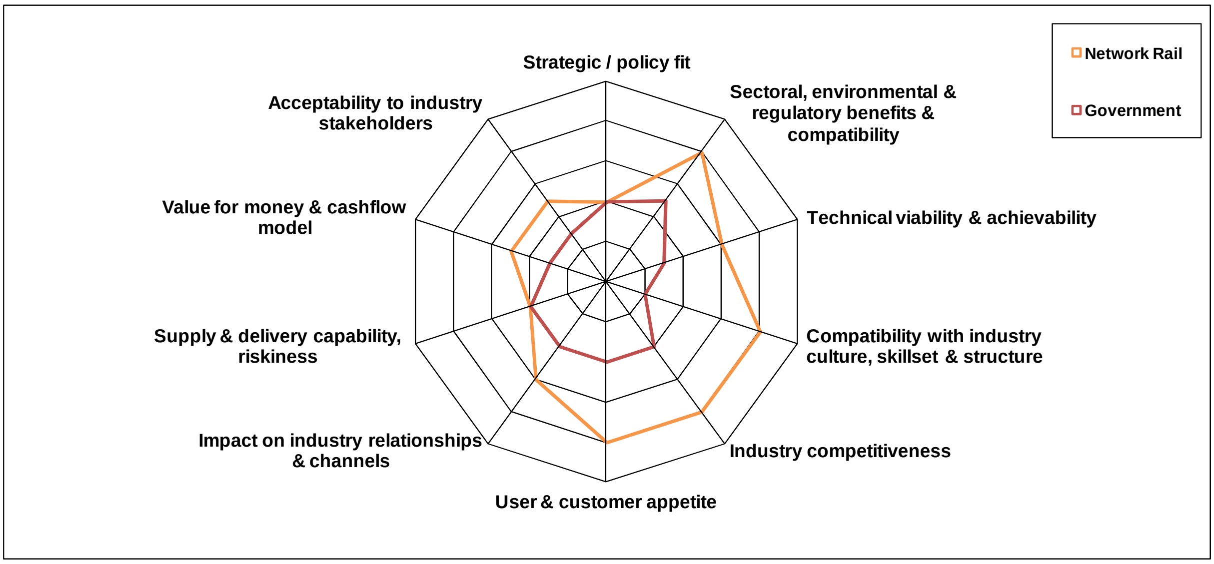


Figure 17: Gap analysis of innovation system structural integrity between Network Rail and the DfT

The gaps between NR's position on innovation system structural integrity and that of the DfT appear widest in terms of benefits to users and customer, industry competitiveness and most of all compatibility with industry culture, skillset and structure. There are also substantial gaps between the fitness for purpose of the technical aspects of the system and the extent to which it is aligned with important sectoral, environmental and regulatory pressures, to which the DfT clearly feels the industry is not responding, compared to the view of NR.

These findings indicate that Network Rail feels that the substantial effort it has contributed to introducing a robust and workable innovation management system for infrastructure development and maintenance has moved them a significant way towards an ideal final result. We believe that this effort deserves due credit but observe that an innovation system representing one group of stakeholders' priorities may not be wholly aligned with the system needs from the point of view of GB rail as a whole. In other words, an optimal whole-system result requires the commercial alignment of many different stakeholders and this cannot be achieved by the introduction of an idea-to-delivery management system, even if it is based on a robust, best practice approach. Network Rail's efforts thus far, described in detail above, demonstrate the appetite for and willingness to make further progress.

Our experience[22] suggests that at best, an extremely small number of ideas result in a successful, sustainable launch, even within organisations that do not rely on the cooperation of external stakeholders – all the more so when considering the entire industry system. Nonetheless, for the entire industry system to reach ideal final result status, each significant organisation involved would have to consider the challenge in at least the same level of detail as Network Rail have.

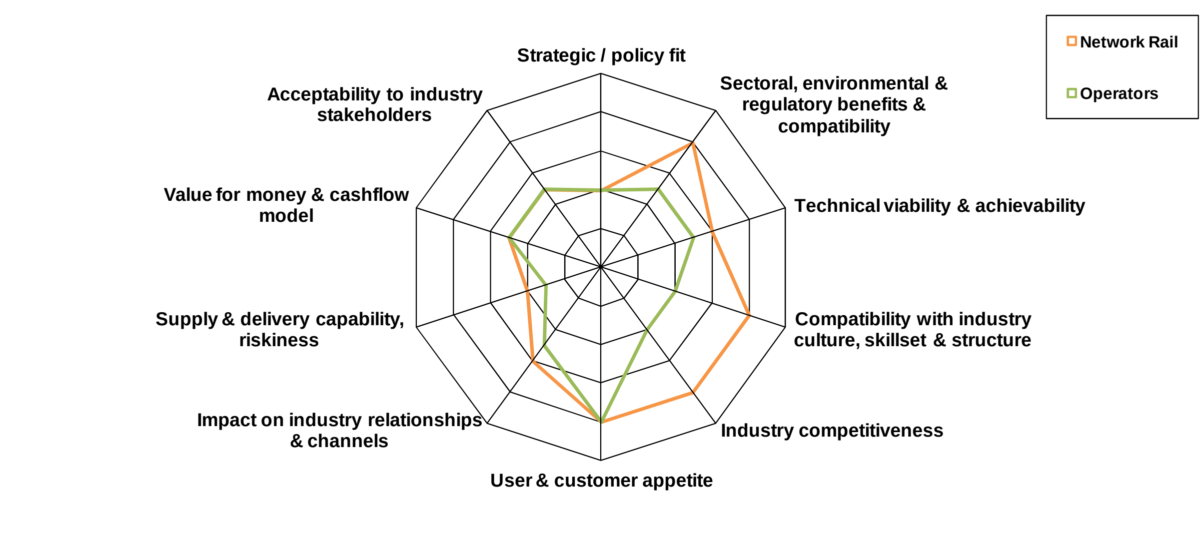


Figure 18: Gap analysis of innovation system structural integrity between Network Rail and operators

This initial hypothesis is supported by the point of view expressed by operators. Again, some of them have made significant effort in the direction of commitment to their own internal innovation systems, albeit here there is more recognition that the success of their own efforts is dependent upon external stakeholder buy-in, with particular reference to NR. Freightliner, for example, point to the successful introduction of the "PowerHaul" GE-manufactured traction equipment, a tried-and-tested US system which they have introduced to Class 70s in the UK. They attribute their comparative success to early engagement with stakeholders in the approvals process.

Nonetheless, the biggest gap here remains a cultural one – an issue with an exhaust subsystem has been subject to significant delays and here, communication appears to have broken down somewhat. Both parties have their own view on what caused the delays but it seems clear that the ability for the industry to show leadership in resolving it and moving forward has not been demonstrated and, in this case, the ability to refer the issue to some form of system authority would have significantly assisted an optimal outcome for all parties. Clearly, this affects the ability of operators to maintain competitive advantage if they feel that their ability to execute is hampered by the difficulty in gaining buy-in through the existing industry structures.

[22] Internal deployment of an idea management system produced results that substantially confirmed the figures referenced from the PhD study referenced earlier, as well as the empirical experience of internal innovation specialists in other industries. There is a thriving "idea management software" industry built around the promise to address this difficulty, but success is still rare and expensive. A leading contender in this field is Imaginatik: http://www.imaginatik.com

We can therefore begin to see that, while the situation is not as dire from the point of view of operators as it is from that of the DfT, why it fails to match the optimistic picture presented by Network Rail:

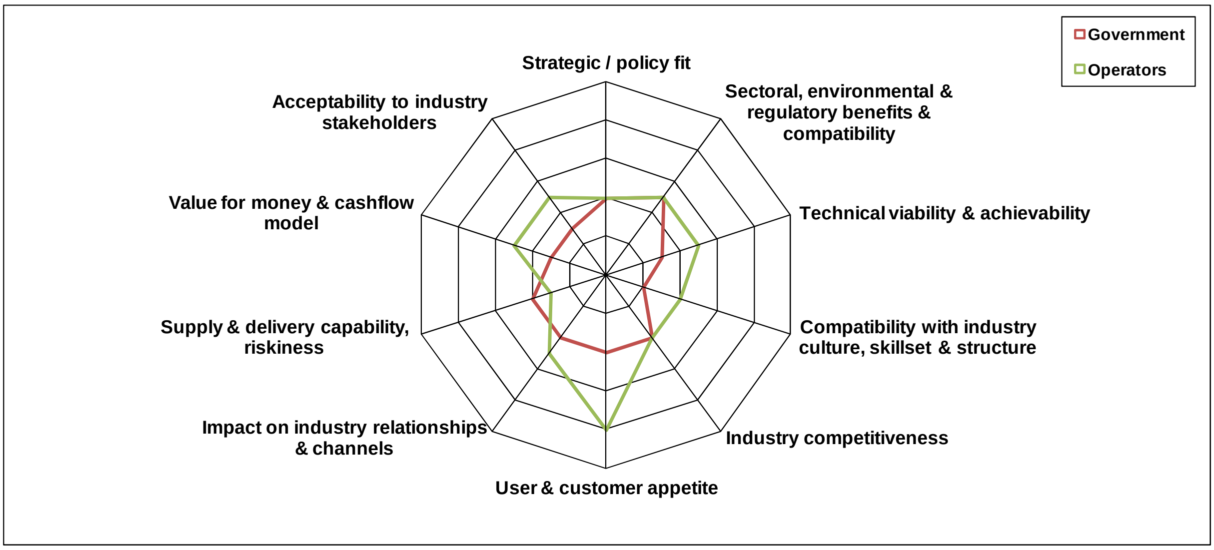


Figure 19: Gap analysis of innovation system structural integrity between operators and the DfT

Train Operators, here, are clearer that the ability to deliver innovation will benefit users and customers of the industry. By virtue of their position in the industry, they are extremely commercially focused and thus are principally concerned with their ability to deliver a good service to their customers at the same time as delivering a good return on investment to their stakeholders. It is thus in their interest to minimise the extent to which they are forced to consider sectoral, environmental and regulatory pressures and allow these to drive innovation. They are far more likely to innovate in areas that are under their direct influence and are adding visible value to their customers, enabling them to enhance the value and profitability of their services. However, due to the structure of the industry and the non-commercial nature of their relationship with NR, both parties struggle to achieve mutually agreeable results from innovation in systems in which they are both have an interest, with the result that their conflicting pressures, more often than not, result in organisational deadlock, which can only be resolved by horse-trading behaviours, thus permitting "gaming" of the system through exploiting idiosyncrasies in the procurement and contracting system through which inter-organisational relationships are commonly mediated.

It is instructive to consider the positions of Train Operators, DfT and NR along the dimension of impact on industry relationships and channels. As previously mentioned, the contractual agreements through which most relationships in this sector are mediated have resulted in, certain cases of TOC Franchising in poor value for money for the taxpayer and a situation in which TOC franchisees cannot be penalised severely enough for withdrawing from a franchise, nor incentivised correctly to deliver superior performance through innovation. The present model militates against private sector innovation to reduce costs, attract passengers and increase revenue; the challenge is to capture the positive aspects of the present system while creating the freedom and incentive for TOCs to drive efficiency, innovation and investment, both in bidding for franchises and in delivery, including on a wider basis, investing for long-term growth in trains station and infrastructure. Passengers and, in the longer term, taxpayers will benefit.

The Governments recent Consultation Document on Reforming Rail Franchising[23] states openly these objectives :

> *"Instead, we want to see a stronger focus on the quality of outcomes for passengers, giving more flexibility to the professionals who run our railways to apply innovation and enterprise in working out the best way to deliver those outcomes."*

> *"We believe that one of the main reasons for involving the private sector in provision of public services is to harness its expertise and innovation to improve the way services are provided*

[23] Department for Transport: "Reforming Rail Franchising": July 2010

and respond flexibly to user demands. In rail, as in other areas of public service provision, we want to see a move away from detailed micromanagement and specification of service inputs to an approach which focuses on outcomes for passengers and gives the private sector more freedom to determine the best way to deliver them."

"The right franchising system should harness private sector innovation and skills to produce better services and to drive efficiency improvements to the benefit of taxpayers and passengers".

The current arrangements do not promote cross-system innovation in many cases where stakeholders' individual business aims are not aligned commercially, because no system-level authority exists to drive through the change.

As already mentioned, stakeholder positioning on the ISS would tend to indicate that Train Operators appear to have enough power in the existing innovation system to fight their own corner as regards innovations within their span of control, which they can deliver without others' help, although when it moves beyond to more systemic areas including infrastructure and control systems, success is harder to come by. ,The imbalance in power in relationships is felt far more keenly when the points of view of suppliers to the industry are considered:

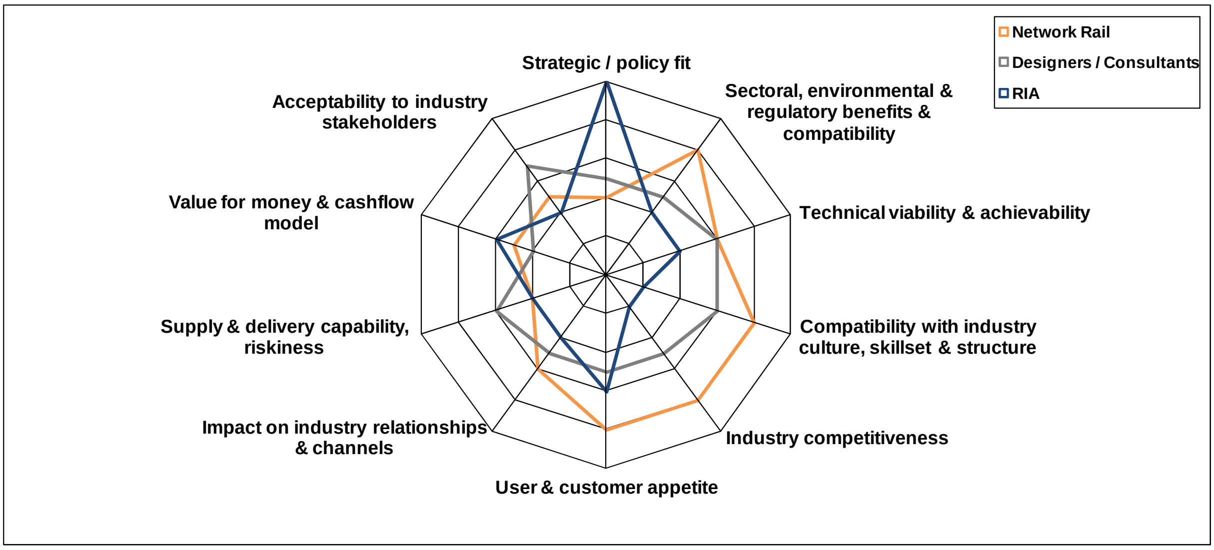


Figure 20: Gap analysis of innovation system structural integrity between Network Rail and suppliers of products and services to the industry

Here we see a situation where the business models of the suppliers to the industry strongly supports a strategic commitment to innovation at every level. With a level playing field, suppliers to the industry would adopt a highly competitive posture through innovation, but where they are constrained by the need to first negotiate the Network Rail approvals process to reach the GB rail market before addressing external markets, there is a large gap between their product and service development culture and the risk-averse posture of the industry. As a result, they struggle to be able to justify investment in innovation to what is likely to be no good purpose as far as Network Rail is concerned. This inability to achieve end-to-end value creation from the point of view of suppliers is an ongoing problem; both Atkins and Bechtel, for instance, are certainly aware of a despondency that sets in when the risk of innovation is considered, the perception being that our services are purchased on a cost basis alone and that added value is virtually eliminated from the tendering process. Innovation is considered a risky activity and one that suppliers to the industry would rather not be penalised for engaging in – it is therefore of little competitive advantage at this point, compared to cost reduction.

Designers, consultants and product suppliers are most likely to innovate when the global market comes into play. GB rail takes the view when procuring products and services that it will only use the tried and tested in other markets, yet when attempts are made to introduce products and services that have been long-established in other markets, these are subject to lengthy approval processes and significant amounts of bespoking and "gold-plating" before they are deemed acceptable to GB rail. NR mentions, however, that although claims of gold-plating are ubiquitous, stakeholders are reluctant to provide them with concrete examples. NR also claims that it does its best to act in the interests of the whole industry, providing as evidence its establishment of the Institute of Rail Welding (circa 2003) in conjunction with TWI to reach common industry practices and competencies across the industry and its adoption of the RUS process as a means of engaging the industry in whole-system solutions such as network electrification, although the latter is a condition of their licence and breaches would probably result in fines from the regulator.

Suppliers would therefore view with approval the introduction of an innovation-enabling authority or body that would act in the best interests of GB rail as a whole, rather than in the narrow interests of lowering the cost of procurement on a contract-by-contract basis. Similarly, the envisaged introduction of an innovation and growth team would enable the collaborative development of new products and services across the system in a partnership environment, rather than the current atmosphere of mistrust in which the perception is that good ideas submitted to Network Rail will simply be assessed according to the needs of infrastructure management and operation and then thrown open to competitive tender, without any credit given for effort or collaborative thinking around the whole problem at a systemic level. This makes for an environment in which IP is jealously guarded and not shared at all in the interests of being able to submit a more competitive tender at a later stage.

This environment and culture is, in no uncertain terms, far from being one in which open innovation can be achieved and we therefore urge the introduction of a system whereby industry-wide platforms can be developed collaboratively by one set of stakeholder organisations regardless of who ends up delivering the applications based upon these platforms to the market and it is to this end that we propose the introduction of a collaborative investment model to overcome this reluctance which is outlined below in section 6.1.2.

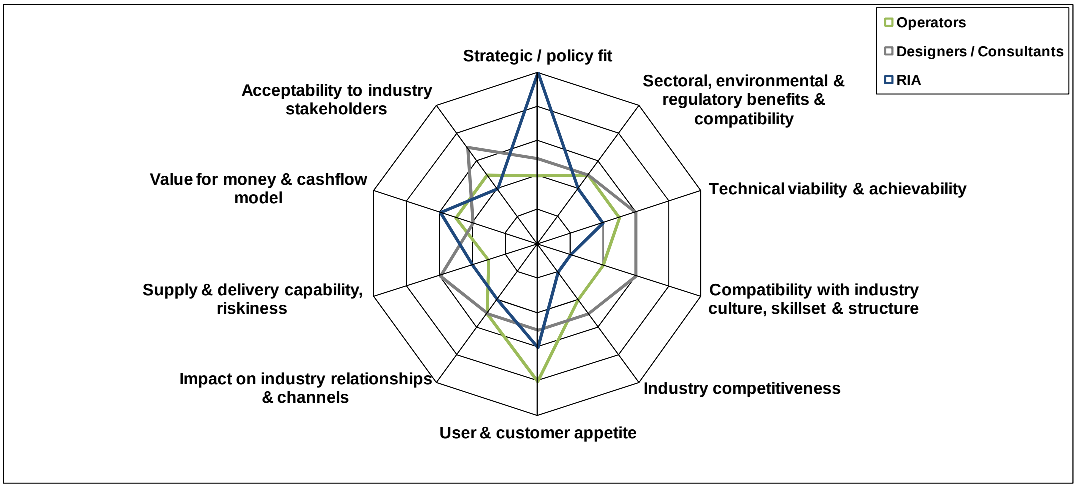


Figure 21: Gap analysis of innovation system structural integrity between operators and suppliers of products and services to the industry

The mismatch between the expectations of suppliers and operators is less extreme but still highly visible in terms of the strategic drivers. As mentioned above, operators wish to minimise the extent to which they are forced to innovate by external factors in order to maintain their service levels and the profitability of their operating models. However, they remain extremely receptive to innovation that enables these factors to be enhanced and, consequently, there is a far closer match between their point of view in terms of user and customer appetite, industry competitiveness and value for money and that of suppliers of products and services to the industry. Therefore, where operators are keen to innovate, they are able to operate extremely effectively with suppliers to the industry – it is only where whole-system considerations of infrastructure provision, management and maintenance come into play that the structural barriers cause difficulty.

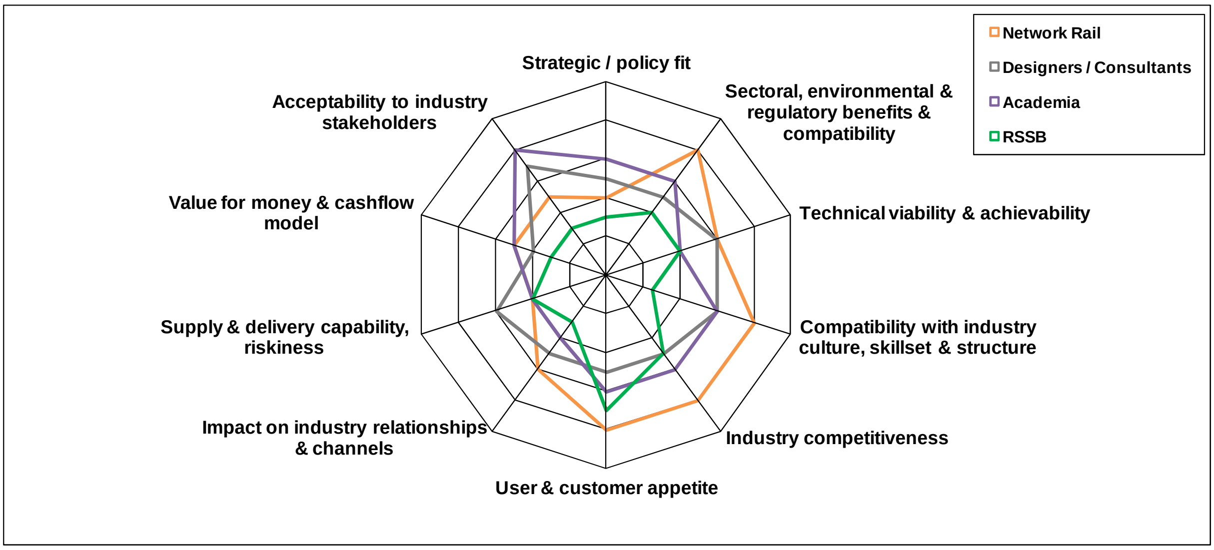


Figure 22: Gap analysis of innovation system structural integrity between Network Rail and suppliers of research and thought leadership to the industry

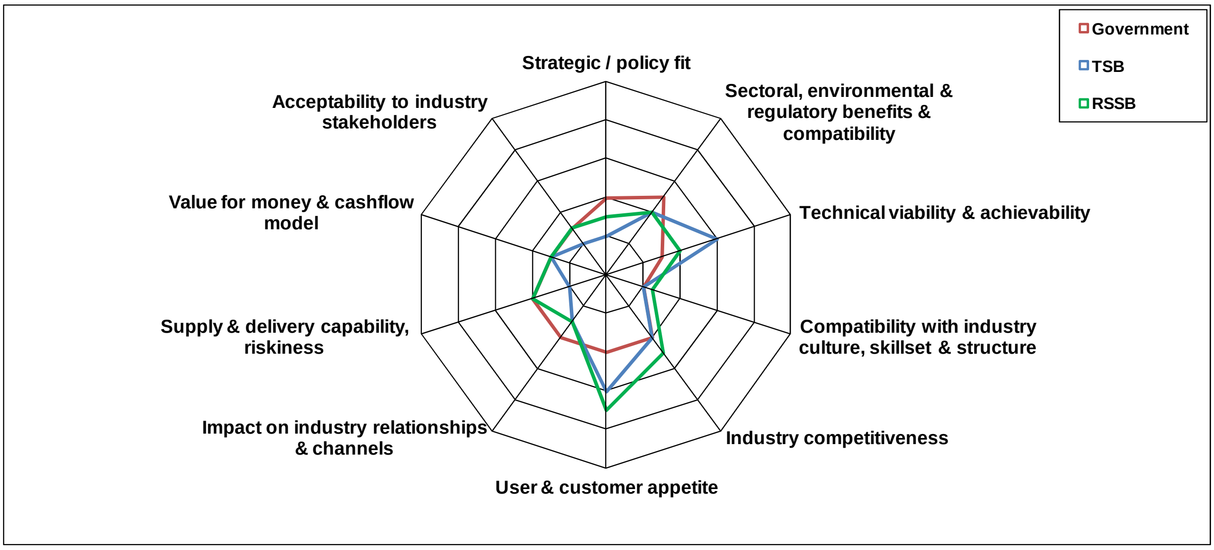


Figure 23: Gap analysis of innovation system structural integrity between DfT, RSSB and TSB

There is a more straightforward and consistent picture that emerges from industry stakeholders when considering the **process maturity** of the industry innovation system:

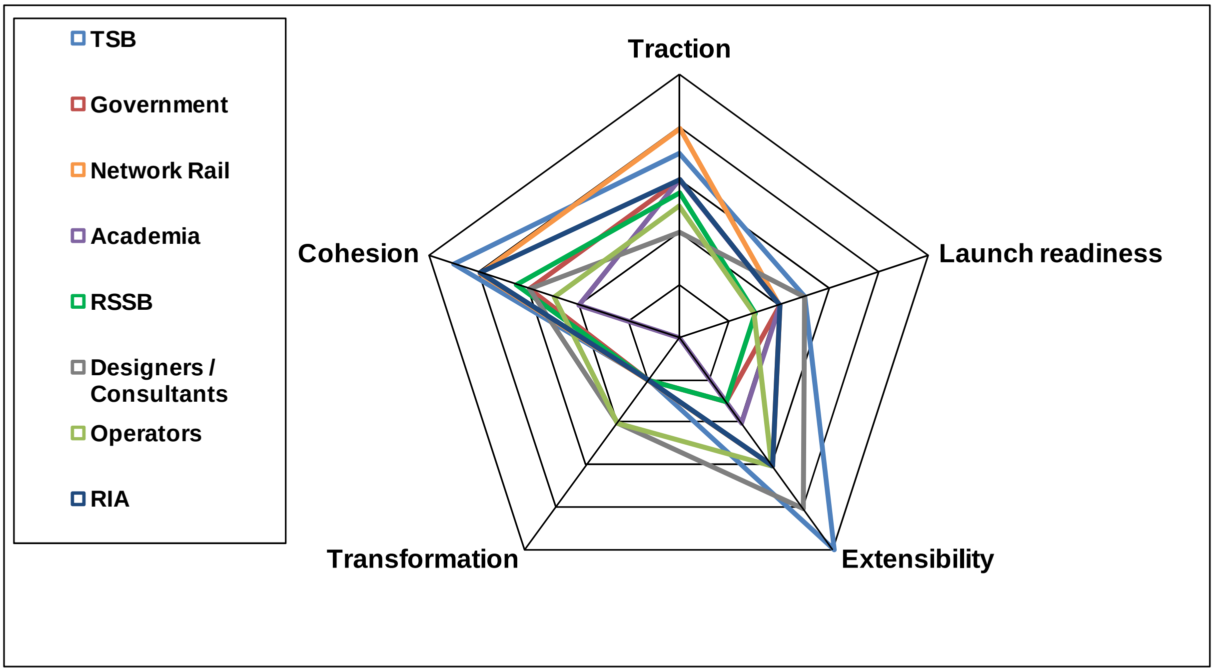


Figure 24: Views of innovation system process maturity from different stakeholder groups within GB rail

There is an overwhelming feeling that GB rail is turned in upon itself in terms of ideas and sources of innovation, represented by the consistently low scores on the transformation dimension. This translates into considerable barriers to entry from the outside-in as well as a lack of technology transfer from GB rail to other industries (effectively GB rail exports).

Similarly, there is a notable consistency in the poor scores given along the launch-readiness dimension, which supports the contention that GB rail lacks ability to ready industry platforms for launch due to the difficulty in achieving commercial alignment between stakeholders as well as the challenge of breaking deadlocks over technical standards and risk management when multiple systems are impacted.

The gap identified by numerous industry stakeholders in system process maturity is between TRLs 4-6 and this is clearly supported by the overwhelming consensus in regard to the platform-building / readiness for launch quadrant of IPMS. Despite the apparent existence of a certain amount of consensus, the profound differences in opinion once more emerge when the points of view of different groups of stakeholders are broken out from the whole:

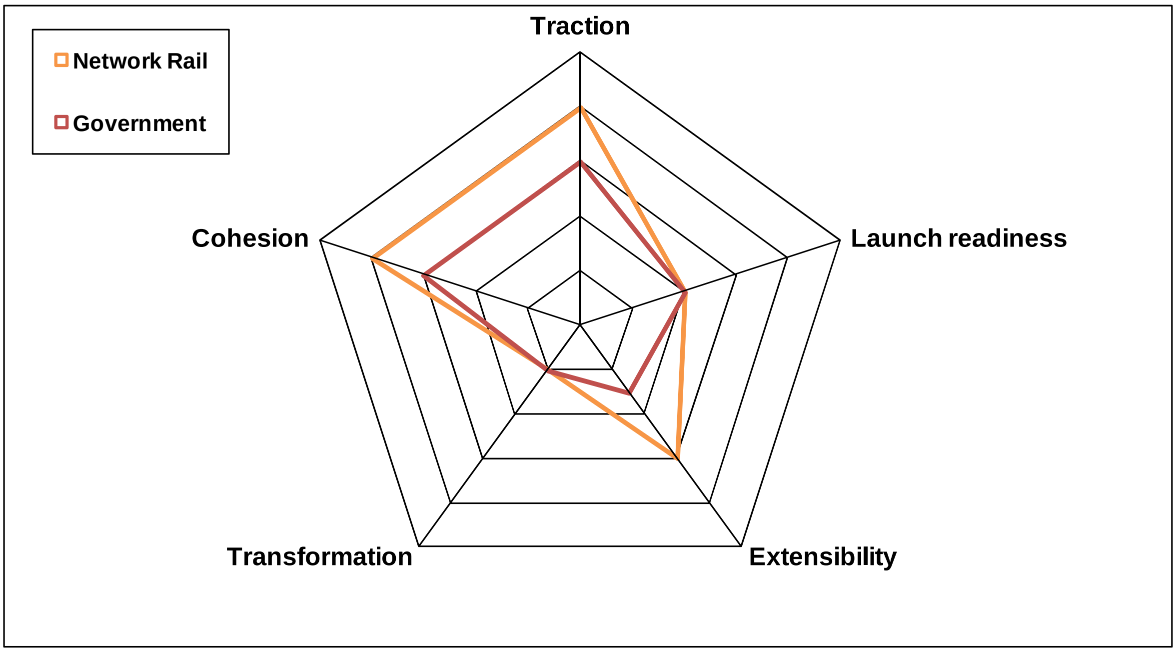


Figure 25: Gap analysis of innovation system process maturity between Network Rail and the DfT

Here, the gap between Network Rail and the DfT is far closer than it is in terms of system integrity. However, NR's position acknowledges the challenge involved in developing an innovation process that is fit for purpose for itself, let alone for the industry as a whole. Both points of view recognise that a lack of ideas is not the problem; fundamental research is at a reasonable state of excellence and the socialisation of new concepts across the industry is comparatively mature. Nonetheless, from both points of view, the "valley of death" is very much visible, despite NR's reasonably positive view of the ability of the industry to roll out innovation that has made it to launch.

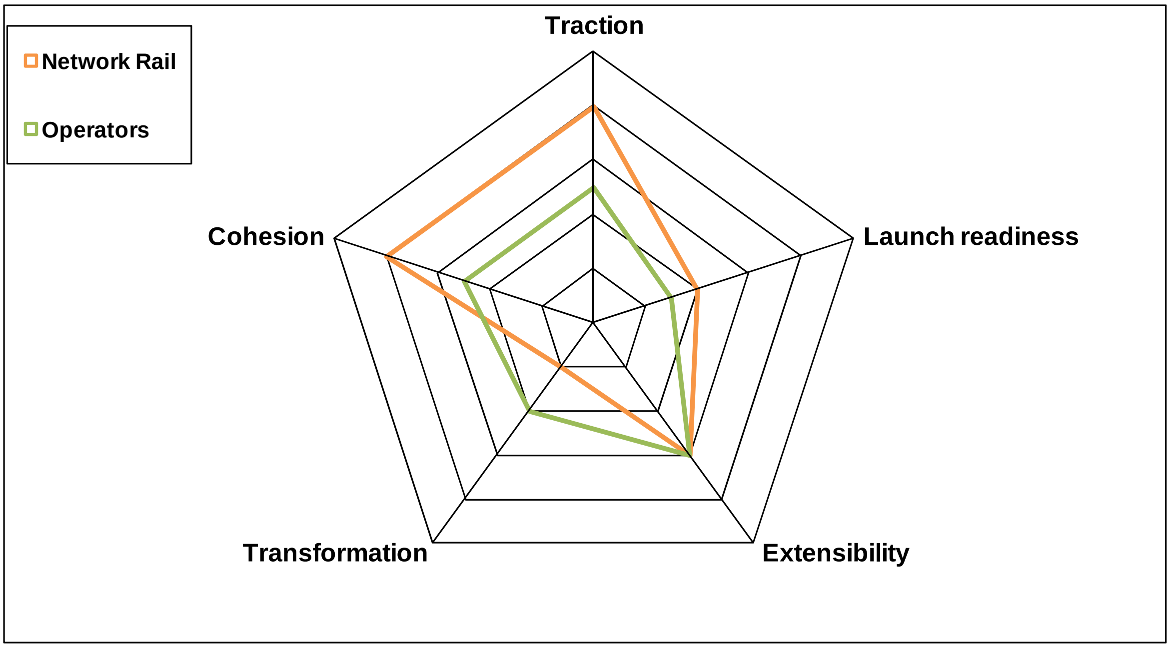


Figure 26: Gap analysis of innovation system process maturity between Network Rail and operators

The view of NR and operators is reasonably consistent in terms of the profile of the industry process, although views of capacity vary. Once more, the ability to execute things that everyone agrees on is visible, as is the "valley of death". However, NR is considerably more positive about the quality of research and ideas, together with the capability to build consensus, than the operators are – this bears further examination; it could be that operators are far more specific about the areas they believe require innovation, or that NR feels far more able to work with researchers and academics, assess early-stage concepts and place them into its own development process. An indicative factor here is the strategic alliance announced between NR and three leading research establishments, as well as the effort mentioned above in constructing a robust, best-practice-led idea management funnel. Nonetheless, it must be emphasised that the ability to deliver innovation where the whole process is under the control of one organisation is far less challenging than for GB rail as a whole to develop such capability.

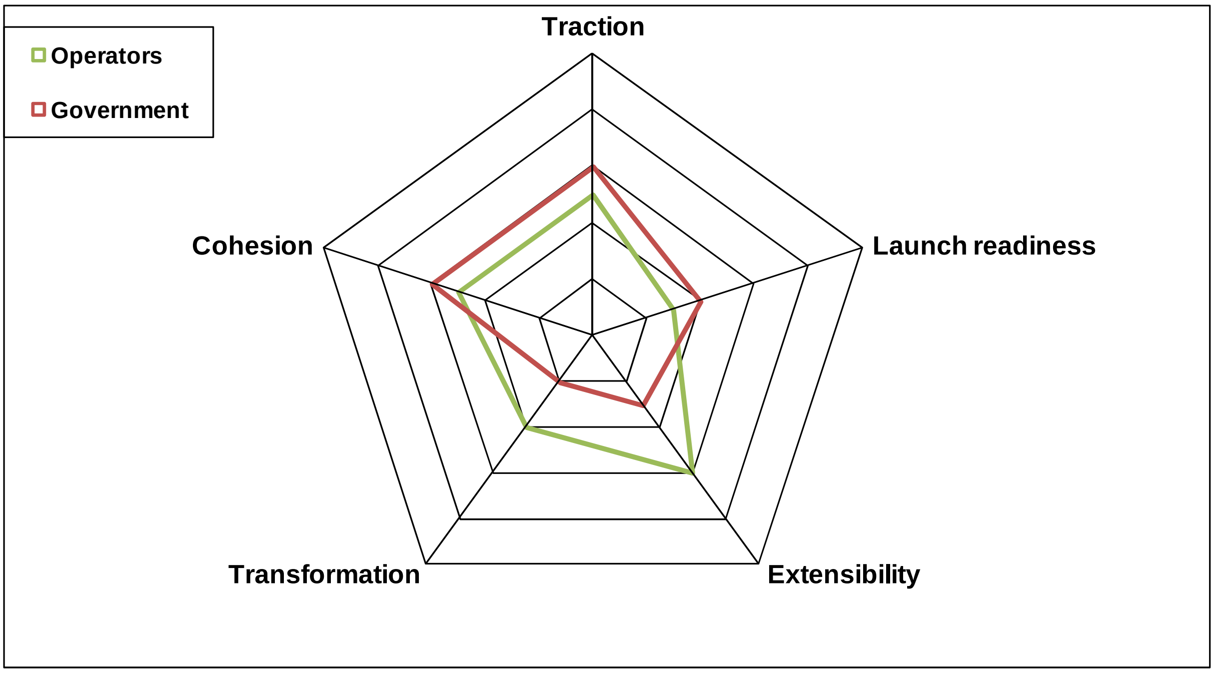


Figure 27: Gap analysis of innovation system process maturity between operators and the DfT

There is far more consistency of perception between operators and the DfT in terms of the industry's innovation process maturity. No significant gaps exist with the exception of the operators' position that innovation that can be agreed can certainly be launched and rolled out. What might account for this gap is the difference between operators' views of what areas in which the industry needs innovation and the rather more systemic view of the DfT.

By contrast to the picture of the system's structural integrity, the perspective of Network Rail and the suppliers to the industry are rather better aligned in terms of process. RIA suppliers, for example, are, effectively, hyper-adapted to the parts of the innovation system process controlled by NR, whereas the designers and consultants have a somewhat wider view reflecting their need to push the envelope in order to achieve ever greater cost competition. However, there is an excellent prospect, should an effective industry-level process be achieved, of overall alignment keeping up with the pace of change.

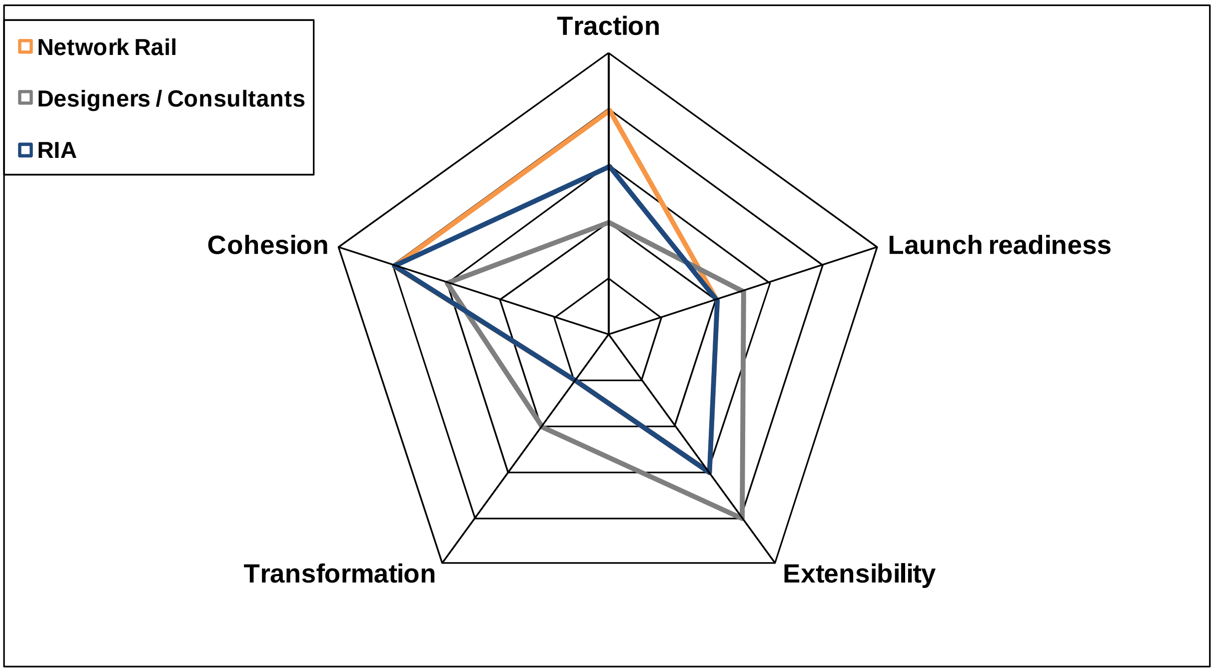


Figure 28: Gap analysis of innovation system process maturity between Network Rail and suppliers of products and services to the industry

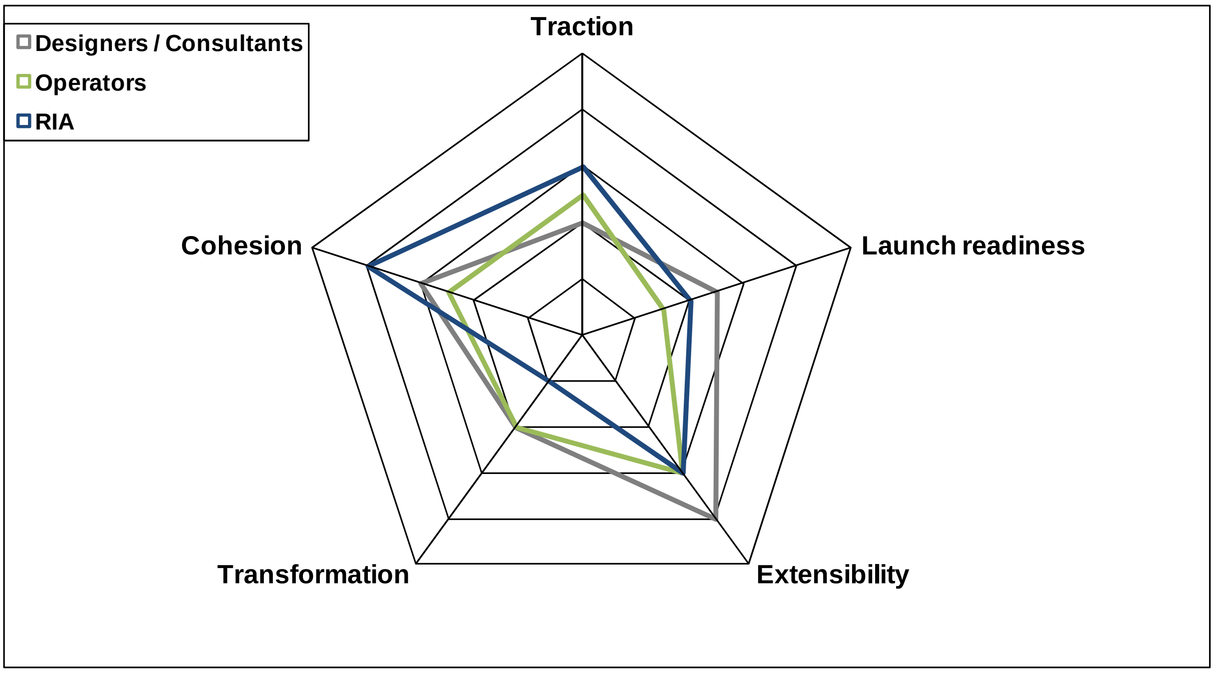


Figure 29: Gap analysis of innovation system process maturity between operators and suppliers of products and services to the industry

A similar picture of the alignment of the views of suppliers of products and services and that of operators obtains. Suppliers, designers and consultants find it easier to adapt to the needs of operators as the commercial relationship is likely to be more straightforward and less dominated by cost. The pace of change does not present a particular challenge.

Somewhat more divergence of perspective is visible when the picture of thought leadership and more radical innovation is considered:

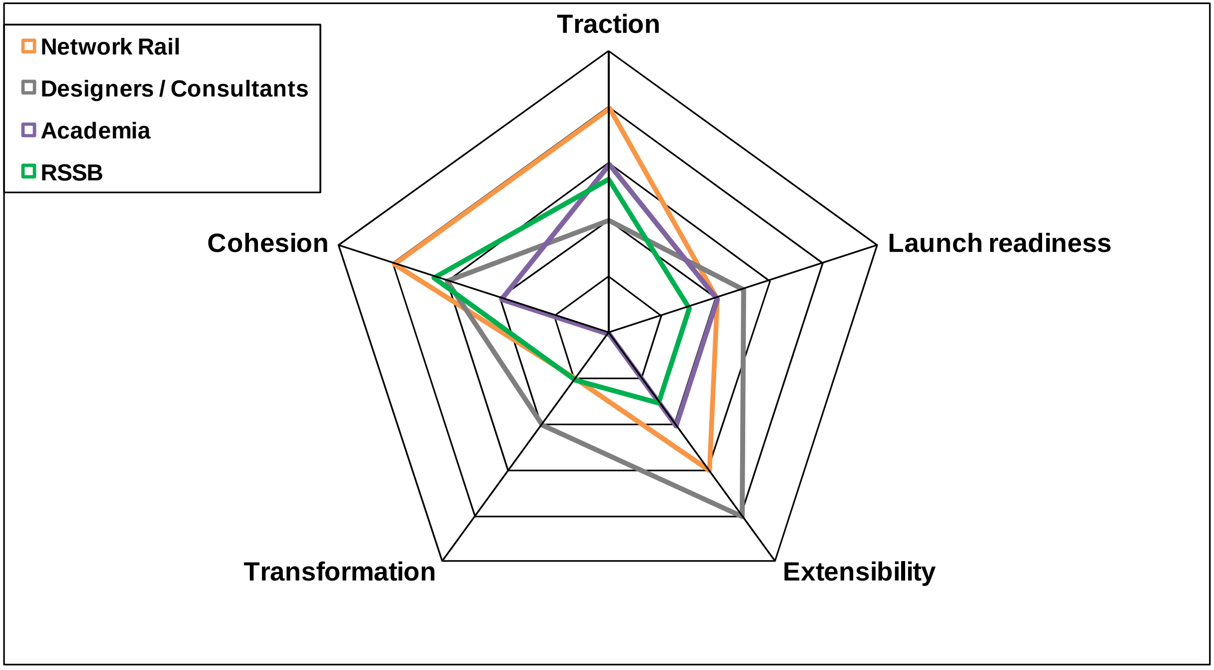


Figure 30: Gap analysis of innovation system process maturity between Network Rail and suppliers of research and thought leadership to the industry

Network Rail considers that GB rail has world-class capability in the area of rail research and the early stages of innovation and points in particular to understanding of the wheel-rail interface. RSSB points to the "All Level Crossing Risk Model", jointly owned by RSSB and Network Rail and the "Safety Culture Toolkit", which is used widely across the industry and is already licensed to Australia (an example of the Hauser principles in action). Interestingly, this optimism (shared by the TSB) diverges with the views of the academic stakeholders consulted (and at least one of the consultancies) and we suggest that a more in-depth analysis of the academic and early stage capabilities be undertaken in order to better understand the areas in which GB rail can demonstrate global excellence.

A senior stakeholder's view:
"The current cost problems of the industry arise from a lack of:
a. clarity about government's **strategic objectives** for the industry
b. coherent **leadership**
c. consistency in government's approach to strategy
d. consistency in timescales and economic **incentives facing different parts** of the industry
e. **system thinking** in government and the railway
f. understanding of the basic principles of risk management
g. **partnering** approach to procurement, particularly in Network Rail
h. data and information management systems within and across the industry to support a **risk based approach**
i. competence in using risk management ideas and making **risk-based decisions**, often at senior levels"

As has already been noted, the TRL 4-6 gap is a matter of general consensus. Designers and consultants feel that capability is greater in the area of extensibility and the adaptation of workable solutions to real application and, as they operate in a global market in any case, have deep capability in translating their experience of challenging GB conditions into competitive advantage elsewhere in the world. The RSSB considers that the largest single deterrent to implementation is the misalignment of incentives in the industry, where an innovative solution may make a good case for implementation, but has to compete for space and time with franchise or regulatory infrastructure commitments, with predictable results. Consequently, tactical is why 'problem solving' research undertaken for the industry by RSSB is generally well received while innovative new ideas are less readily adopted.

It is worth noting that the points of view expressed by the RSSB are perhaps overly sobering. It is possible that this is due to the nature of its position in the industry and its Systems Interface Committees (SICs), which expose the RSSB in no uncertain terms to the shortcomings that result from the misalignment of commercial drivers between different stakeholder groups. The RSSB is perceived by some (but by no means all) stakeholders as a discussion forum which fails to provide leadership for the industry. In some cases, there are areas where RSSB has the capability and expertise to intervene and lead, but the structure of the industry and RSSB's own remit hamstrings them. It is often difficult to reconcile the agendas of powerful stakeholders and given the lack of a suitable process and forum in which to resolve deadlock productively, it is hard to see how RSSB as currently constituted might have acted otherwise.

Clearly, the RSSB contains people with a great deal of technical expertise and it has proven itself able to manage a great deal of research as well as craft a credible technology strategy. Moreover, it devotes significant effort and attention to seeking international collaboration, including significant relationships with research bodies in Australia, the USA (FRA and TTCI), Japan (RTRI, on Human Factors and Wheelsets) and France (SNCF and UIC) and the ERA, as well as being part of the organising committee of the World Congress on Railway Research. However, it is in the field of deriving benefit from these influential relationships, as well as putting innovation into practice and driving the strategic innovation agenda, that the gap exists and it seems unrealistic to expect the RSSB (within its defined role) to provide leadership in this area. This is yet more reason to propose the formation of the a suitable set of innovation enablers to provide this leadership and de-emphasise the overly technical focus of innovation in the industry to date, although it is worth pointing out that the skills of TSAG/TSLG will be invaluable in providing much of the technology-facing enabling functions.

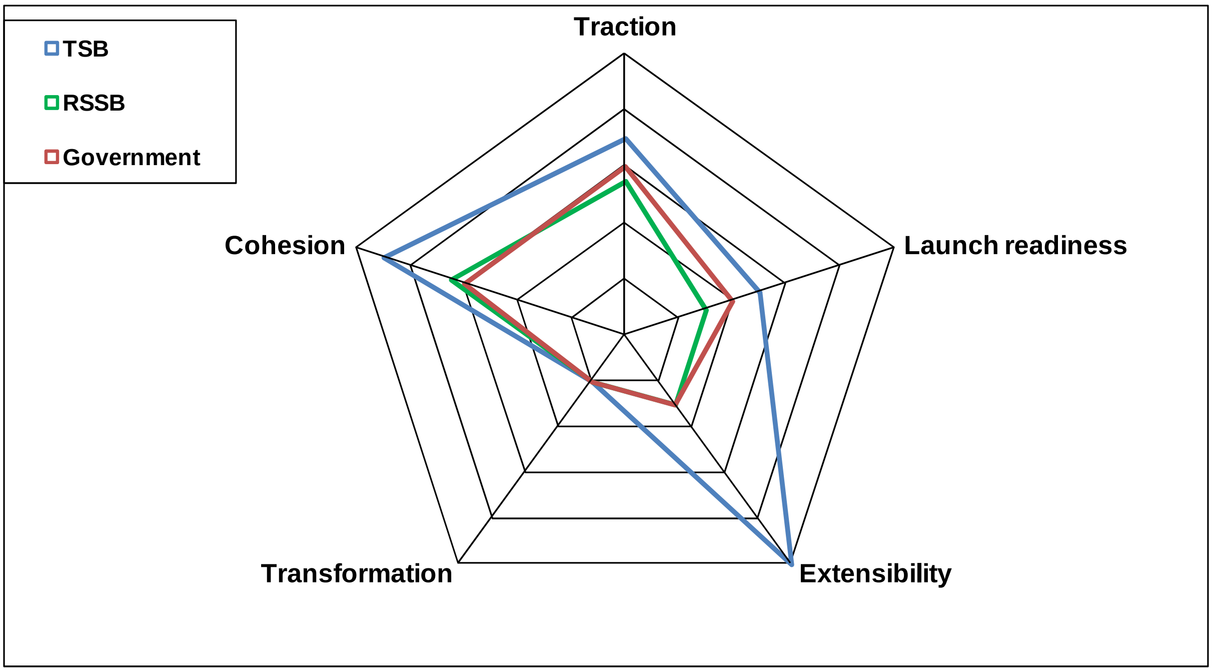


Figure 31: Gap analysis of innovation system process maturity between the DfT, RSSB and TSB

The TSB, owing to its view across the whole of UK plc, has a somewhat wider view of innovation system process and it is worth pointing out that whilst its view of the general lack of capability in terms of traction, launch readiness and transformation is consistent with those of other stakeholders and its generally positive view of the front end of the process, it appears to have an extremely positive view of the extensibility capability in the industry's innovation process. However, on closer examination this turns out to be a criticism – the high extensibility is felt to be occurring as a result of the industry's propensity to over-indulge in bespoking and "gold plating", so every idea is effectively treated as a niche idea and the benefits of capability platform development are entirely overlooked. The TSB's view across UK plc is further borne out when the capability of GB rail as an industry is benchmarked against that of other industries.

5.5 Examination of comparators from other railways

5.5.1 Comparison with Japanese railway industry innovation system

In 1987, the privatisation of Japanese National Railway (JNR) demonstrated that a large, state-owned railway can complete the transition from public ownership to private ownership successfully. At the end of this process it was able to show that it could compete successfully for passengers, for freight, and for capital. However, the reform process took 10 years in a crisis environment, when JNR's debt burden exceeded $300bn – and it was neither a smooth or easy transition.

The privatisation was preceded by the restructuring of JNR into seven separate companies — six regional passenger railways and one national freight railway and two other non-rail service companies. In contrast to what is now the general pattern in Europe, the Japanese Railways are vertically integrated, owning and operating their track, but still require an accounting separation so that access for through running is granted fairly. Also, because of the sheer density of traffic, rail operators carry volumes of passengers way in excess of any European railway. The number of operators and the complexity of the interrelationships between them dwarfs that in any of the European systems. However, mainly due to the high traffic density and the number of competing railways, as well as the cooperative nature of Japanese culture, the system is not only largely free of regulation, but also of strong contentions between operators.

The non-rail service companies, Railway Technical Research Institute (RTRI) and Railway Information Systems (RIS), are focused on innovation, research and development and information systems respectively. The companies in JR Group are independent and do not have group headquarters or a holding company to set the overall business policy.

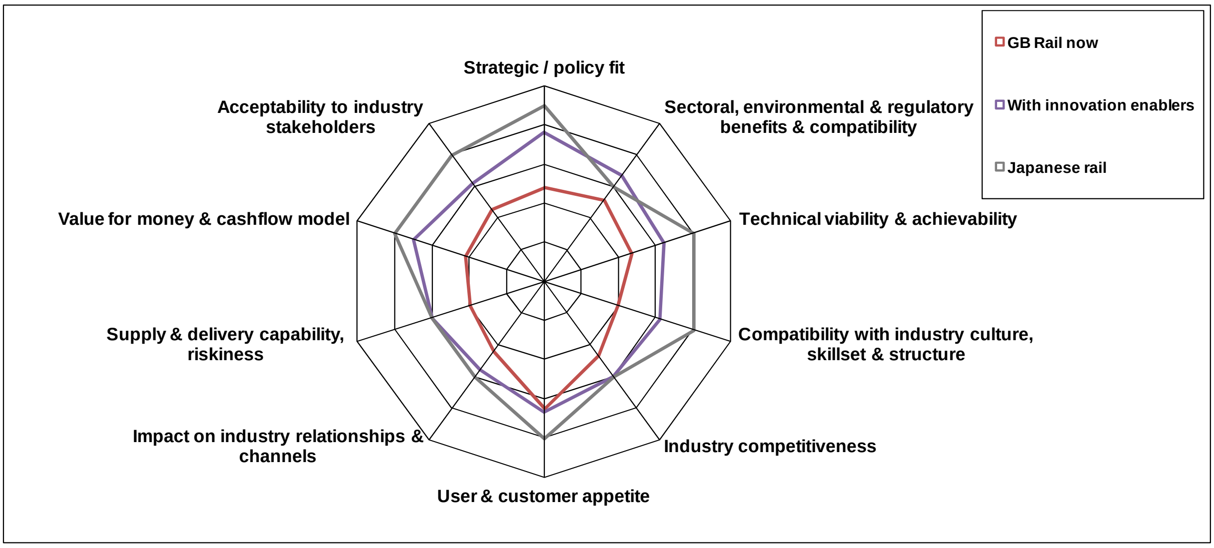


Figure 32: Comparisons of GB rail and Japanese Rail innovation system structural integrity

Innovation in the Japanese Railway (JR) business is highly driven by industry strategy and policy, which covers technology innovation from basic research to developed applications in almost all railway fields like rolling stock, civil engineering, electrical engineering, IT, material, environment and human sciences. This is supported by the existence of 'Railway Technical Research Institute (RTRI)' as an independent research and development wing jointly resourced by the revenue from JR companies and subsidy from the government and contract revenue from the private companies.

In 2004, RTRI adopted a five year master plan approach to define the targets and prioritised objectives and procedures for R&D activities. The short termed master plans are justified on the basis that it is inherently difficult to make accurate long term estimations of external trends like new technologies, management environment and funding uncertainties. Within RTRI, there also exists the "Railway Technology Promotion Centre" (RTPC), which is focused on solving problems of its member corporations by understanding their common technological needs and to assure the overall system reliability. The RTPC makes necessary proposals to the government so that the results of its activities are reflected in government policies. The principal goals of the RTPC are to:

- Maintain and improve technological capabilities (competence management for the industry)
- Systemise technologies and problem solutions (e.g. technical standards, R&D and contract projects)
- Provide technology information services (e.g. technologies, safety and international standards)

The overarching challenges for the JR industry include enhancement of RTRI capabilities, collaboration with railway operators, universities and research institutes both in Japan and overseas, R&D aimed at enhancing competitiveness of railways to support operators in difficult business environment. The initial research indicates that RTRI has made good progress in achieving desirable targets so far.

The innovation processes and activities in the JR industry are closely aligned with the sectoral, environmental and regulatory trends, a prime example of which is the foundation of the 'Railway International Standards Centre (RISC)' (owned by RTRI) in Apr 2010 to address the accelerated trends of energy efficiency, eco-friendliness and increased demand for safety requirements. The International Standards Center of RTRI serves as the liaison office for the Japanese Industrial Standards Committee (JISC) and carries out activities as the secretariat for the National Committee of the International Electrotechnical Commission's Technical Committee for Electrical Equipment and Systems for Railway (IEC/TC9), related committees and working groups.

The diverse technical challenges from the stakeholders (in particular JR companies) are addressed continuously through promoting R&D projects that are designated by stakeholders (JR companies) to solve local problems and that can be practically applied in the field. RTRI promotes R&D projects with other corporations, aimed at wide-ranging practical applications of research results. It also pursues carefully selected self-directed projects, especially when there is a competitive advantage in development, by using in-house knowledge, know-how and test facilities.

Case Study: Maglev Technology R&D using Dedicated Research Centre and Test Facilities

RTRI promotes the development and durability test and performance evaluation methods for ground coils and superconductive magnets, as well as necessary studies on Maglev riding comfort evaluation methods, to maintain the technical ability required for application to conventional railway systems. This is a good example of mature and proven technology transfer into other wider applications.

Culturally speaking, Japan is often considered to be one of the most innovative nations in the world and this legacy is successfully embedded into R&D activities conducted by JR Group. Since the formation of RTRI in 1986, innovation in railway has taken a strategic position with a holistic systems view to manage overall railway reliability. Institutions like RTRI, RTPC and four highly advanced testing facilities play a pivotal role in enabling innovation from basic research through to advance application development and standardisation. A number of public corporations, like the Japanese Association of Rolling Stock Industries, Japan Railway Technical Service, play a significant role in compiling and enabling data for R&D, conducting market research and encouraging new technologies or improved processes to support operation industry and advance the public interest.

JR industry innovation activities drive industry competitiveness in a significant fashion and in some cases (like the attempt to export Maglev technology to USA and Vietnam) clearly demonstrate attempts to create entirely unique market opportunities. However, there is a perceived weakness in the JR industry around the marketing and negotiating of overseas deals, hence a contingent lack of success in moving Maglev and other technologies out of the lab into application in the real world. Nonetheless, the obvious advantages of speed and capacity of the Shinkansen system has stimulated the construction of dedicated high speed lines in many other countries, the birth of which was initially viewed with considerable scepticism in Europe.

The 2009 annual report from RTRI further exemplifies the R&D potential of the JR industry, where RTRI made a large number of patent applications and, consequently, exceeded the total number of patents owned by over 2,200. RTRI also prepares learning materials for leading railway engineers and promotes personnel exchanges with operating companies to accumulate and transfer technical expertise to new graduates and mid-career researchers. All these features underpin the competitive edge of the JR Group as a whole.

Mainly due to highly innovative technology enabling a high capacity and frequency railway, number of competing railways, as well as the cooperative nature of Japanese culture, the system is not only largely free of regulation, but also of strong disagreements between operators. This has caused the JR group to be seen as a world leader in terms of delivering safety, punctuality and comfort to its end users, competing companies and other industry stakeholders.

There is significant evidence that the RTRI has developed strong industry relationships and channels through collaboration agreements at national and international levels, in particular with China, Korea, SNCF in France and with the RSSB in UK. A wide range of activities and collaborative R&D approaches have been taken in the past under each research and co-operation agreement. RTRI also cooperates with domestic rail-related organisations to strengthen relationships with overseas railways.

Innovation practises significantly stretches the supply and delivery capability of all segments of the Japanese industry. Recently, RTRI has installed two super-computers from the global super-computer leader Cray Inc. to accelerate large scale simulations and R&D that push the boundaries of innovation in railway technologies. So far, these technologies are not exploited extensively by commercial organisations and are most often used by government and academic customers. RTRI has nonetheless demonstrated a keen interest in enhancing their R&D capabilities by exploiting off-the-shelf advanced technologies.

Research suggests that the role of R&D plays a significant role in delivering value for money; furthermore there are strong indicators that the RTRI has taken increasingly active steps to establish a system to promote Japanese technologies and railway systems in the global export market. For example, Central Japan Railway (JR Central) Company's is currently in bid to sell Bullet Train technology in the US rail market. This indicates the value they put in moving technology out of the lab and into application, so it can be sold and, ultimately, commercialised. This also underpins the conclusion that the Japanese railway is well adapted to commercialising new innovations and technologies.

The 2009 RTRI annual report states that it conducted approximately 279 R&D projects in the FY2009, incurring an expenditure of $172.6m and delivering an income of $184.5m. During this period it maintained a total head count of approximately 660 staff, almost a fourth of which are Ph.D. holders. The RTRI makes a significant effort to live up to stakeholder expectations by following the fundamental policy on R&D (each of which translates into an IPMS-style capability platform) as follows:

- Create railway technologies for the 21st century
- Demonstrate integrated power as a group of railway engineering experts
- Respond quickly to needs
- Hand down railway technologies and accumulate basic expertise
- Disseminate railway technologies and transmit railway-related information

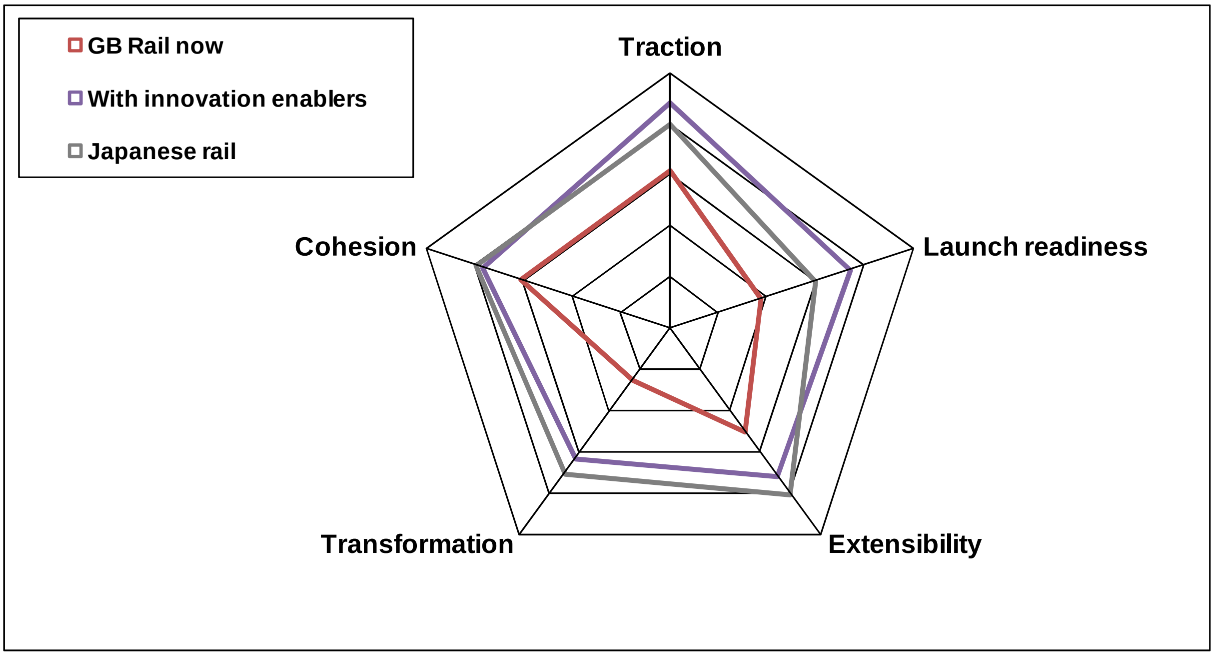


Figure 33: Comparisons of GB rail and Japanese Rail industry innovation system process maturity

5.5.2 Comparison with US rail industry innovation system

The predominantly freight railway in US is led by the Federal Railroad Agency (FRA), one of the ten administrations of the US Department of Transportation (DOT). The role of the FRA is to advocate and enforce the rail safety regulations, administer railway programmes and conduct research and development to improve railway safety and rail transportation policy and consolidate government support for rail transportation activities.

Unlike Europe and Japan, the US does not have an extensive intercity passenger network and the sole operator for intercity railway is Amtrak. It must be noted that most of the track infrastructure used by Amtrak is owned by the freight providers and in return Amtrak pays a fees to cover the usage costs, potentially one of the key causes for a slow and less attractive public transportation compared to the aviation and highways industry. Also, there are more than a dozen metropolitan commuter railway systems and many more are currently being proposed for other cities; however, these systems are not seamlessly interconnected.

On the other hand the US freight railways operate in highly-competitive market against other transportation modes and therefore are primarily focused on providing high quality services at a competitive rate. Since the inter-modal transportation is one of the fastest growing segments of the US railway business, freight railway continues to shares nearly 40% of the transportation market.

To maintain the competitiveness of the US national transportation network through advancing technologies and improving safety, operations and reliability of the network, the USDOT enforces a cross-cutting Research, Development and Technology (RD&T) programme for inter-modal transportation systems and a specialised Research, Development and Demonstrations (RD&D) for railways through FRA.

It is the office of Railroad Policy and Development (RPD) of FRA, which is mainly responsible for Federal investment and assistance to the rail industry as well as the development and implementation of policy concerning intercity rail passenger service and high-speed rail. The RPD actively conducts research, develops, tests, and evaluates analytical frameworks, methodologies, technologies, systems and processes in support of the FRA's core safety mission to enhance and optimize operation of the nation's rail transportation system. R&D projects are undertaken both independently and in partnership with public or private organisations. This collaborative approach is mutually beneficial and advantageous because it leverages scarce public resources and disperses R&D costs among stakeholders, reduces or eliminates redundant R&D efforts that benefit multiple end product users, provides FRA with a direct means to assess the safety needs of the railroad industry and provides assurance that safety is at the forefront of explorations of new technologies, methods and practices.

Beneficiaries of RPD's work include freight and passenger railroads, railroad employees and passengers, manufacturers, suppliers, shippers, communities and the public at-large. Alongside FRA, the Federal Transit Administration (FTA) provides technical and financial funding assistance to improve, operate and maintain local public transit systems including, subways, light rail and commuter rail. It also engages in R&D to provide transit industry and policy makers with the information and skills to make business decisions about technology, operational and capital investments and chart the course for future developments. An economic regulatory agency, the Surface Transportation Board (STB), also exists to resolve railroad rate and service disputes and review proposed railroad mergers.

Another overarching R&D administration of DOT is the Research and Innovation Technology Administration (RITA), which coordinates DOT's R&D activities and investments for all transportation modes, including railways. It sponsors advanced research and awards grants to universities, including 60 University Transportation Centres (UTC) to advance US technology and expertise to improve the national transportation network. The RITA brings together important data, research and technology transfer assets and provides strategic directions and oversight to DOT. While the FRA continue to conduct R&D based on its unique mission and stakeholder needs, the RITA ensures it is integrated with other programmes and fully supports the DOT's strategic objectives. A number of private not-for-profit institutions similar to the TSB also exist within the National Research Council, providing leadership in transportation innovation and progress through research and information exchange.

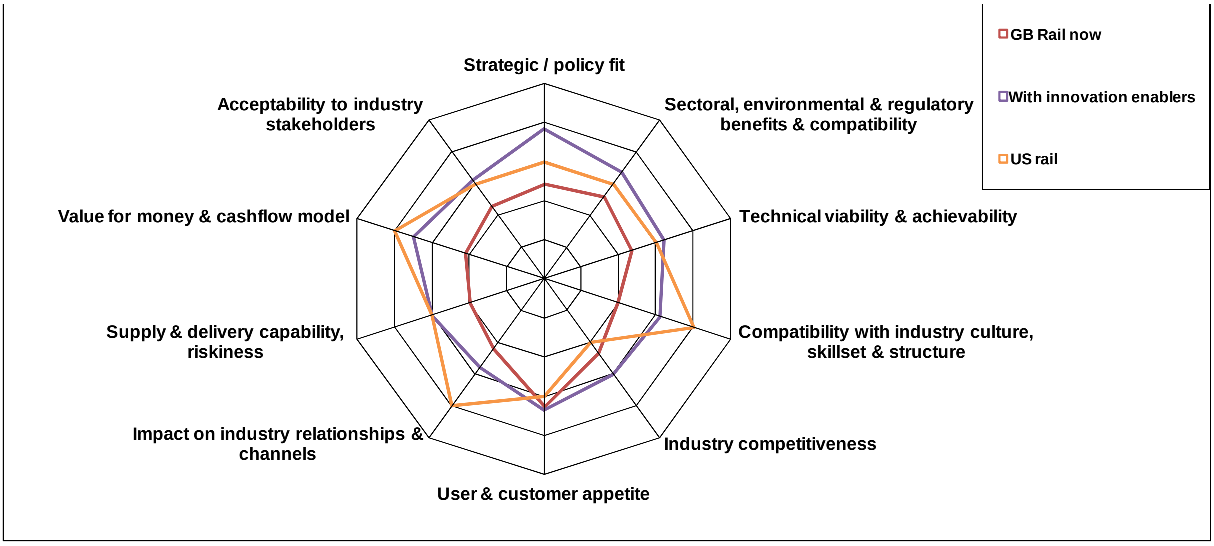


Figure 34: Comparisons of GB rail and US Rail innovation system structural integrity

Innovation and R&D in the US transportation industry, including the railway, is largely driven by both national and industry strategy and policy and stakeholder needs. However, it has certain imitations, in particular its ability to address inter-modal transport R&D issues and the alignment of modal agencies towards the strategic goals of DOT. To reinforce the importance of Federal leadership in innovation and R&D, the National Surface Transportation Policy and Revenue Study stated that:

> *"Research plays an essential role in the development of technology and science. It has made possible much of the progress in transportation over the last century through the development of new materials, production methods, design and planning tools, and data management techniques. The Federal role in transportation research, development, and technology (RD&T) is particularly vital…"*

In order to address the industry technology challenges and stakeholder needs, the FRA developed a five-year strategic plan for railway specific research, development and demonstrations (RD&D). The plan outlines the future of railways and the technologies needed to support them and has three main elements: Railroad R&D, the next generation High Speed rail technology demonstration and a Maglev technology deployment program. Unfortunately, this plan covered the period from 2002-5 and has not been updated since.

Nonetheless, in 2005/6, the need for an overarching strategic plan was realised, mainly to align the individual transport administration R&D programs with DOT's strategic goals for all transportation modes and to fill gaps in cross-sectional inter-modal research and development. The RD&T strategic plan 2006-2010 was prepared by RITA to provide policy makers, an overview that can be helpful in comprehending program coverage, funding levels and subject matter and fostering dialogue among the operating agencies to reduce potential for duplicate research. However it had certain limitations, in particular that it produces an overly simplified and potentially misleading picture of modal agencies' alignment to DOT's strategic goals.

It can be observed from FRA's strategic RD&D plan (Mar 2002), that the railway innovation system and process is fairly well aligned with sectoral, environment and regulatory trends. It is evident that the elements of the plan were developed based on historical risk and accident analysis, strategic review of industry trends and a review of current research, development and demonstration projects promising significant results. At a higher strategic level, DOT share a commitment of resources for common goals and strategies identified in Transportation RD&T Strategic plan 2006, for example investing $397m (33%) and $81m (7%) for safety and environment related R&D of the overall funding budget in FY2009.

FRA's R&D program primarily supports safety and regulatory processes, but also provides support to railroads involved in the freight transportation, intercity passengers, employees, labour organisations and suppliers. Also, the next generation high speed rail technology demonstration program seeks to develop pubic interest in door-to-door high speed passenger service, which could be introduced through improved partnerships with suppliers, railroads and state governments. FRA has also planned to initiate plan and build of Maglev project in US, attracting a Federal finding of $55m for planning and about $950m for final engineering and construction of the project.

Case study: TTCI/AAR and the Volpe Center

The Transportation Technology Centre (TTCI), at Pueblo, Colorado, a wholly-owned subsidiary of Association of American Railroads (AAR), provides the infrastructure necessary to conduct experiments and to test theories, concepts, and other technologies in support of the R&D program run by FRA, government agencies, railroad industry, transit operators, suppliers, and foreign organisations. Yet another significant research facility for FRA's RD&D program is the John A. Volpe National Transportation Systems Center ("Volpe Center"), Cambridge, Massachusetts. Another major portion of FRA's RD&D program is carried out by universities, railroads, and railroad suppliers, consulting and technical companies working under competitively awarded contracts. However, recent financial difficulties has caused the large railroads to cut back significantly on their in-house R&D programs and to reduce their jointly funded program carried out at TTCI. Furthermore, Amtrak and commuter railroads have no surplus funds to spend on R&D, which underscores the importance of FRA RD&D program. It is difficult to assess the success of FRA's RD&D program at this stage, because many of its projects are still under development and their benefits and scale of implementation largely depends on the rate of benefit return and availability of capital in the rail road industry. However, it is anticipated that the programs will begin to show up tangible benefits in earnest about ten years of implementation and will have a long-term effect on the US railroad system.

The US economy is considered by most economic modellers to be the most innovative in the world followed by Germany, UK, Japan and France. It links its readiness to respond to challenges to its ability to adopt, and benefit from innovative technologies, science and engineering workforce, scientific knowledge and organisational capabilities. However, initial analysis suggests that this advantage is rapidly eroding due to under investment in R&D by Federal resources. Particularly in the railroad industry, there has been a decrease in the overall funding received in FY2009 ($36.7m) by 5% to what was received in FY2008. Furthermore, a majority of the funds were dispersed in safety and operations (92%) improvement of the railway, which is highlighted as the main priority of the RD&D strategic plan of FRA. Although there are current plans to address these issues identified in FRA's and RITA's strategic plans, there could nonetheless still be funding inadequacies for R&D projects going forward, enabling alternative technology leadership or spin-offs to gain increased market share.

US intercity passenger services has lost its competitive edge to the European and Japanese counterparts for being a slow, infrequent and disconnected network. In the 21^{st} century, while European intercity networks run at least one service per 30mins for their customers, the Amtrak can only offer a daily intercity service between cities of similar size and scale, which again is often riddled with delays and stopovers to give way to the freight services. However, the recent proposal by the Federal government to build a High Speed rail network in the US has stimulated a lot of R&D and procurement activities, including a Maglev test and roll out plan to improve public interest in the passenger service. Similarly, as the freight industry has evolved, the passenger operators (Amtrak) has also begun to invest in electrification and new electrified trains that provide up to 150 miles per hour service on proportions of the Northeast Corridor.

Nevertheless, the extensive freight railroads operate in highly challenging environments to compete with aviation and roadways transportation and, so far, continue to grow market share in challenging economic times. One of the key reasons behind this is technical innovations allowing low costs, high safety records and increased system reliability and the ability to offer transportation services at a very competitive rate. This, in turn, has converted a high volume of its truck industry competitors into long term customers. Similarly, higher fuel efficiencies of the railroads have clear advantage over the other modes of transportation. Despite the above favourable features, however, the railroad industry has yet to develop the capabilities to offer global technological leadership or catalyse a global trend.

Over the past 20 years, the railroad industry has invested over $80bn in track and equipment technology. This has played a key role in drastically improving the industry's safety record. Since 1981, the frequency of accidents and incidents is down almost 74% and the number of accidents per train-mile is down almost 65%. In addition to increased infrastructure investment, this improvement is attributed to a number of factors, including application of the results of the R&D programs of the FRA and the railroad industry.

The benefits of innovation to the freight customers and stakeholders are clearly visible through the passing of cost reduction savings straight to the end customers. The fuel efficiency of railroads also has a clear advantage over the other modes of transports. However, these innovation benefits are often limited to the freight industry and have yet to be realised for the passenger services particularly in view of a pervasive bias in stakeholder priorities.

Case study: stakeholder misalignment affecting asset performance

Amtrak being a customer of freight railroads, pays the fees for its usage for tracks owned by infrastructure (freight) companies, but is not in return guaranteed fair access to the railway and in fact is often given a lower priority compared to the profitable freight services. There have been instances when a freight railroad totally abandoned its operations, leading either to line closure or excessive maintenance costs to be picked up by Amtrak. In some cases, Amtrak's infrastructure maintenance and upgrade requests are not fulfilled in time, as they may not align with the freight railroad asset investment plan, affecting its overall performance and reliability.

The recent innovation initiatives and strategic R&D plans of DOT and FRA has stimulated trends for fostering dialogues between operators, federal and state governments and industry suppliers, who all seem to be able to integrate together to respond to the industry challenges and maximise their share in the growing market. This could be typically represented by the fact that 34 states, including New York, Virginia, North Carolina, Ohio, Michigan, Illinois, Wisconsin, Washington, Oregon and California, are participating in the development of a high-speed rail network.

The FRA also encourages collaboration via such mechanisms as the oversight and review committee of the FRA Research and Development Programme, which includes representation from GB's RSSB with a view to comparing notes on how GB and US programmes work. The RSSB representative considers that there is a significant gap between the views of stakeholders as to what research should be carried out, far more so than there is in the GB, with the result that the FRA has often researched new products that the industry has no interest in launching. This situation occurs because there is no requirement to secure stakeholder support in the evaluation process for new research projects, as was the case in GB rail about 8 years ago. The RSSB are encouraging the FRA to increase the importance of stakeholder support for research other than that relating to its regulatory functions, interestingly enough an example of the US seeking to learn from best practice in GB Rail to increase both relationship-led research and stakeholder engagement.

A better example of relationship-led innovation is the establishment of the Safety Assurance and Compliance Program (SACP) by FRA, which has led to its improved relations with railroad industry. It acts as a vehicle for FRA to address safety issues outside the realm of regulation and reduces the adversarial relationship that often exists between the regulator and the regulated community. Through SACP, railroad labour and management have engaged in collaborative partnerships with FRA to help identify and solve problems related to rail safety. As a result of FRA R&D activities, it has also increased its cooperative activities with foreign entities, like jointly sponsoring research activities with Transport Canada and sharing research results with the European Railway Research Institute.

The case study for High Speed rail network for US railway passenger service below exemplifies the effectiveness of innovation in challenging supply and delivery capability and stretching its risk taking ability to stimulate economic growth:

Case Study: A High-Speed Network For America

In September 1997, the FRA published its report, High-Speed Ground Transportation for America, which examined the commercial feasibility of upgraded passenger train service, new high speed rail service and maglev service on eight corridors around the country. The report examined the "partnership potential," for each corridor.

It was concluded that as a self sustaining entity, the private enterprise could run the corridor once it is built and paid for and that the total benefits of a corridor service would be equal or more than its total costs. It was furthermore concluded that all eight corridors qualified this commercial feasibility test, with five corridors meeting the criteria for high speed service and four satisfying the requirements for a maglev service.

Furthermore, the establishment of the TTCI for specialised testing works underscores the appetite for investing in research centres and testing facilities to bolster engineering capabilities, improving industry collaboration, dispersing R&D costs to stakeholders and innovating new technologies and processes.

It is envisaged that RITA (DOT) and FRA-led R&D strategic plan initiatives will have a long-term effect in US railway system. However, at this stage, many of the projects and programmes are in developmental stage and their full benefits could only be realised in term of the actual return rates and scale of deployment in future. It is anticipated that the programs will begin to show up tangible benefits in earnest after about ten years of implementation.

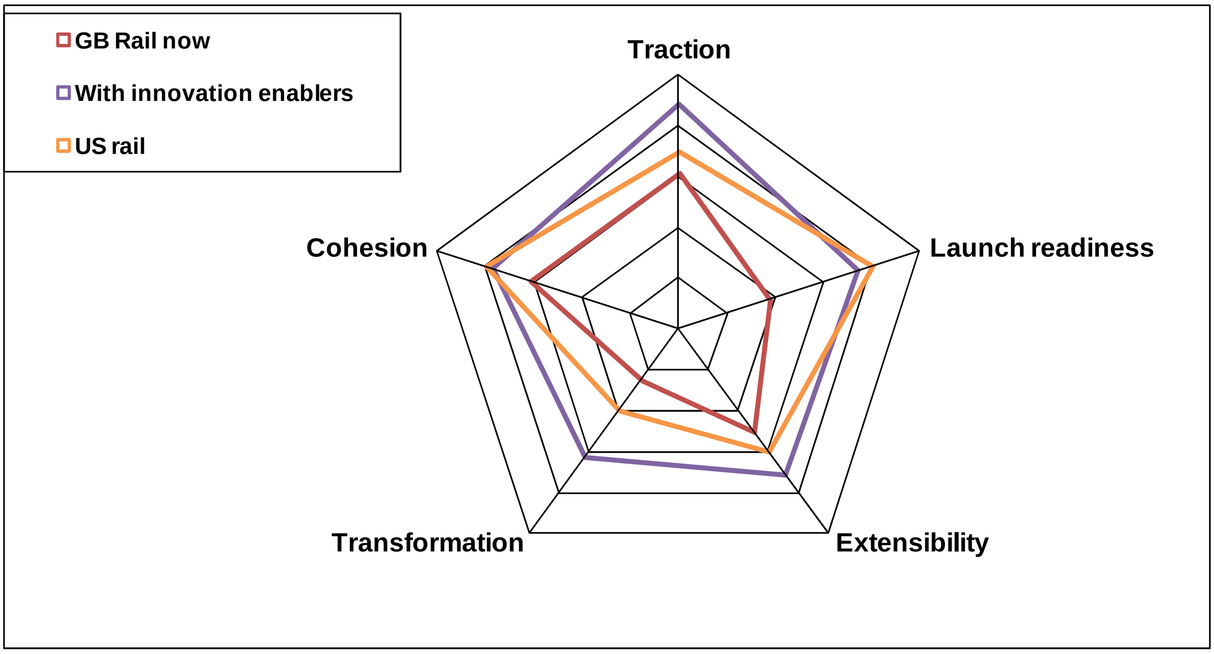


Figure 35: Comparisons of GB rail and US Rail industry innovation system process maturity

It must be noted that the commuter rail and inter-modal transportation markets are the most rapidly growing segments of the railroad industry. Congestion on highways in and between some major urban areas has brought about renewed interest in commuter and intercity rail passenger services. It is reported that congestion delays on highways frequently results in losses of multimillion dollars very year, which could be averted by providing alternative freight transportation mode in form of railroads. Here the case for value for money through innovation could not simply be justified on the basis of financial returns and but other factors like increased safety, lower fatalities and competitive cost control should also be considered.

As discussed extensively in the sections above, the FRA and RITA innovation initiatives and strategies have been developed with an extensive stakeholder consultation and contain specific elements to address issues and problems faced by the industry stakeholders. The system currently stands with several limitations deep rooted in the historical development of rail roads in US and the political environment of the transportation industry's modal orientation. The industry strives to meet stakeholder holder needs and has taken a number of steps to increased collaborative working towards common strategic goals.

5.6 Examination of comparators from other industries

5.6.1 Comparison with aerospace manufacturing industry innovation system

A comparison of GB rail and Aerospace manufacturing innovation systems is shown below:

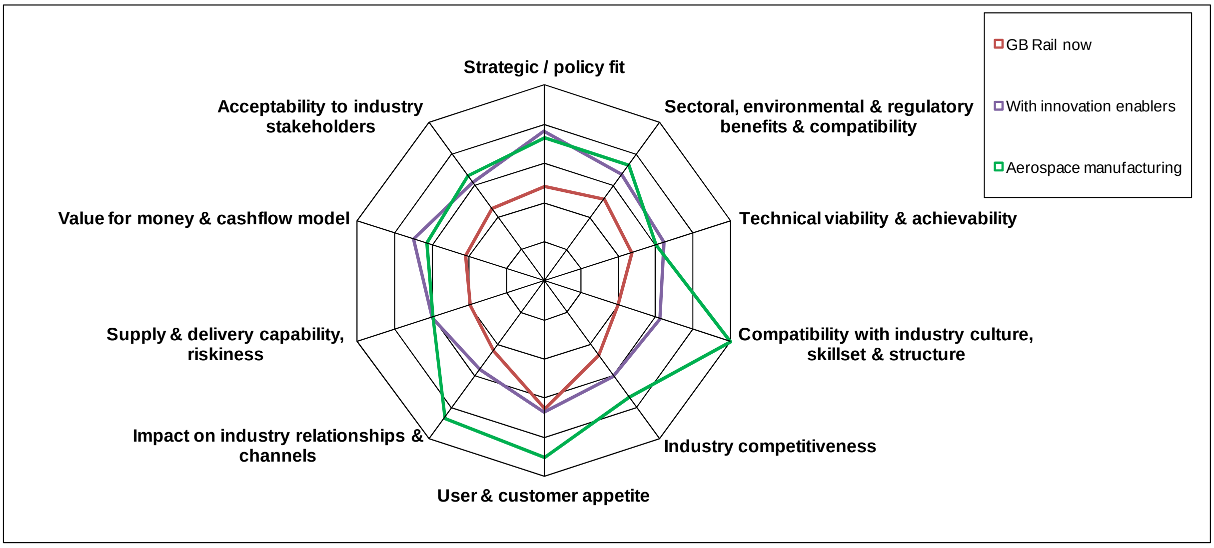


Figure 36: Comparisons of GB rail and Aerospace manufacturing industry innovation system structural integrity

Although there are significant gaps along each of the ten dimensions of ISS, the two most striking gaps in structural integrity of the innovation process between GB rail and aerospace manufacturing (AM) appear to be along the dimensions of “compatibility of innovation with industry structure, skillset and culture” and “impact of innovation on industry relationships and channels”.

GB rail is seen as lacking innovation skills and culturally in conflict with innovation. The culture of GB rail is one of consensus and committees and, whilst this is superficially collaborative and groups such as TSAG function effectively as discussion forums, as the structure of the industry makes it difficult to overcome a fundamental lack of clarity about who should be leading innovation at an industry level. This means that the beneficial effects of the collegiate discussions that do take place are not sufficiently leveraged into actual application (or at least have not been universally so to date).

Innovation is stymied by adversarial, procurement-driven relationships and a lack of clear accountability. When impasses are reached, horse-trading rather than leadership is the rule. Stakeholders recognise that some innovation happens despite these factors and instances of success have relied in the past on strong personal relationships. Time and again, misalignment of commercial drivers is cited as a reason that whole-system value is not sought.

It therefore seems logical to conclude that some way of referring difficult decisions to some form of systems authority to break the logjam would offer a solution. However, for this authority to be effective, it must be able to consider not just technical issues, but commercial issues and those of investment risk. In fact, it must be able to take an informed view around the entire ISS framework for decisions to be made on a sufficiently systemic basis. We therefore recommend that best practice guidelines for systemic and systematic innovation decision support be developed for the industry as a matter of urgency.

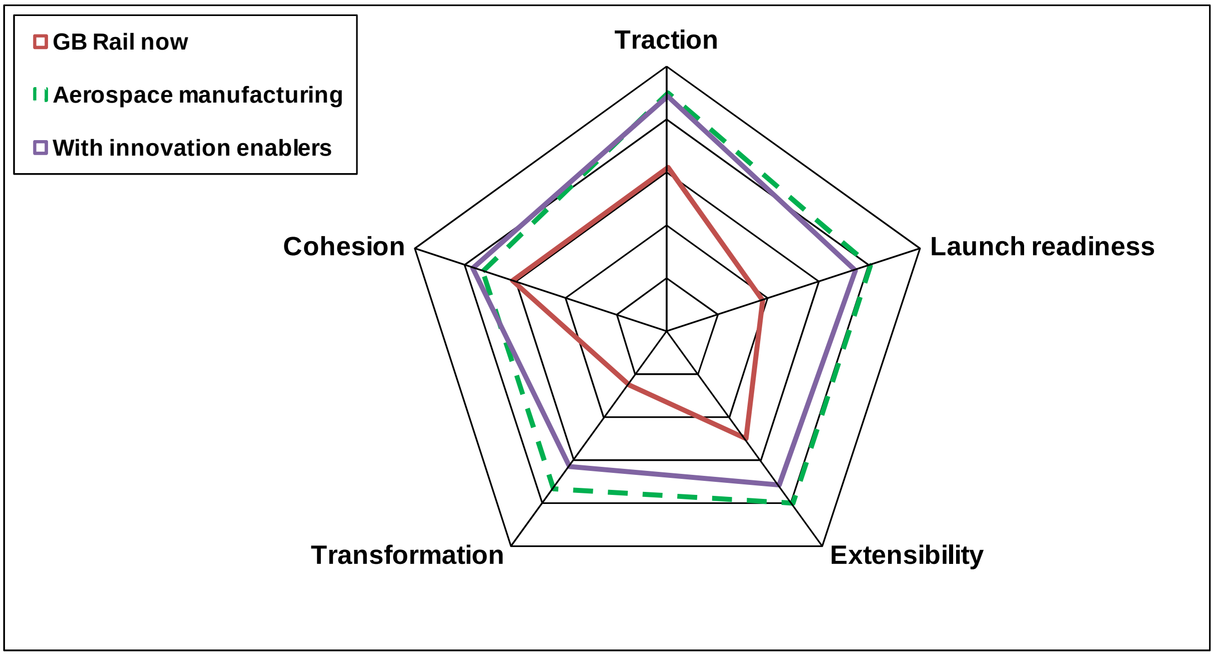


Figure 37: Comparisons of GB rail and Aerospace manufacturing industry innovation system process maturity

The gaps between GB rail and AM in terms of innovation system process maturity are even more striking. Whilst the number of early-stage insights and the level of research at low TRLs are in both cases (the "cohesion" dimension) are high enough to be considered appropriate, the gap starts to widen at the "traction" dimension, in the expected "valley of death" between TRLs 4-6.

Here, whilst AM can offer appropriate acceleration to valid ideas and well-functioning forums in which prospective innovation challenges can be socialised, GB rail starts to fall behind. Although the technical details of innovation can easily be socialised in the industry, the lack of openness in collaboration as participants start to stake their claims to created value make it difficult for innovation projects to reach a more advanced stage unless, as in the case of Network Rail, one player is able to control and progress the entire development process.

The aerospace manufacturing industry views a strong R&D base (the portfolio is worth about £1.5bn) as critical but key to this strength is stability; the TSB as a key enabler of early stage TRL work has undergone a significant amount of changes in the last few years and in the opinion of some industry experts this has harmed long-term stability in both portfolio and process. This is most visible in the large number of changes the TSB has been through and can perhaps be linked to lower-than-anticipated benefits from its aerospace innovation projects, as well as the identification of some elements of weakness in the industry research base. By contrast, the approach of the Fraunhofer Institutes and their clear and distinct technical remits provides greater long-term stability.

The gap widens yet further at the stage of launch-readiness, due to the lack of GB rail capability to bring platforms to market. Again, where an individual player is in sole control or a group of organisations is able to align its commercial drivers (for example, a freight operating company and a rolling-stock manufacturer), innovations will be launched, but by parts of the value chain rather than the industry as a whole. More problematic, system-wide platforms requiring alignment of a greater number of organisations (ERTMS is a clear example of this kind of challenge) will be delayed by issues of culture and commercial relationships, or will simply stall and fail.

Once a launch is in place, however, GB rail's ability to create variants immediately comes into play, but this is not due to a genuine desire to create product and service extensions to extract maximum value from the platform, but rather due to the fragmented nature of the industry driving highly divergent local requirements of questionable value, with scant interest in the system-wide picture. Essentially, immature platforms are being launched as products and then bespoke development is continuing in the market without regard to the original platform. Once more, the lack of a system authority to maintain platform integrity until launch maturity has been achieved drives fragmented launch and "early niching" rather than true extensibility.

The gap now increases to its greatest extent between the capability of GB rail and AM as the limits of niche applications are reached, yet the inward focus of GB rail means that insights that could be transferred to other industries are not identified and indeed not even sought, unless this occurs within the strategies of individual suppliers with wider markets. Certainly no industry-wide technology transfer programme is currently in operation to apply knowledge and insights from GB rail externally, although there is recognition in the GB rail industry that these could be a source of considerable value in at very least other railway systems.

To summarise, the difference between GB rail and AM revealed by ISS and IPMS is between an inward-looking, technically focused and non-collaborative system and one that is more mature, highly integrated and aligned, with more productive relationships.

Innovation in aerospace manufacturing is highly driven by the setting of regulations, which drive shifts in aircraft design, a good example being fuel efficiency driving lighter aircraft. The industry has also developed mechanisms to embrace external trends, for example the simulation and fly-by-wire capabilities that come out of the videogaming industry. The industry is clear that it operates in a global context as far as these trends are concerned and is also highly affected by issues around public awareness (e.g. carbon emissions) and skills regeneration. The Aerospace KTN is seen as a key enabler for keeping the industry from turning in on itself and focusing relentlessly on the bigger picture, with an ability to provide up-to-date snapshots of industry capability and requirements, for example in legislation; a key driver of innovation in aerospace manufacturing has been the policy objectives of both the UK government and the European Commission with regard to the reduction of harmful emissions.

The KTN also works in the "network of networks" to bring in influences from other industries, a good example of this being the move in modern built environment for all new build materials and processes to be carbon-neutral, which affects many aspects of both aerospace manufacturing and the larger aviation industry.

Because of past experience in the industry, there is a key focus on technical challenges and R&D in particular and awareness that without continuous investment, R&D capability degrades over time. Key technical drivers include IT architectures. The "value stack focus" principle operates at a technical level as well – technical consideration follows the structure of the UK industry, which is unable, competitively, to provide fuselages for big jets, but via Airbus and Rolls-Royce, demonstrate world-class innovation capability in wing technology and aero engines respectively. This clarity of technical focus is viewed as a key driver of technical innovation and maximises pull-through into development. This is encapsulated in the technology strategies that support the industry's innovation platforms.

Aerospace manufacturing is highly structured because of the long development cycle and asset life. Given the concentration on particular subsystems in the value stack, testing capability obviously focuses on these subsystems but is seen as a critical enabler.

The aerospace industry views its innovation success as coming from an ability to align the market drivers of the various participants. One of the key enablers for this is the importance of taking account of cultural factors at a national level. The UK is not a speculative investment culture, investing to "see what happens", which is far more common in the German equivalent. The UK industry focuses on its ability to deploy high-flexibility and high calibre people, but is also seen as more individualistic and profit-driven rather than taking a whole-system view.

This raises the issue of the difference between the aerospace manufacturing industry innovation system, which displays a high level of both system integrity and maturity and that of the aviation industry innovation system, which incorporates additional stakeholders from airport infrastructure, air traffic control, airlines and fleet operations and requires interfaces with other transport modes, all of which are more involved with the end-user.

Support for innovation from industry stakeholders consequently depends on vertical alignment – although the ultimate goal for aerospace manufacture is to make an aircraft, outside of aerospace manufacturing, the drivers for airlines and airports, air traffic management and modal shift are poorly aligned. An example of this can be seen from the difficulty in agreeing a standard for engine warm-ups, if the manufacturing view demands four hours, but this is incompatible with operational procedures in use.

Obviously, this presents a cultural challenge to “pull-through”, leading to a belief that long-term pull-through across the aviation industry may not be achievable; the aviation industry does not appear to have a “Systems Authority” in place to resolve conflicts at whole-system level. Although a comprehensive aviation innovation system can be outlined, every current programme that cuts across vertical silos (e.g. the goal of Manchester Airport to be “carbon neutral on the ground” by 2014, or the issue of taxation of airspace and the “single sky” which is affected by the propensity of individual countries to permit over-flights) faces these systemic barriers; the same is true of GB rail.

Competitive pressures also drive innovation in aerospace manufacturing by forcing re-evaluation of the global markets. This competition is stimulated by clear challenges, in which the KTN plays its part in the “cell” section of the industry IPMS, priming the innovation cycle with networking events on, for example, simulation. The market demands specific requirements which drive these benefits, both long-term, like the need for “a new short-range jet” or driven by urgent operational requirements like safety incidents, such as the recent issues with the engines on the Airbus 380s, the Trent 900 series built by Rolls-Royce. Because of this global view, the global market also feeds competition at every level from “Airbus versus Boeing” right down to component level. This is analogous behaviour to that displayed by pantograph or signalling specialists within the global rail systems industry.

Industry structure is a huge issue in aerospace manufacturing; it is a highly hierarchical sector, according to not just function but size, from SMEs through to, large and very large businesses. Relationships within the industry are built on knowledge transfer all the way down to component level – if a manufacturer is not aware that the composition of springs must evolve from metal to composites in order to be compatible with a lighter or even non-metal airframe, the downstream consequences for systems integration will be considerable for the whole supply chain.

Innovation delivery capability is embedded directly into the manufacturing side. The component business relies on tight integration with a complex supply chain, which means that collaboration tends to become more difficult when a part of that supply chain can accelerate innovation to market, a good example being that of the “integrated aerospace composite wing”, for which organisations are far less keen to cooperate.

Taking a system-level view of value for money from innovation requires a view of development cycles that can take 15-20 years. However, the maturity of the aerospace manufacturing industry innovation system remains high in all quadrants of IPMS; input at early stages is increasingly coming from parallel industries (e.g. videogaming) and capability transfer (e.g. flight training in defence applications), as well as academia. In fact, the close relationship between aerospace manufacturing and defence (they even share a KTN) is a key enabler of this kind of transfer, as clearly many aerospace manufacturing platforms are key components of the defence industry system value stack – aero engines and wings both being found in military aircraft, for example.

The cell quadrant of the aerospace industry IPMS is fully populated with networking events run by the KTN among others and the capabilities of the TSB are fully leveraged. Knowledge is seen as owned by the industry, players complement each other with skills and capabilities, thus the collective requirements for challenge-based competitions are able to take place. This is in full accordance with the Hauser principles and the introduction of the new Technology Innovation Centres will also be aligned going forward.

Industry platforms (described as “systems” and “subsystems) are specified by the industry only when it is clear that the industry will be open to collaboration. The standard practice is for complementary stakeholders to come together for, say, five different platforms and, although the investment in each platform is not shared, but rather made individually by each stakeholder, the resulting value is shared across all stakeholders at industry level. Finding the common drivers for complementary stakeholders is key – where UK aerospace is fortunate is that it has Rolls Royce and Airbus, which are clear complementers, whereas at the equipment supply layers below, competitive behaviour around more modular components drives out the collaboration.

Case study: Platform development at Airbus

Where platforms can be identified, stakeholders are not prevented from collaborating by their lack of involvement across the whole spiral – Airbus do not fly the planes, but they still benefit from the planes being delivered and flown. This alignment of commercial drivers enables, in most cases, platform developers to build business cases that stack up individually. Platform specifications are not just technical, but cover all dimensions of ISS to the appropriate level of detail, thus ensuring a robust business case even at early TRLs.

Despite the bulk of investment spend coming as expected at TRLs 4-6 as in rail, public funding is largely unnecessary for civil platforms as the platform developers are prepared to put up the money and therefore manage the risk. What enables them to do so is the visibility of their interest in the downstream market. Where this differs from GB rail is that the income stream is visible over the long term, not subject to constant pressure from competitive procurement. Similarly, the market has global volume, as envisaged by the Hauser principles, ensuring continuity of use for platform development capability and hence steady building of industry capability and contingent steadiness in employment. Where the market size is highly variable over short timescales, this causes difficulty because the development capability has to be flexed up and down, negatively impacting on value for money. Effectively, what makes investment in platform capability possible is "lean"-style reduction of variation and a constant flow of the development process. The lack of vertical integration in GB rail, by contrast, combined with the procurement environment and short-term focus, prevents the development of this kind of constant flow.

The greatest challenge observed over time in platform-building, according to some AM industry experts, is that of achieving total accuracy in development costs based on clear understanding of the market. Platforms always take longer to deliver and cost more to develop than anticipated. What keeps the industry focused is the clear understanding that there is substantial downstream revenue over several decades. Where the payback period is too long, as was the case with the Airbus A380's 50-year timeline, the business case is far less convincing and collaborative stakeholder participation can be difficult to achieve. Where it is far clearer, as in the case of the A320, it was clear that the plane would be flying for 30-40 years, that there would be 4,000 planes in the global fleet and that every time a plane was delivered the platform developers would receive a delivery bonus.

For platforms, the closer innovation comes to a launchable application ("standard" in IPMS terms), the risk of non-delivery begins to decrease, competitiveness goes up and there is less desire to collaborate as behaviours begin to resemble that of the more modular equipment suppliers.

Aerospace manufacturing is strongly considering the benefit to be derived from influencing other industries through innovation, in particular with regard to the space industry, which has just published a UK innovation and growth strategy and set up an innovation and growth forum. This is seen as a key driver of the recent refresh of the National Aerospace Technical Strategy (NATS). The industry has some visibility of downstream technology transfer to other industries, including telecommunications, automotive, freight and rail and indeed to our certain knowledge sees distinct commercial opportunity for technology transfer to rail. Such insights are not available to GB rail as there is as yet no *agreed* equivalent to the NATS which could deliver this degree of understanding. Our research revealed that certain Aerospace and Defence suppliers had a much more developed vision of the potential for innovation in GB rail than we found amongst GB rail stakeholders.

It is instructive to look in more detail at how the AM system has evolved over the last ten years. Aerospace manufacturing is unusual in that there is an industry-level strategy in operation which was implemented during the tenure of Patricia Hewitt as Secretary of State for Trade and Industry, from ministerial level. At the time, the competitive position of UK aerospace manufacturing was regarded as being at risk, although it was clear that, if the situation could be addressed, global potential could be unlocked. This led to the implementation of the Aerospace Innovation and Growth team and the development of the National Aerospace Technical Strategy (NATS) to encapsulate an industry-level strategic approach and a close analysis of this approach against the criteria of ISS and IPMS would be particularly helpful in understanding how aerospace manufacturing has managed to develop an integrated, comprehensive and well-balanced industry-level management system.

Case study: the National Aerospace Technical Strategy (NATS)	
Policy, strategy & objectives	The NATS was a principal output of the Aerospace Innovation and Growth team after its formation in 2002, setting out a vision of the UK as a key location for innovative and productive inward investment and a driver of successful participation and competitive advantage in highly competitive global markets and key international development programmes such as "Boeing New Short Range Aircraft", of $3 trillion over the next 20 years. Specifically, the strategy seeks to establish leading, high-value roles in the design and manufacturing supply chain. The NATS is intended to support this by ensuring that investment is coherent and focused on key UK capabilities.
Trends (social, cultural, political, economic, regulatory)	The NATS notes the economic drivers as a key enabler of aerospace manufacturing, in particular its contribution to the development of global economics itself. It places itself in the context of a 50-year growth trend and makes explicit assumptions about ongoing growth rates of 4-5%. It is equally aware of constraints on aviation itself arising from environmental considerations as further drivers, such as the 2% of global CO_2 emissions for which the industry is responsible as well as noise pollution and air quality reduction.
Stakeholders & funding	The investment requirements from stakeholders are clearly set out – £1bn over 5 years (central government has contributed £300m to early-stage research and regional government £70m) as well as the overall required funding model for R&D investment (12.4% of turnover) benchmarking this against best practice from the pharmaceutical industry. It is also clearly stated that the industry seeks to be attractive to global investors.
Technical capability, skills & best practice	Key technical challenges are set out, including the minimisation of environmental harm through increasing propulsion efficiency, lighter weight materials and airframe drag reduction and, in a military context, integrating on-board and off-board systems to enhance information management in highly networked operations in challenging environments. Identified key technologies are researched by the National Technical Committees, which focus on specific areas of research and technology.
Value for money & operating models	The NATS clearly sets out the "size of the prize" for the industry: an improvement in global market from the current 17%, primarily from the manufacture of 25,000 new passenger and freighter aircraft over the next 20 years worth $3.1 trillion and, as an opportunity, growing at twice the rate of UK GDP. The industry recognises that it is a significant employer (over 100,700 people in the UK) and delivers £14bn of export earnings annually, as well as ten years worth of surplus to the balance of payments.
Organisations, people & collaboration	One of the key strengths of the NATS is the synergies it sets out between the civil and defence aerospace sectors. The KTN is one of the principal enablers, as it is the organisation that "hosts" the NATS on behalf of the industry and provides a forum for collaboration between government, industry and academia. Technology roadmaps in particular are developed in a collaborative way, driven by consensus views and open and inclusive processes – they are visible to anyone who wishes to register as part of the KTN and, significantly, integrate the technology with a collaborative investment profile. The National Technical Committees have also come together with the KTN to deliver a collective view from the supply chain to influence the Government's strategy in key cross-sectoral technical areas such as the national composites strategy. In fact, collaboration is so key to success that even where specific strengths in the academic and scientific research base are mentioned (e.g. QinetiQ and ARA) lack of co-ordination is identified as putting these at risk.
Competition & communication	Key existing international competitors (USA, France and Germany) are identified at national level, as well as emerging competition from China, Canada, Russia, India, Japan and Brazil. It is explicitly stated that national skill sets and manufacturing processes, rather than lower cost of labour are seen as competitive differentiators.

Delivery, standards & risk	It is noted that core capabilities, key facilities and infrastructure on which the industry depends are eroding. Inability to launch programmes is identified as a key risk to the NATS.
Internal & external relationships	The reduction in sovereign procurement from the defence sector is driving the search for export market potential as well as increased participation in partnerships. The KTN's technology roadmaps in particular drive future relationships as they set out the future insertion points for technology based on when platforms and aircraft are expected to enter service, thus allowing calibration of the supply chain. The validation programmes for these technologies are also explicitly set out to support the timely development of the relevant relationships.
User & customer needs	The NATS is very aware of the separate and shared needs of its civil and military user bases, as wall as displaying clarity about the difference between leisure and business requirements. Improvement in safety and security are mentioned in this context, as are improved research capabilities (see below) and significant improvements in the efficiency of delivering large research programmes.
Cohesion enablers	The NATS makes explicit mention of the complexity of launching large research programmes and the necessity for early-stage (and therefore high-risk) investment, as well as the support the industry has received through the regional development agencies and the devolved government administrations, seeking to improve inward investment. However, it also appears to identify a weakness in the research establishment and generally at low TRLs and therefore acts as a vehicle to raise this concern directly and explicitly on behalf of the industry.
Traction enablers	The risk involved in lengthy development times is mentioned and the Technology Strategy Board is clearly held up as a key channel of funding and government support via its open competition frameworks and particularly its industrial research support framework, as are the academic Research Councils. The TSB is specifically mentioned as an enabler of government support for a sector that forms part of core national capabilities as well as delivering major market opportunities. Significant participation from government, academia and industry is involved in the functioning of collaboration forums like the KTN, as well as specific technology research centres, such as the the Advanced Manufacturing Research Centre with Boeing (AMRC), Advanced Forming Research Centre (AFRC), Manufacturing Technology Centre (MTC) and the National Composites Centre (NCC). The industry also makes significant use of the EU Framework Programme to complement national and corporate investment.
Launch-readiness enablers	The NATS is notable for its highly prevalent mention of platform development. These platforms are not defined explicitly as capability platforms (see the diagram below) – it seems clear that they are generally technology platforms like "Integrated Wing" – however, the underlying capability platforms (e.g. the development of autonomous unmanned aircraft systems, or the reduction of airframe drag, or supporting software and hardware equipment supply subsystems, or the supersystems such as rotorcraft) can be inferred from the way the industry manages collaboration and integration of technology as well as how they are described in terms of function, capability and securing the investment to support them. The requirement for large demonstration and validation programmes is linked to future market needs.
Extensibility enablers	Specific existing markets are set out as targets for leveraging the development of world-class UK platforms, such as new short range programmes in Brazil, China and India as well as the markets for rotorcraft, which is believed to be worth $46bn (commercial) and $135bn (military) over the next 10 years.
Transformation enablers	The NATS recognises the commercial importance of a number of platforms with significant transformational potential, for example unmanned air systems. The technology research centres mentioned above are also able to function as enablers of cross-sectoral

	transformation. The national technical committees also consider opportunities for cross-sector exploitation as well as military-civil dual-use.

The NATS also acts as a visioning platform to identify the enablers that UK plc should be investing in to support the aerospace manufacturing industry innovation system. In short, it is not just a technology strategy, but an industry-level innovation framework, supported by the following explicitly enumerated enablers: **improved skillsets**, a skilled **research base**, **high-performance computing capability**, **strategic facilities and infrastructure**, interdependent **partnerships between government, academia and industry** and alignment with the wider **economic and social environment**. It has led to clarity for the industry about precisely where growth is coming from globally, thus enabling innovation to be aligned to meet these goals and long-term economic objectives for UK plc.

Figure 38: NATS industry capability platforms (described as “market drivers and research themes”)

Driven by the NATS, aerospace manufacturing can demonstrate a clear example of successful integration of the Hauser principles for a distinct industry sector – select a part of the industry “value stack” and concentrate on building world-class capability platforms in that area. GB rail’s vision, by contrast is far narrower, far more technically focused and far too concerned with the challenge to the existing stakeholders of delivering the service in the home market, rather than looking to global markets as an engine of growth and a deliverer of inward investment which can refresh and re-imagine GB rail itself.

5.6.2 Comparison with energy generation and supply industry innovation system

A comparison of GB rail and Energy Generation and Supply manufacturing innovation systems is shown below:

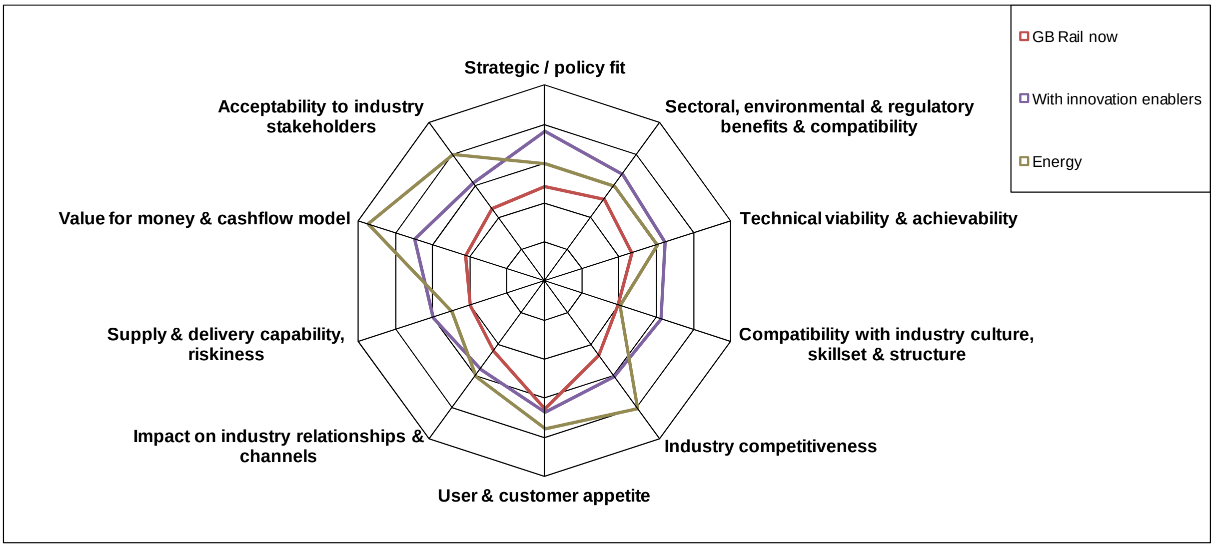


Figure 39: Comparisons of GB rail and Energy Generation and Supply industry innovation system structural integrity

The differences between GB rail and EGS innovation system integrity is instructive particularly because the EGS system is less balanced than that of AM. The most striking gaps between rail and EGS are in terms of the value for money and cashflow, acceptability to stakeholders and industry competitiveness dimensions.

Compared to GB rail, the EGS innovation system is far more certain of the value for money from innovation and this is likely to be because the areas for innovation are so clear and incentivised by substantial regulatory penalties. The penalty for not innovating is clear, present and serious and, as a result, stakeholders are able to take action to align their priorities far more, although there is no particular industry-level strategy pushing them to do so as a group.

Similarly, innovation is seen as a source of competitive advantage despite the challenges it poses to EGS industry culture, skillset and structure. This may be because of the competitive disadvantage for *not innovating* is so clear. Innovation is still highly challenging for the relationships in the industry, which are not aligned commercially for collaborative development of industry platforms.

By comparison, there is no real commercial penalty for GB rail from not innovating, as it is obscured by the issue of overall cost, which is so large that crisis management is perceived to make it difficult to justify investing time in what is perceived to be a source of additional risk, except ultimately in terms of the encroachment of other modes in both passenger and freight. It is worth remembering that automatic electric cars may be as close as five years away.

Were this penalty to be commercially visible, then the example of EGS would be likely to be followed in spite of the challenge to traditional industry relationships and culture. The industry would, in effect, be forced to innovate because they can no longer afford to ignore or obscure the pain from not doing so. An instructive example can be drawn from the current issue in EGS with the Gulf of Mexico deep-water drilling crisis involving BP, Halliburton and a number of other players. During the crisis, the industry pulled together in order to provide innovative solutions to the challenge, because each day the cost of not having dealt with it yet and public pressure grew greater, together with the threat, now realised, of legal and punitive action from the United States government.

By contrast, the operational phases of crises in the GB rail industry are soon over and consequently do not produce this kind of action, despite the enormous change brought about by major accidents. Rather, in the case of systemically caused, chronic delays and perturbations, the traditional adversarial relationships within the industry are reinforced by instant recourse to the customary intertrading of fines and penalties between the various stakeholders and a strengthening of safeguards – what is known in some circles as “scraping burned toast” (rather than not burning it in the first place). Here, innovation could be enabled by an oversight role detailing not just the lessons learned and the required safeguards, but rather by posing a challenge to the industry to provide an innovative response to the problems that caused the crisis; leadership could be given by a systems authority which was tasked with overseeing the development of relevant platforms to benefit the industry as a whole – an instructive example here is that of the UK Government’s “COBRA” committee, which acts as a cross-departmental systems authority in co-ordinating response to serious threats to UK security and providing leadership in crisis situations.

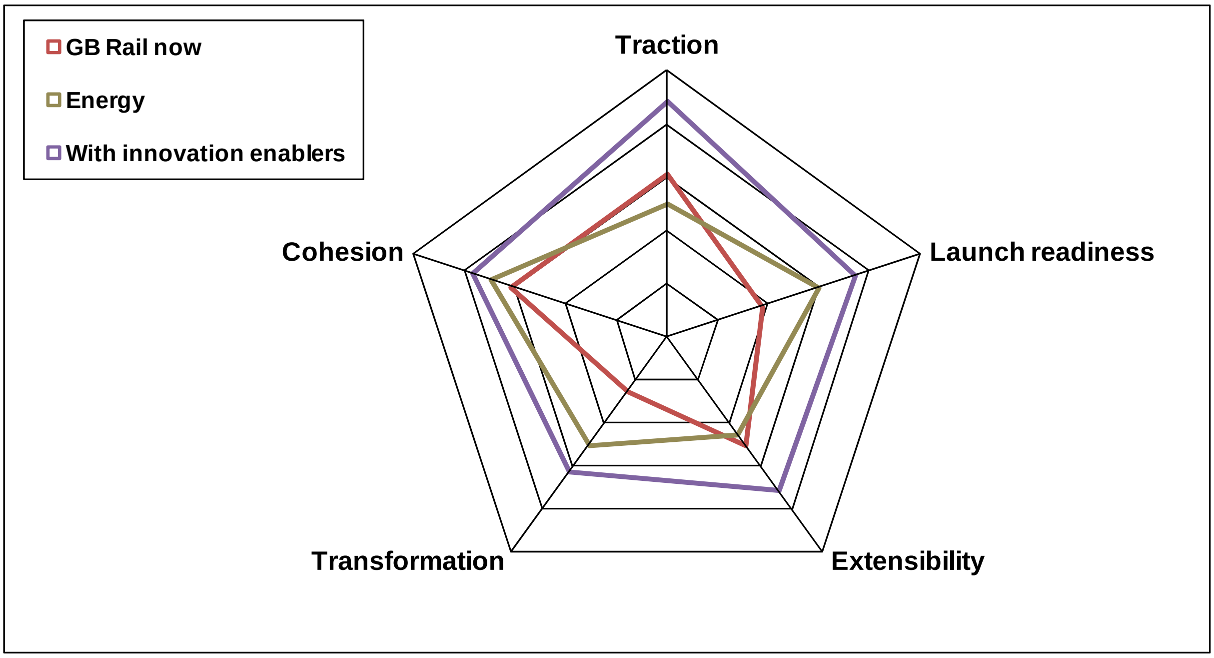


Figure 40: Comparisons of GB rail and Energy Generation and Supply manufacturing industry innovation system process maturity

Again, as with AM, the EGS industry innovation process is slightly better calibrated for the production of an appropriate amount of research at insight/cohesion stage. However, EGS is somewhat under-resourced at the stage of cell/traction even compared to GB rail, as can be seen by the fact that the ETI (see below) as an innovation enabler has only reached the stage of 60% of its desired size of investment fund.

The largest gap is immediately apparent at the next stage, that of launch-readiness. Once more, the “valley of death” is apparent between TRLs 4-6 and EGS platform-building capability forges ahead of that of GB rail. Here, it is worth mentioning the higher level of engagement of the EGS KTN, which is fully integrated with the UKERC (see below), which provides enabling facilitation and collaboration capability from TRLs 2-9, which contrasts strongly with the far lower level of engagement between GB rail and the Transport KTN, which is patchy despite some areas of interest, notably in the challenge-led areas of logistics and integrated information systems.

The ability to apply the principles of application extensibility to launched platforms is similar in both EGS and GB rail, albeit better calibrated within EGS given its greater capacity to build and launch industry platforms. As a result, the pull-through is greater and EGS shows particular ability to transfer its innovation across industry boundaries, particularly into built environment and automotive applications, as the example of fuel cells indicates.

To summarise, the EGS industry innovation system is noticeably more advanced than the GB rail industry innovation system but less so than that of aerospace manufacturing. EGS lends itself particularly easy to whole-systems views because of the prevalence of output flow tracking (as shown in a “Sankey diagram”) showing how outputs from one subsystem feed into input in other subsystems – oil and gas power, for example, feeds into transport which also transports oil and gas itself. The regulatory impact is also similar, in that large sections of the value chain are highly regulated or highly taxed, resulting in high levels of government intervention. In railways, regulation shows as levels of subsidy rather than tax, but there are still strong economic levers in the hand of the government which determine the success or failure of investment strategy.

A caveat worth making at this point concerns the true validity of sectoral comparisons. It might not be as correct to compare rail with EGS as it would be to compare it with modes of EGS, electricity, for example, Other modes of EGS can also satisfy the need for energy, so it could be argued that EGS is more properly compared with transport as a whole. EGS modes also have the same issues as transport modes concerning modal shift – oil and gas to renewables, for example, in comparison to automotive to rail.

The EGS innovation system is functioning in a privatised, regulated market. The regulation appears to be driven by coherent government policy, in particular with regard to extremely clear requirements for the reduction and capture of carbon emissions from the sector by a set date. Organisations working in the sector can expect substantial fines for non-compliance, so legislative targets are clear.

For example, fleet operators need to reduce average exhaust emissions by a set amount on pain of a substantial fine. There are equivalent binding targets across the industry, with the not inconsiderable penalty of a reduction in government subsidy if the required improvements are not met in this timescale. However, there have been reports of this strong set of regulatory drivers creating "perverse incentives" for industry players; an example of this is the immediate closure of coal-fired power stations that fail to meet carbon capture and storage standards.

The industry can also demonstrate a clear strategy to meet government policy objectives with regards to nuclear power. However, nuclear generation and supply capability has been reduced to a small part of the value chain, namely in decommissioning and supporting the supply chain for new power generation. Actual build and design capability is almost certain to be brought in from France via EDF, as local capability has disappeared over the last thirty years. This is regarded by the TSB as a clear example of lack of investment in innovation resulting in the need for UK plc to buy capability in from overseas and a parallel is drawn with GB rail; rolling stock functional components are increasingly imported, but developed elsewhere by, for example, Hitachi, Siemens, Alstom and GE. Even where assembly is UK-based (Bombardier) the role is essentially the integration of sub-systems from a global and predominantly non-UK supply chain.

Value for money is a principal driver of innovation in EGS; there is a perception that without it, the cost of energy would have increased significantly. Innovation is seen as helping to maintain the freedom of end-user supply for energy products and services. Players in the EGS industry have understood the principle that building unique, hard-to-emulate industry capability creates barriers to entry and this has led them to invest in strategic innovation platforms. Competition within the industry is extremely fierce and lack of differentiated platforms would be a substantial risk.

The appreciation of the value of innovation platforms and the lack of cross-system infrastructural dependencies and standards (by contrast with GB rail) means that the industry has been able to embed strategic best practice and consequently the industry as a whole is able to be sufficiently reactive to regulatory, environmental or cost pressures. In other words, rather than having a strategy for the industry as a whole, strategy appears to have been devolved down to platform level, so individual platforms are developed in response to strategic challenges with supporting technology roadmaps by industry platform interest groups. An example of one of these strategic platforms is that of "carbon capture and storage", which is driven by the Advanced Power Growth Technologies Forum (APGTF), which owns the technology roadmap for the platform.

Collaboration in the industry is driven by closeness to "core value generation"; when innovation is close to primary sources of value, industry is less likely to collaborate. Examples of this include oil reserve modelling and design for both renewable energy systems like wind turbines or nuclear reactors. It is standard practice for innovative products and services to be launched single-handedly by major stakeholders like BP or National Grid.

The National Grid is the part of the industry system concerned with infrastructure provision and maintenance, the equivalent in EGS of Network Rail. It is also considered to be the "least innovative part of the system", with its principal concern being that of capacity across the grid and substations. The functional scope for innovation appears quite limited; almost all generating issues can be addressed by attention to efficiency of baseload and microgeneration. Moreover, capacity problems can be addressed by clever demand management and "smart gridding".

There are, nonetheless, significant collaborations under way in the industry, some of which include Atkins, for example the "SAFEBUCK" project to design pipelines for deepwater energy sources and a fleet management system for deep water operation rigs which has reduced the design cost by 25%. The cost of innovation, although substantial, does not prevent collaboration; sharing the costs of innovation are not seen as an issue when compared to the financial benefits.

Specific organisations available to the industry to promote collaboration, functioning specifically as innovation enablers, include the Energy Technologies Institute (ETI) and the UK Energy Research Centre (UKERC), as well as the EGS KTN and the subsector trade associations.

Case study: The Energy Technologies Institute

The ETI is 50% state-funded by the Department for Energy and Climate Change (DECC) the DfT, BIS, EPSRC and TSB and 50% funded by its industrial members, including BP, EDF, E-On, Rolls-Royce, Caterpillar and Shell, each of which contributes up to £5m per year for the next ten years. The ETI appears to fulfil a role in the industry similar to the RSSB in GB Rail but has sought to make available an investment fund of £1bn for new energy technologies, of which it has secured up to 60%. The ETI sits squarely in the "Valley of Death", covering TRLs from 3-7 and is recognised as having an ability to carry out demonstration projects and support technology roll-outs.

It is recognised in the industry, however, that there are some significant shortfalls in the innovation performance enabled by the ETI. Although the original ETI proposition was well thought out – below-par investment in the UK and a need for more collaboration in energy research, requiring a joint innovation model to really tackle the major challenges – the organisation has not been able to really show leadership at a systemic level. Confidential inquiries revealed that the problems could be traced to the IP collaboration model.

Part of the thinking behind the ETI involved the need to avoid the appearance or actuality of government subsidy for innovation undertaken by major multinationals such as the ETI's funders and the importance of participation by third parties and SMEs in open innovation models. However, the commercial considerations of the funders – why should they fund to such a significant degree without the ability to control and profit from downstream launches? – posed a significant challenge for the resulting IPR models. The ETI's prospectus ended up stating that its funders would retain the IP generated in the products and services launched as the result of engagement with the Institute. Unfortunately, this model raised commercial questions about the benefit for the SMEs and other third parties that were expected to rush to participate, particularly when compared to the established models used by, for example, the TSB.

On the ETI route, consortia had to surrender 100% of their IPR to the funding partners, whereas the TSB route means that participants keep 100% of IPR without having to surrender it to the TSB. As a result, there was little incentive for SMEs and third parties to participate, meaning that the quality of ideas submitted to the ETI was lacking and consequently even the significant amount of money collected failed to find projects suitable to invest in.

The difficulties inherent in the ETI approach effectively stem from its treatment by powerful funders as an entire IPMS system in its own right, when it is more properly considered as an enabler of core capability to the total system as, for example, is done in the Fraunhofer model – and should be a warning to similarly powerful stakeholders in GB rail to use their size and weight in trying to dominate potential collaborators without their deep pockets and influence. A more complete picture of the system includes the remit of the UKERC, which rolls from TRL 2-9 in specific subsectors of EGS but without funding specific projects, rather facilitating collaboration within the industry and overlapping with the remit of the EGS KTN. Major stakeholders use both organisations to enable collaboration at early TRLs with both SMEs and universities, as well as the TSB itself, which has run directly at least one highly successful challenge-led industry platform:

Case study: The Technology Strategy Board "Fuel Cells Programme"

The Fuel Cells programme was based on policy (during the tenure of Patricia Hewitt at the then-DTI) directing the TSB to investigate energy technologies of strategic value in the early 2000s. Activities began with a small number of spin-outs from universities and some funding from the TSB for base technology development and systems integration and, most recently, a demonstrator programme funded by the Department for Energy and Climate Change. As at the time of the report, the programme has reached the "platform" quadrant of IPMS and the spin-outs are now developing partnerships with big players to create globally launchable industry platforms.

The TSB considers this programme a clear application of the Hauser principles: individual fuel cell capabilities have been developed but there is still no clear platform for market launch, as there is still a lack of integration with the infrastructure supporting the wider UK systems. Therefore, an "open competition"-format call for is shortly anticipated, to focus on proposals to develop a launch capability for fuel cells in the UK. The preparatory work for this competition involves a study by TSB into the addressable markets and available leverage funding. Interested consortia are also being encouraged to seek sources of equity funding and one such consortia based on a previous spin-out, Intelligent Energy, has just been able to secure £200m for this purpose.

Here, it is worth taking a closer look at the role and approach of the TSB as the government agency tasked with improving innovation across UK plc, as well as its track record, which has included a number of notable successes, demonstrably contributing to the enhancement of its position subsequent to the recent reorganisation of government agencies:

The Technology Strategy Board and the UK plc vision for innovation

The TSB, as an agency of the Department for Business, Innovation and Skills (BIS), takes a view across the entire breadth of UK plc, with a view to obtaining the best value for money from investing in innovation. The aspirational target return ratio is 10:1, based on the assumption that this represents a return on investment for market penetration in 5-10 years time, suitably discounted for risk, (normally in the region of 25% in a commercial business case) and includes strong arguments for 'additionality' – i.e. the indirect benefits of innovation such as the socio-economic benefits of a reduction in congestion resulting from a decrease in wasted journeys of home delivery vehicles over the last couple of freight miles.

Where the target return ratio is not met, the TSB prefers to find more attractive targets for innovation investment return, such as the Low Carbon Vehicle platform.

In the view of the TSB, this programme has been a great success in demonstrating that the UK is an environment that is highly supportive of innovation. From the TSB's point of view, the entire programme has been managed as what is termed an "Integrated Delivery Programme", linking links research, ideas, building a platform of industry capability and ultimately launchable applications based that platform; essentially, supporting transition across the entire IPMS spiral and providing a bridge across TRLs 4-6.

Case study: Technology Strategy Board "Low Carbon Vehicle programme"

This programme began with a 'call for technology' (known colloquially as "Bring out your dead") aligned with the technology roadmapping by the Automotive Innovation and Growth Team. Some capability work was done by Ricardo, based on scoping the market opportunities, revealing four or five "sticky" technologies in which the UK might benefit from building world-class capability platforms. This scoping work stimulated in-depth research into these technologies, which led to the TSB's "Ultra Low Carbon Vehicle" demonstrator programme. The ultimate outcome of this programme has been the investment from Nissan in the North East to build the Leaf electric vehicle as well as a battery plant.

"The production of Nissan LEAF and the batteries represents a total investment of more than 420 million GBP (468.2 million euros) in the Sunderland Plant and is expected to maintain about 2,250 jobs at Nissan and across the UK supply chain.

The investment will be supported by a 20.7 million GBP (23.1 million euros) Grant for Business Investment (GBI) from the UK Government and a proposed finance package from the European Investment Bank of up to 220 million euros (197.3 million GBP)." (Nissan press release, 2010)

The benefit from investing in innovation in this case, from the point of view of the TSB and UK plc, has been a return of 50:1.

5.6.3 Comparison with Defence industry innovation system

A comparison of GB rail and Defence innovation systems is shown below:

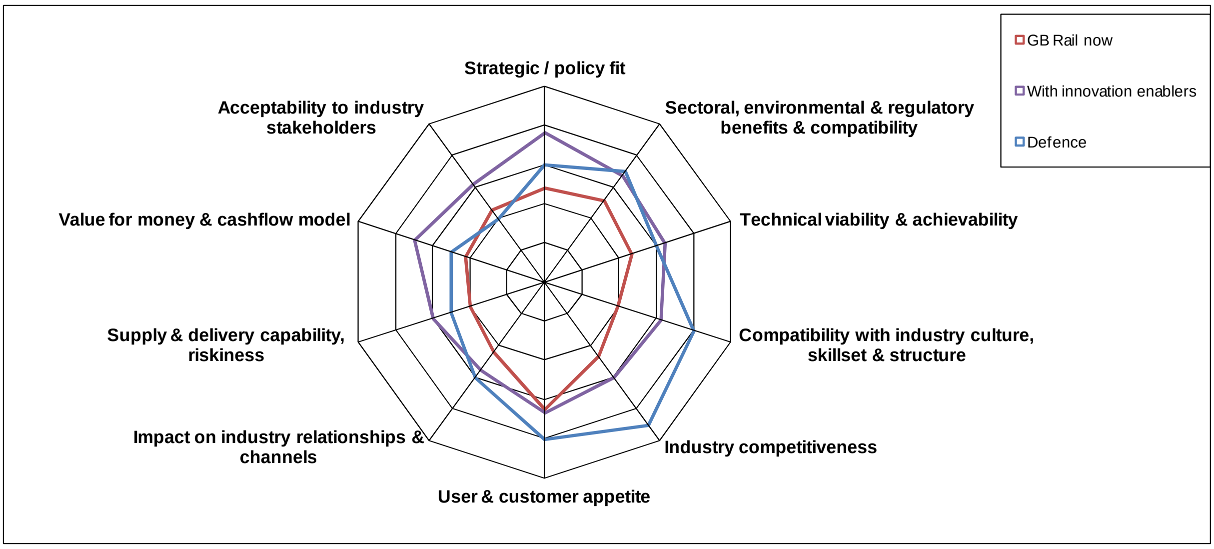


Figure 41: Comparisons of GB rail and Defence industry innovation system structural integrity

The most immediately visible gaps between the structural integrity of the innovation systems of GB rail and defence are along the dimensions of industry culture, skillset and competitiveness. Innovation is viewed as being directly embedded into development processes via continuous improvement and the ubiquitous availability of inventive problem-solving skillsets such as TRIZ and C-K theory. There is also a strong sense of responding directly to clear and loud user and customer demand (up to the point of generals banging on the table and shouting for faster pull-through) in which inventive problem-solving approaches are deployed right down to the front line.

TRIZ & C-K Theory:
TRIZ is a Russian acronym for "Theory of Inventive Problem-Solving", developed in the 1950s onwards, mostly in the Soviet navy and space programme and since 1989 widely adopted in the West, particularly in the defence sector. C-K theory is a French knowledge development methodology.

The industry has a very strong culture due to the prevalence of currently and previously operational military personnel and the operational mentality of “adapt, reconfigure and find another way” feeds back up into the innovation system, leading to cultural and skillset alignment, bolstered by a robust collaborative processes and specific drivers of interoperability. Interoperability is also seen as an enabler in its own right, an example of this being Atkins’ work with the MoD in safety systems based on cross-sector insight integrated using a systems engineering approach. By contrast with rail, there is also a clear competitive drive: systems developers are in no doubt that there is a strong commercial appetite for “new and sexy” and innovation is decidedly seen as a way to win bids in a competitive tendering environment. An excellent example is the XSMG, a lift-and-drop of a platform from high-end powerboat racing with applications in border control, anti-drug-smuggling enforcement and special forces insertion.

Innovation is not the primary driver of strategy, but remains a strong enabler. However, due to the network of military alliances which underpins the UK’s geopolitical engagement, the defence industry is a leading proponent of the global market. As a result, they are already deploying a version of the Hauser principles set out in the Defence Industrial Strategy and the SDSR (Strategic Defence and Security Review) Green Paper. The strategy is also highly influenced by the need to respond to emerging threats and whether or not sovereign capability (i.e. without help from other states) is required. For example, the challenges of both “cyber-attack” and “cyber-defence” drive engagement in cryptographic technology. The UK is currently reliant on American systems in this area, which has been deemed a risk and therefore worth investing in world-class domestic capability. Innovation therefore follows this strategic agenda. Similarly, BAE’s the Tyranis and Mantis UAV (unmanned aerial vehicle) projects ensure sovereign UAV capability.

The defence industry is unfazed by the technical prospects of innovation, leading to a “no problem too big” mentality, but this itself can lead to problems at “system of systems” level. When too many innovative approaches are crammed into a new system, this in itself can end up leading to systemic technical risks, as in the recent embarrassing and expensive problems with the new Astute-class submarine. The development of an “Advanced Technology Centre” for materials, computing and mathematical algorithms has driven technical innovation at BAE Systems, following a model of base capability development and such approaches remain common, although the focus on base materials leads to the criticism of poor links to client requirements. The sector is nevertheless notable for its commitment to the people-facing, skill-based aspects of innovation; it is typical for organisations to make training available in different ways of brainstorming and harnessing creativity, for example TRIZ, which is a key skill-set for the defence government practices of PA Consulting and KPMG.

Significantly, the industry as already adopted a more or less equivalent approach to ISS in determining innovation requirements to ensure structural integrity. This was originally developed by Deloitte in the US and is known as TEPID OIL: **T**raining, **E**quipment, **P**ersonnel, **I**nfrastructure, **D**octrine, **O**rganisation, **I**nteroperability, **L**ogistics. Each dimension of TEPID OIL follows a checklist approach, which is also combined with CADMID (see below) to define through-lifecycle requirements on how to train, infrastructure requirements and so on. The production a URD (user requirements document) drives procurement, flowing to a SRD (systems requirements document). Some industry experts have expressed misgivings about TEPID OIL in that it can appear focused on providing equipment and technology rather than capability and may consequently lack a robust enough approach to functional experimentation. For example, if an aircraft is expected, an aircraft is likely to be produced at the end of the process, without sufficient attention to the question of whether an aircraft is really the best way of delivering the functions sought. A better approach would be to conduct a functional analysis: for example, the functions fulfilled by a tank are to be big, fear-inducing, invulnerable to hand-held weapons such as rocket-propelled grenades, able to knock down or clear buildings, move cross-country without the need for a road, or provide mobile protective shielding for accompanying infantry. The TEPID OIL approach can in some situations fail to consider ways of challenging the traditional answer of how these functions can be delivered.

The defence sector considers itself risk-averse in terms of the cost of innovation, despite its clarity about the benefits of innovative capability. The major profit pools in defence (and consequently, the resources allocated at bid stage) are in supporting the reconfiguration and refresh of older kit in order to extend the life of managed assets, rather than in developing entirely new systems. As in rail, innovation efforts pale next to that focused on milestone delivery of existing priorities and firefighting, at least in industry, especially since the advent of the recent high-profile and highly critical Gray report into defence overspends and inefficiencies. However, innovation remains a higher priority at the MoD, with its eye on the bigger picture and the longer-term horizons and the industry itself, in conjunction with the government as an anchor tenant for innovation, has been successful in building an impressively mature collaborative innovation process.

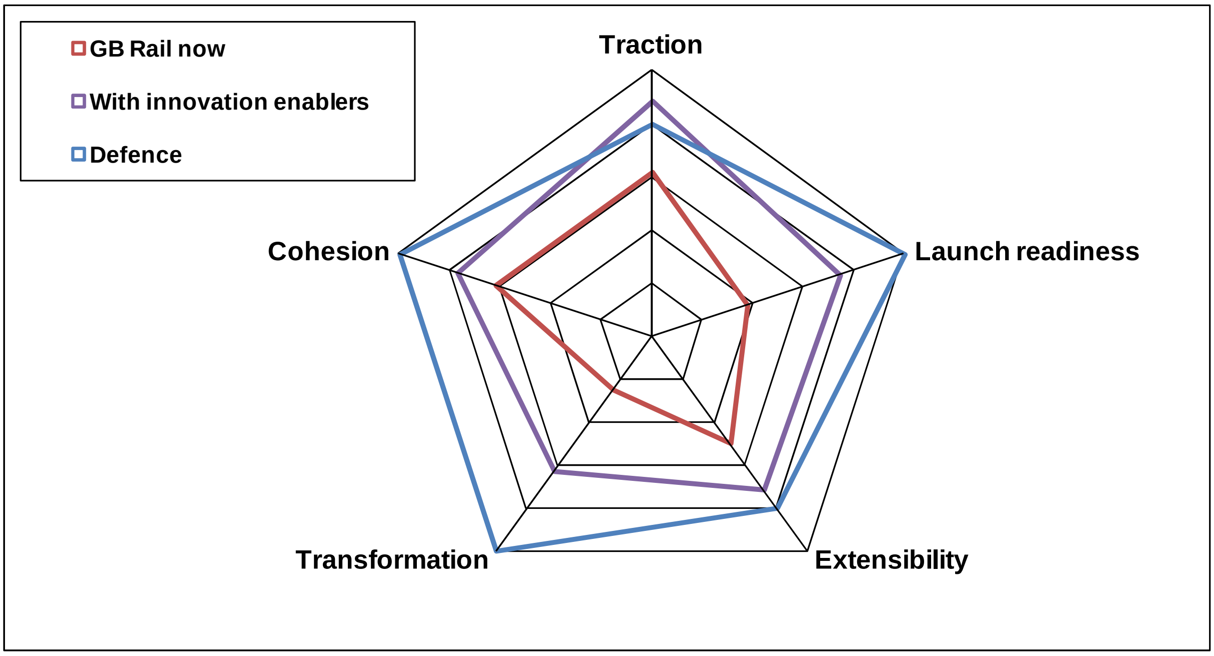


Figure 42: Comparisons of GB rail and Defence industry innovation system process maturity

A clear common process, analogous to IPMS, is used to manage the innovation pipeline at industry level, known by the acronym CADMID: **C**oncept, **A**ssessment, **D**evelopment, **M**anufacture, **I**n-service and **D**isposal. CADMID provides a shared understanding of innovation maturity that can be followed by the MoD's heads of capability who act, in effect, as the customers for system-level platforms. Top-level capability platforms such as ISTAR (**I**ntelligence, **S**urveillance, **T**arget **A**cquisition and **R**econnaissance), CCII (**C**ommand and **C**ontrol **I**nformation **I**nfrastructure), Deep Target Attack and Theatre Airspace each operate a "Capability Assessment Board" which acts as a system authority[24] which decides whether a capability, say, "the next concept for electric drive vehicles", has reached an appropriate maturity level for incorporation in the platform. The system authority is thus able to use CADMID, combined with the TEPID OIL systems structure framework to determine the timeframe for the insertion point of a given capability.

An excellent example of this type of organisation comes from the challenge of remote management of UAVs in theatre. Rather than centrally determining an optimal standard for remote management of UAVs, the head of the CCII capability uses output-driven specifications to drive the best solution, assessing the pros and cons of using another UAV in the line of sight as against satellite connectivity. Historically, there has been a weakness in the capability head system in that it remains vulnerable to "modal preferences" – each capability head tends to be associated with a particular service, so if, as is usual, the Head of ISTAR capability is from the air force, there has been a history of partiality, hence ISTAR solutions are likely to end up being delivered by the air force. Nonetheless, as this weakness has now been identified, it is anticipated that this state of affairs will be changed fairly soon.

The heads of capability report in to the CDM (Chief of Defence Material), who was, historically, always from a military background. However, the new CDM is a civilian: Bernard Gray, author of the "Gray Report", a civil servant whose background is in media, telecommunications and defence in the UK and abroad. The CDM's job is to look at through-life capability management, which includes costs, but, surprisingly, does not include CADMID for defence "lines of development".

The early stage TRLs of the defence IPMS are fertile and well populated: ideas are plentiful and there are a large number of forums in which they can be shared, from the KTN to DSTL (the government-funded Defence Science and Technology Laboratory) open days. There are some issues with the capability of DSTL that have been raised by some industry experts in regards to Capability Visions platform development projects (for which Atkins ran the project management office). They have been accused of both an attraction to novelty for novelty's sake in terms of ideas as well as insufficiently powerful filters for "hobby horses" which have promised but not yet delivered over a long period, electric armour being a particular case in point. DSTL's approach has also been accused of being too academic, rather than providing leadership or challenge, the identified cause being a lack of closeness to the industry strategy at one end and the user at the other; this appears analogous to some of the challenges faced by the RSSB.

The principal challenge at early TRLs is one of future visioning. The defence sector makes use of horizon-scanning and futurist websites such as Foresight, to look at 5 / 10 / 15 / 20 –year horizons for military applications. The sector has also already integrated TIC-type "Innovation Centres" into the process, but rather than focusing Fraunhofer-style on technology capabilities they are focused on the extensibility quadrant via end-user communities in the traditional services: Land, Naval and Air Warfare Centres. This results in incremental rather than game-changing innovation (however valuable), does not assist the challenge of interoperability and bolsters modal silos rather than industry platform thinking at a systemic level – this example may shed valuable light on the discussion whether to have a Transport TIC.

Thales has addressed early-stage innovation in an unusual way, starting with key questions and a call for good ideas, then trying to map the ideas onto the questions. The converse approach is also used: turn it round, starting with the ideas and then pair-wise comparisons on all questions and all ideas. They also use "Focal Points", an IBM tool which assesses ideas statistically.

As might be expected, given the deep sectoral skills in inventive problem-solving and the focus on end-user community pull-through, the defence sector is highly skilled at re-use and other activities in the extensibility part of the spiral. British armed forces are trained to adapt to the current situation and equipment is no exception. To give an example, in artillery, the basic configuration is an officer dealing with targeting and tactics, placed on high ground (or with other high-level view of the battlefield) with some form of target acquisition capability. The co-ordinates of the selected target are sent down to the artillery platform operator, typically situated at an optimal firing position, who actually does the firing. However, every time artillery is deployed there is a different process based on a configuration that suits the tactical environment. The sector is highly effective at following protocols of this nature when the need is near-term.

Ideas for extensible exploitation of potential system-level platforms can also be raised through the KTN, including such examples as cost savings from leveraging the use of MoD's "Ro-Ro" ferries, which are not used much of the time, typically being lent or leased to industry or elsewhere. Another platform that can potentially provide considerable extensible benefits in terms of novel usage is the Empire Training School for flying, which caters for everything from basic principles on simulators, all the way up to fast jet training.

On the other hand, longer-term innovative responses continues to raise challenges. It continues to be difficult to adapt long-standing industry platforms for new strategic realities. A particular example of this type of challenge is that of the upgrade path for the Type 45 destroyer, where the adaptation timeframe is approximately 15 years but there appears to be a lack of threat requiring this capability at present. It is difficult to tell what planning needs to be done without this knowledge. It is this level of uncertainty and time-lag that has led to the issues in Iraq with tanks designed for use on the Northern European plain now facing extreme heat and having to cope with sandy conditions. Similarly, tanker ships designed to support this capability are having to be replaced because they do not work well in warm seas. In short, there is an ongoing problem of "design to fight the last war", with systems designed for the requirements of the Cold War the only ones available until relatively recently in defence procurement terms.

One area of innovation in which the defence sector excels is that of capability transfer; mission rehearsal, for example, is now done with resources from the videogaming industry, as the most advanced source of synthetic environments. Transformational "inside-out" innovation is extremely prevalent and transfer paths have become well-trodden. Much advanced technology in motor sport is sourced from defence and from motor sport, the technology ends up in the automotive retail market, for example high manoeuvrability and "anti-sluicing" technologies. In some cases the relationships are institutionalised – Mercedes Maclaren, for instance, have three systems engineers in-house at BAE sourcing telemetry, gearbox technology and smart materials for which they gain first use and consequent competitive advantage in their home market.

Technology is not all that is transferred – there are significant transfers of IP and processes, particularly in command-and-control, a particular focus of the work of Peter Gershon, the CEO of the Office of Government Commerce (OGC) and transferred advances in electro-magnetic conductivity and route evaluation, Health and usage monitoring systems in cars also came from development in the military. Leading-edge safety practices were transferred from the MoD to the oil and gas sector after the Piper Alpha disaster and indeed to rail after the Nimrod crash via the Haddon Cave report, whilst leading-edge security cryptographic and electronic key distribution systems are now routinely transferred into financial services. However, it is most usual for these links to follow people – cultural issues (and, of course, security clearance) often act as barriers to external participation in defence industry forums, but there are numerous routes for defence-trained experts to enter other industries,

There is also a formal challenge-based programme for inside-out technology transfer out run by the DSTL's "Centre for Defence Enterprise", (CDE) who make periodic calls for good ideas from defence sector stakeholders to solve questions posed to them externally. As with the SBRI model, they then fund research based on the initial studies.

The most interesting aspect of the defence industry innovation system, however, is the response to recognition that there was not enough engagement between government, the forces and industry, in part as a result of highly protective attitudes to IPR, especially where IP was held by multiple stakeholders for a shared platform. In 2003, the MoD attempted to overcome this using a new innovation partnership model known as Niteworks.

Case study: Niteworks

At the heart of the Niteworks approach is the combination of the need for a clear strategic imperative and a strict focus on "things that are worth doing", which means a particular focus on innovation for the purpose of driving costs down. Traditional strategic innovation in defence follows the path of technology to support tactical platforms, a good example being the concept of a "force multiplier", notably trialled in World War 1 with the introduction of tanks. "Force multiplier" technology was then widely adopted and then evolved along an evolutionary path to produce the current last word in "force multiplier" technologies, namely smart missiles with nuclear warheads[25]. By contrast, the approach used by Niteworks is more systemic and challenge-led – for example, to look at the cost of a force of 50,000 people with expensive manpower costs with a view to deploying innovation to reduce injuries in the front line. A Niteworks-style business case will be on cost reduction across the board against the benefits of less breakdowns, less engagements, less "friendly fire" incidents and greater operational effectiveness. This more holistic approach has challenged the historic cost modelling business cases used by the MoD.

Niteworks is intended to allow different types of government, military and industrial stakeholders to collaborate effectively. It is split into two tiers of membership, tier one being OEMs such as QinetiQ, BAE Systems, Thales, General Dynamics and Finmeccanica. Tier one members ("industry partners") conduct research and bring prospective solutions to Niteworks. The IPR model used is that background research IP is retained, whereas the foreground research is shared by the partnership. The tier two partners ("industry associates") include Atkins as well as numerous other major systems and engineering consultancies and SMEs. Industry associates follow the same IPR model, with background IP retained and foreground IP shared. As well as the industry partners and associates, the MoD, DSTL and front-line military commanders are involved. Niteworks is therefore able to provide a framework for the MoD to commission studies and other projects covering early TRLs, but with a specific focus on transformative innovation rather than brand new concepts – for example, different ways to use existing equipment and leverage functional technology into new areas.

The approach used by Niteworks is first and foremost to make sure that they understand the depth of the complex problems that they are asked to solve, which will usually involve a couple of months of root cause investigations and talking to users. A "rainbow team" of about three or four people drawn from major talent in the industry is then tasked with to looking at the whole system and coming up with

[25] It is notable that incremental improvements in force multiplier technology have not prevented the emergence of "disruptive" innovations along the lines of Clayton Christensen's "innovator's dilemma" (see bibliography), namely the techniques of "low-intensity" warfare much in vogue amongst guerrillas and insurgents in recent decades, against which traditional use of force multipliers is ineffective.

solutions. The solution is then put to the industry for testing, most usually method at a conference, at which the problem and solution are presented with a view to identifying alternative solutions. All industry partners and associates are invited to the conference to consult and share solutions. Then the project team test, prototype in a synthetic environment and examine the real benefits of progressing the solution. Finally, the benefits are captured and handed back to the MoD. The DSTL provides significant "traction" input, via a technology watch and their own technical research as well as in-depth analysis, particularly in the nuclear field. The costs of manpower for staff working in Niteworks is borne by the MoD.

There are well-established models for collaboration, particularly between sizeable concerns, if IPR issues are resolved, as the case of Niteworks shows. Stakeholders can see the benefits of supporting each other and other facilitators of collaboration, such as output-based specifications, are now routine for BAE Systems, for example, as are long contracts of 15-20 years. Nonetheless, BAE, like some other large companies such as Lockheed Martin, are known for squeezing SME partners over IPR, although IP standards differ at different TRLs. When working with Thales and Suzuki IP under NDA, Atkins commonly agrees to act as a contract R&D house and the client retains IP. Situations that are knotty and problematic still occur even when government is involved upon occasion, a notable example being the failure of MoD to come to a particularly advantageous arrangement with Microsoft over security issues with government builds of the Windows XP operating system, despite direct negotiations beween the Permanent Secretary and Bill Gates; processes to develop IPR were eventually shared, but IPR ultimately remained with Microsoft.

System risk, testing and approvals in the defence innovation system

The defence industry handles safety risk "doctrine" in the same way as rail, the overarching source document emerging from government Health & Safety at Work legislation, feeding through into MoD policy documents and defence standards on how policy should be implemented. Each stage of development or subsystem requires a safety management plan (front-line commanders are responsible for the health and safety of their men, but so are equipment providers and procurers of equipment) but a "system of systems" is generally not available, which can makes it difficult to determine the owner of the risk.

The sector has learned some lessons from aviation, where the CAA certify safety, but there was no similar body in defence until the Military Airworthiness Authority was set up as a result of the Nimrod crash, which was due to a disconnect between designers and operational maintenance what was going on operationally, which made things a lot more reliable. Normally, design would not result in a decision to place a piece of equipment that runs hot near a fuel line, but in this case it wasn't realised that a piece of equipment was getting hot. The Haddon-Cave inquiry drove the need for an independent body.

Defence enjoys extensive testing capability around the spiral. The MoD have extensive land holdings (for example, large parts of Salisbury Plain) so space for manoeuvrability and dangerous or explosive testing does not present an issue. Nevertheless, some conditions and equipment cannot be test in the climatic conditions and topography of the UK and therefore equipment like a tank, for example, is generally transported using military capability, It is typically cheaper to transport equipment than build a suitable testing environment, even a synthetic environment. Test facilities constitute significant long-term investment, including large simulation models, synthetic environments, people and process.

The large industrial concerns such as BAE create their own facilities. Niteworks work on a more virtual model, competing their simulated environment out to third parties. An interesting extensibility / transformation testing facility is the "Land-based Reference Centre" at Warminster, which can be described essentially as a "warehouse full of kit", which can be interoperability-tested with newly developed (or captured) technology. Interoperability testing is also specifically focused on at the annual CWID ("Coalition Warfighter Interoperability Demonstration") showcase held every year with tri-service UK participation as well as that of US forces. This is a demonstration of interoperability specifically focused on coalition-based warfare, using synthetic environments. Lessons for GB rail might well be learned from this focus on interoperability and we therefore recommend the further investigation of a case for this type of capability as a priority for the proposed innovation management system.

Testing is typically extensive and scenario-driven. The most important barrier remains at TRL 6-7, when demonstration of innovation has to move from relevant to an operational environment, synthetic to real. The systems authority for this jump is provided by scrutineers sent from the MoD, who look at the models being used and the results of testing. Significant effort is given to the importance of early engagement with this authority to get agreement in the standard of scrutiny up front. For example, for simulating cockpit environments, a big sun-lamp, including a "cloud simulator" was built for pilots to test specifically how this environmental factor affects how they use controls. Another example (and possibly a transferable one) is that of sensitive edges for closing doors, where the door detects obstructions to closing, which then affects how hard the door closes. False alarms and positives for this kind of scenario are typically hard to simulate, though. It is worth pointing out that in many cases in defence, systemic factors are often addressed by training users to act correctly in the first place, although this is not so straightforward with the travelling public or indeed other customers.

Typical value for money scenarios from collaborative defence innovation can be illustrated thus:

Case study: Atkins RAM4 and MALPAS

Atkins has sole rights to marketing and sell a reliability tool called RAM4 developed by the MoD, who put the contract for support of the tool out to tender, which was won by Atkins. The royalty paid to MoD is 12% of the licence cost on a case-by-case basis. The global turnover on licences is not substantial, but as it opens the markets for consultancy around support, on which there is greater margin, this opens up global consultancy turnover, which if we assume the DES margin of 8% in the published accounts holds true, results in a ratio of 14 : 1 operating profit cost against cost.

Atkins also has sole rights to market and sell MALPAS (Malvern Programming Analysis Suite) which is the only tool in world that allows meaningful analysis of the C programming language. The core IPR is owned by the MoD, but anything that is changed in the system becomes Atkins IPR. Licence royalty is 10-15% of the licence costs. The software static analysis done on the Sizewell nuclear facility resulted in substantial turnover of single-source consultancy fees and the tool has also been taken to Network Rail. Globally, royalty turnover is minimal, but turnover from consultancy based on that is substantial. At 8% margin, this works out at a 12 : 1 ratio of operating profit to cost.

5.6.4 Alternative models for IPR

In a standard IPR model, participants contribute their IPR as "background" and then typically balance the risk of their investment in innovation platforms with the benefit they can expect to receive from launched applications via a sharing agreement covering the "foreground" IPR that is developed as a result of collaboration or funding arrangements. Typically, this foreground IPR is retained collaboratively so as to build deep, long-term and open partner engagement. This is the model followed by the defence industry for the Niteworks enabler and would appear at this stage to be worth further investigation.

At early TRLs, a highly successful model has been used by the Small Business Research Initiative (SBRI) run by the TSB. SBRI has been principally used for public procurement of solutions to bounded problems posed as challenges. The TSB poses the problem and then offers 100% funding for small R&D contracts (typically £30-50k) to be carried out by organisations who think they can solve the problem. A number of SMEs have built small but profitable business models around this structure of solving challenges and taking the solution to the next stage. The prospect for participants is the sale of a successful solution to the government albeit, significantly, retention of the IPR by the SME.

IPR
Intellectual Property Rights – the question of who has the right to access, use and profit from "creations of the mind" – in other words, knowledge, information, data sets, models and so on. IP is commonly held in copyrights, trademarks, patents, industrial design rights and trade secrets, but is a typical by-product (and sometimes the desired output) of innovation.

SBRI has been particularly successful in promoting transformational innovation using "spiral-jumping" behaviours from other systems, as it does not restrict the supply chain. A good example that of an infection detection system developed for hospitals, which was solved successfully by an organisation from the optical industry, The successful solution involved the testing of fluorescence on work surfaces using optical rather than medical analytical techniques and, moreover, using a completely different technology to solve the problem. There is a challenge here to big-systems based industries like GB rail as to whether they could use this kind of approach. Certainly, existing PQQ, ITT and procurement procedures used in GB rail would preclude this.

Both the experiences of the ETI and SBRI are useful lessons for GB rail in terms of the proposed innovation management framework. It is critically important to be aware of the perception from the point of view of SMEs and non-traditional participants in GB rail. Prospective small equity investors in the development of innovative solutions will be put off by the loss of IPR and will not be attracted by the prospect of what amounts to contract research work. Although, as in the defence R&D world, Crown use of rights for 100% funded projects could be used as a way to avoid the risk of critical national infrastructure depending on the IPR of SMEs. Consequently, it will be important to establish the optimal percentage splits in IPR to attract collaborators of all sizes and types. For industry-level innovation to succeed as an open model, big organisations will have to be much less proprietorial in their behaviour, as demonstrated by the experience of the ETI.

However, a recommendation of the best models for IPR collaboration for GB rail stakeholders to produce an optimal result at system level is beyond the scope of this report and we therefore recommend a more in-depth study to assess and select the best of these for adoption by the innovation management solution, rather than opting too early for what might potentially be the wrong IP model. In particular, we believe that instructive perspectives on optimal systemic IPR models to underpin collaborative industry-level innovation could come from not just ETI and SBRI, but successful academic spin-out vehicles like Imperial Innovations and Oxford University's "ISIS" hub, particularly those concerned with pharmaceuticals, who have significant experience in crafting suitable IPR models for collaborative open innovation involving both large and small organisations.

5.6.5 The role of testing facilities in innovation

Overview of current rail industry facilities

In any industry, proof of the viability of a novel concept and its development into a production application is not achievable without extensive testing at system, subsystem and component level. In the rail industry, the fundamental reasons for on-track testing of novel systems or components are:

- Proof of concept in an 'operational railway' environment
- Product development in the light of testing and service experience
- Proving compliance with functional and technical requirements ('on-track' type testing)
- Reliability growth
- Evaluation of inter-dependencies and interactions between systems (e.g. between trains, track and signalling)
- Staff training

Suppliers to the rail industry generally have access to test facilities which enable them to carry out type and routine tests to prove that their products are 'fit for purpose', i.e. safe, reliable and compliant with mandatory standards, legislation and functional and technical requirements. For component and sub-system manufacturers, these facilities are mainly in-house, but for specialised tests (e.g. fire safety or electro-magnetic compatibility) or where the investment in plant and equipment cannot be justified, the GB rail market is served by a sizeable network of independent test centres which also cater for the needs of other industries.

At the system level, the principal rolling stock manufacturers generally have a short track at each manufacturing site, where factory acceptance tests can be carried out. However, these tracks are not generally suitable for testing novel technology, owing to their short length and limited range of facilities. To overcome this (and the economic and logistical issues associated with testing on national rail networks) the principal players in the European rail industry have constructed several large-scale test centres. Typically, these operate as a stand-alone business but are owned by a consortium or rail industry OEMs, national rail research organisations or independent testing and certification organisations. The principal sites and their locations are as follows:

- Siemens Wegberg-Wildenrath Test and Validation Centre, Germany

- VUZ (Czech Republic Railway Research Institute) Test Centre, Velim, Czech Republic
- Centre d'Essais Ferroviaire (CEF), Valenciennes, France (owned by ALSTOM, Bombardier Transportation and CERTIFER)
- Transportation Technology Center, Pueblo, Colorado, USA (owned by the Federal Railroad Administration and operated by TTC Inc, a wholly owned subsidiary of the Association of American Railroads)
- China Academy of Railway Sciences (CARS) Circular Railway Test Track, Chaoyang District, Beijing, China, owned by the Chinese Ministry of Railways
- Asfordby Test Centre (former British Rail Research 'Old Dalby' test track), owned by British Rail Board Residuary and currently operated by Serco Rail operations Limited.
- Rail Innovation and Development Centre, High Marnham, Nottinghamshire, UK, owned and operated by Network Rail.

An overview of these facilities is provided in the table below:

Test site	Siemens Wegberg-Wildenrath	VUZ Velim	CEF Valenciennes	TTC Pueblo	CARS Beijing	BRBR Asfordby (Old Dalby)	Network Rail High Marnham
Continuous running?	Yes, 2 ovals	Yes, 2 ovals	Yes, 2 ovals (medium/low speed only)	Yes, 3 main ovals with loops	Yes, 1 circle, 1 oval	No	No
High speed track characteristics	V_{max} 160 km/h Length 6.08 km, continuous oval	V_{max} 230 km/h Length 13.28 km, continuous oval	V_{max} 120 km/h Length 2.75 km, single line	Vmax 265 km/h Length 26.5 km, continuous oval	Vmax not known Length 9 km, circular	V_{max} 200 km/h Length 21 km with 10km of double track	V_{max} 80 km/h Length 16 km, single line with 5 km double track section
Low speed track characteristics	V_{max} 100 km/h Length 2.49 km	V_{max} 90 km/h Length 3.95 km Min. curve rad. 300 & 800 m	V_{max} 90 km/h Length 1.84 km Min. curve rad. 190 & 310 m	Vmax 130 km/h Length 14.6 km Includes spur with 46 m radius curve	Vmax not known Length 8.5 km, oval with 1.473 km and 0.864 km straight lengths	Four different track types, wooden sleepers, standard continuous welded, UIC 60 rail , jointed track	
Other track characteristics	1500m long, 80 km/h straight (used for brake tests) 600 m curved track (urban light rail, 15/25/50 m curves) 400 m inclined track (gradients of 1 in 25, 1 in 14)		Endurance test oval, 3 km long, 40 – 90 km/h, curve radius 185 & 305 m. Suitable for automatic driverless metro operations 1200 m urban light rail track (planned)	High tonnage loop, max. axle load 35t, Vmax 64 km/h 5.6 km wheel-rail interaction test loop 10 km Precision Test Track (includes specified track perturbations)	Turning triangle, including 125 m and 250 m radius curves Inner oval includes gradients of 1 in 166 and 1 in 111 for train resistance tests		
Track gauge(s)	1435 mm, 1000 mm	1435 mm	1435 mm	1435 mm	1435 mm	1435 mm	1435 mm
Electrification systems	Overhead line: 25 kV 50 & 60 Hz 15 kV 16.67 Hz 12 kV 25 Hz 3 kV DC 1.5 kV DC 750 V DC 3rd rail:	Overhead line: 25 kV 50 Hz 15 kV 16.67 Hz 3 kV DC 1.5 kV DC 750 V DC	Overhead line: 25 kV 50 & 60 Hz 15 kV 16.67 Hz 12 kV 25 Hz 3 kV DC 1.5 kV DC 750 V DC	Overhead line: 12.5 kV 60 Hz 25 kV 60 Hz 50 kV 60 Hz 0 – 1 kV DC (variable) 3rd rail 0 – 1 kV DC (variable)	Overhead line: 25 kV 50 Hz	Overhead line: 25 kV 50 Hz 3rd & 4th rail: 750 V DC	None

Test site	Siemens Wegberg-Wildenrath	VUZ Velim	CEF Valenciennes	TTC Pueblo	CARS Beijing	BRBR Asfordby (Old Dalby)	Network Rail High Marnham
	750 V DC (GB) 750 V DC (Berlin type)						
Signalling / train control systems	ETCS Levels 1 & 2 ATB-EG LZB/PZB	ETCS Levels 1 & 2	ETCS Levels 1 & 2 TVM 430 KVB			ETCS Level 1	
Other test facilities / workshop provision	Extensive	Extensive	Extensive	Extensive	Extensive	Moderate	Minimal

Table 8: Worldwide Rail Test tracks – principal characteristics

In addition to the above sites, there are a number of specialist test centres with the capability to carry out static tests on complete items of rolling stock. One of the most important of these is RailTec Arsenal in Vienna, which is the only known European location where complete rail vehicles can be subjected to extreme climatic conditions. Ownership is shared between the Austrian Government, Bombardier, Siemens and AnsaldoBreda / Firema.

GB Rail Test Facilities

It is obvious from the table above that the capabilities of the two UK test sites are limited in comparison with the three European sites, which are capable of carrying out most, if not all of the testing required to support innovation.

Since they design and manufacture trains for the UK in their European factories, ALSTOM and Siemens are unlikely to see the lack of a UK test track as a significant barrier to innovation. Whilst Bombardier has access to the three European facilities, their remoteness from its Derby factory has led to their use of the nearby Asfordby test site for commissioning of London Underground ‘S’ Stock and investigation of diesel engine exhaust problems on the Class 172 DMU fleet. This site has also been used in recent years by ALSTOM to commission Class 390 ‘Pendolino’ trains and rapidly develop and test changes to the brake control software, where it proved invaluable in avoiding temporary withdrawal of the fleet from service. Siemens also used it for checking compatibility of new Desiro trains with UK signalling.

Other UK industry stakeholders could theoretically utilise the three European test tracks. However, the cost and logistical issues, together with the probable conflicts regarding capacity, are likely to make this impractical in most cases.

Network Rail’s new Rail Innovation and Development Centre at High Marnham is predominantly aimed at testing innovations in rail infrastructure and the people, plant and processes involved in its maintenance and renewal. It can also be used for testing rolling stock but, based on an initial assessment, it appears to have several shortcomings in this regard:

- Relatively low line speed (50 m.p.h. although it is planned to raise this to 75 mph).
- The route is not electrified, so only self-powered vehicles can be tested.
- the ‘end to end’ layout of the route precludes continuous running and is not conducive to accelerated life testing.
- Details of the signalling system are not yet available, but the indications are that it is not equipped with ETCS or any other form of automatic train control.
- Limited capacity, which is likely to result in resource conflicts. Capacity will be enhanced during 2011 by splitting the line into three independent sections for operating purposes,
- Little or no workshop facilities for vehicle storage, installing test equipment / instrumentation and carrying out static tests.

Although other GB rail industry stakeholders such as the ROSCOs, passenger and freight operators and sub-system/component suppliers can use the High Marnham track on a commercial basis, its usefulness for testing rolling stock and its interactions with other elements of the rail system is somewhat limited, unless extensive work is carried out to address the above issues.

Of the two existing UK test sites, Asfordby appears to have the most potential for integrated, 'whole system' testing, being electrified on all three principal UK systems (25 kV 50 Hz AC overhead and 750 V DC 3rd/4th rail) and having a representative cross-section of infrastructure features, including tunnels. Despite its physical limitations (principally the lack of a continuous loop of track), the scope of upgrade work necessary to provide a viable facility for the UK industry is worthy of further investigation, together with potential funding models.

There may also a number of rail-connected sites in the UK with sufficient land area to build a high speed test oval, for example:

- Redundant MOD sites, especially former RAF bases are topographically very suitable for building a high speed test circuit. However, the few sites that are being disposed of at present, or likely to become available in the foreseeable future are not conveniently located for rail industry use (e.g. the former RAF Llanbedr in north Wales).

- The Motor Industry Research Association (MIRA) test centre at Nuneaton is built on a former RAF airfield and is very close to the West Coast Main Line, adjacent to the trackbed of the former branch line to Ashby, which makes a south-facing connection on to the WCML and continues via an overbridge on to the Nuneaton-Birmingham line. The advantages here are that MIRA is centrally located, already has a degree of rail expertise and possesses extensive workshop and test facilities which could be further upgraded for specific rail industry requirements. However, construction of a high speed test track will almost certainly require the purchase of neighbouring land to achieve a viable curve radius for high speed operation, together with possible relocation of some of the present test tracks and re-instatement of approximately 2.5 km of former railway which is now a public footpath.

The capital investment required to build a high speed test circuit on a green or brownfield site (Wegberg-Wildenrath cost over £100m at late 1990s prices), together with operating costs (bearing in mind that the site has to be maintained as an operational railway) are likely to be prohibitive, especially when compared to upgrading an existing facility. Nor is there likely to be sufficient demand from the UK industry to recover those costs, although if global markets were factored in, perhaps the business case would improve.

One key element of testing which appears to be missing from the UK industry's capability is an engineering development workshop facility which could be accessed by all stakeholders on an equitable basis. The former Engineering Development Unit, located on the Railway Technical Centre Site in Derby (now the maintenance centre for Network Rail's infrastructure vehicle fleet) is a typical example of such a facility. The role of this workshop would be to fill the gap between concept design and implementation by supporting prototype installation, static testing and engineering development to build confidence before on-track testing; ideally it should be co-located with a test track.

The Asfordby test site currently has a small depot adjacent to the Old Dalby control centre and a larger building on a branch off the test track at Asfordby, on the former mine site. The former is relatively small with little potential for expansion due to site constraints, but the latter is significantly larger, with potential for further development. The Asfordby depot building was converted from a coal store to house Class 390 trains under test and its facilities are therefore basic, even in comparison with a typical rolling stock maintenance depot. Further study is necessary to establish whether a viable development and testing support facility could be created by adapting this building or creating a new facility on the adjacent land. The ability to exchange major components and assemblies on a vehicle, e.g. bogies/wheelsets, pantographs or underframe mounted equipment, would be highly desirable and this would require investment in plant, machinery and the physical layout of the depot (e.g. creating inspection pits and platforms for working at vehicle roof height). Appropriate provision for storing and installing instrumentation and measuring equipment is also essential.

There are several options for funding and operating a pan-industry test facility, including:

- An independent 'stand alone' commercial venture,
- Operation by a management company funded by via an industry levy,
- A partnership between industry, government and academia, with commercial rates being charged for access by other parties.

- Placing the facility under central Government control, possibly under the auspices of a national rail Systems Authority, with access charged at commercially rates.

Given the current state of innovation the GB rail industry, it is unrealistic to expect a test facility to be commercially viable in the short to medium term, however this may be a realistic long-term aspiration (MIRA has successfully made the transition to a commercial venture, having originally been funded by the automotive industry). A combination of capital investment from central government) with operating costs being met through a partnership between industry, academia and government, via the proposed industry-level innovation management system, appears to be the most viable option and should be explored with all relevant stakeholders.

'Synthetic Environments' – use and opportunities in rail

Similar industries, notably aerospace and defence, make extensive use of Synthetic Environments (Ses) for testing and evaluation of people, processes, systems and hardware. A synthetic environment can be concisely defined as a computer-based representation of the real world, within which any combination of 'players' may interact. The 'players' may be computer models, simulations, people or instrumented items of real equipment. At its simplest, a synthetic environment could be a piece of procedural training software running on a desktop PC, but at the opposite end of the spectrum there are highly complex simulated battle spaces where a large number of elements may interact. Applying this definition to the rail industry, extensive use is already made of synthetic environments:

- Training of safety critical staff, e.g. driver training simulators (physical representation of a real driving cab within a computer-generated rail environment). In this context, synthetic environments are a very powerful and cost-effective tool. The rail industry is also taking a keen interest in adopting the latest technology developments in the computer games industry to improve the quality and consistency of training whilst reducing costs.
- 'RailSys' is another example of a synthetic environments, used for modelling rail system operation which is particularly powerful, as it can model extensive sections of the rail infrastructure and train operation in great detail. It includes tools for calculating running times, infrastructure mapping, timetable construction and evaluation/planning of vehicle rosters. There are a number of similar systems on the market but RailSys is arguably the most widely used. Software packages such as VTISM, ClearRoute and Vampire (software for modelling vehicle-track interaction gauging and dynamic behaviour respectively) could also be defined as synthetic environments. Synthetic environments are also used in the design of stations, e.g. for modelling passenger flows. These systems have been progressively refined to model passenger behaviour, based on real experience.

The Defence industry makes extensive use of synthetic environments, principally for training people and for assessment of interactions between systems. Their main advantage lies in the ability to reproduce a wide variety of potential operational scenarios and 'what if?' permutations at much less cost than physical testing, enabling their effects to be fully evaluated and lessons learned in a risk-free environment rather than in front-line operations. However, they appear to play a lesser role in testing of actual hardware prior to production or deployment in the field and physical testing is still necessary.

The costs of creating synthetic environments are not generally seen as significant in the overall context of Defence spending; partly because budgets are generally much larger than in rail and also because their use reduces the need for physical tests, in turn lowering overall project costs and timescales. However, for most rail projects, a typical 'high end' synthetic environments is relatively expensive, hence their use is limited to those areas outlined above, where they can be clearly shown to be cost-effective.

Using synthetic environments instead of physical testing and validation of safety-critical rail hardware and systems will require extensive effort to be expended in creating and more importantly, validating computer models as their fidelity depends entirely upon the input data and the assumptions made during construction. The rail industry will still require innovations to be validated by physical testing in an operational railway environment, although there is undoubtedly a substantial and expanding role for synthetic environments and other Computer-Aided Engineering (CAE) techniques in establishing confidence in novel technology prior to testing as well as in such areas as rapid prototyping and reducing time to market.

Overall, synthetic environments are an excellent tool for evaluating the interactions between systems and people and there is an expanding role for them in the rail industry, particularly in staff training and in 'human factors' aspects of equipment design. However, the opportunities for their use in place of physical testing of safety critical equipment and systems are limited at present. With that said, the rail industry should continue to monitor developments in the field, with a view to potential future applications of synthetic environment technology.

6 GB Rail Innovation Solution Development

6.1 Implementing a “Rail Innovation & Growth Team” (RIGT)

We believe that the establishment of a **Rail Innovation & Growth Team (RIGT)** following the best practice of the long-established Aerospace and Automotive teams and the Niteworks partnership from the Defence sector offers the greatest likelihood of providing a forum for improving all three modes of innovation: traditional internal and suppler-led innovation, “outside-in”/ “lift-and-drop” leveraged from other railways and other industries and the most challenging, namely the collaborative development of industry platforms. The RIGT’s remit should follow that described above in section 5.2.3, covering the entire TRL cycle and enabling the alignment of people, processes, structure and culture around the IPMS to identify, assess, develop, test, launch and leverage innovation.

Rail Innovation & Growth Team (RIGT)
A proposed new GB rail innovation and growth team to parallel the approach established by other sectors including aerospace automotive and defence. The RIGT is envisaged to be a virtual organisation concerned exclusively with achieving value for money for GB Rail from innovation and growth both domestically and from international markets, although it will have a close relationship with and could be included in the putative System Authority (SA), which is charged with identifying and facilitating the implementation of systems solutions that improve value for money. The precise structure and functionality of the SA is discussed in the parallel report “Achieving VfM from a Railway Systems Authority” by Risk Solutions and Steer Davis Gleave.

As regards processes, NR believes that the stage-gate process it has developed for its internal innovation management system is robust and designed to be scalable to industry level. Whether the NR process is truly scalable or not would have to be explored and addressed by the RIGT, but if it is suitable for the industry, it would undoubtedly save time to leverage work based on best practice that has already been carried out.

There is no reason that the technical aspects of the proposed RIGT could not be drawn at least in part from the established TSAG / TSLG, but as outlined above the RIGT must be able to make an informed assessment in terms of not only technical issues, but all ten dimensions of innovation system structure as described in ISS. The RIGT can be tasked with the identification of transferable innovation from external sources as well as reporting on it to the industry. If a piece of innovation is deemed applicable, then its porting and development into GB rail can be commissioned as a platform as described in IPMS.

Nonetheless, it is important to point out that the introduction of TICs presents the industry with another powerful mechanism for focusing on the technical aspects of innovation particularly with regard to accessing the knowledge base for world-leading science and engineering and the ability to undertake collaborative applied research projects with business, as well as undertaking applied research and development contracted directly by business. The envisaged Transport TIC will be most effective if it is business focused with a highly professional delivery ethos if it is to create a critical mass of activity between industry and the knowledge base. TICs are also intended to provide skills development at all levels, implying an interface with the National Skills Academy and a conduit for world class-knowledge, implying that a Transport TIC will have extremely close links with the Transport KTN. This is of course facilitated by the expectation that both will be utilising operational best practice, process and the resources of the TSB.

It is worth noting at this point that it is still under discussion as to whether a “Transport TIC” is really the best model, considering that the centres should ideally be applicable to multiple markets and applications. Care must therefore be taken by the RIGT to ensure that industry silos do not develop and that the RIGT remains free to act as a customer of multiple TICs as required. However, Network Rail point to the example of GE’s market-facing Global Research Centres as a successful model to emulate which has not restricted innovation within market boundaries.

It should be noted that as with the example of the Hong Kong AdsCom committee, unless a referral is seen by the industry as something to be avoided, there may be a risk of the RIGT simply adding another layer of bureaucracy and this is a critical risk to the success of innovation leadership at industry level. If the approval functions of the industry are functioning properly in terms of innovation, referrals ought to be managed down to a sustainable level. The less of this operational and tactical innovation leadership is required by the industry, the more effort the industry will be able to devote to addressing the potential of global growth markets and thus bring in valuable revenue which can ultimately be used to improve the cost-effectiveness of delivering the agreed level of service for GB rail. The evolution of the innovation leadership function of the GB rail industry will principally be its extension from technical strategy and leadership to systemic strategy, management and leadership. This implies the following structure for the RIGT:

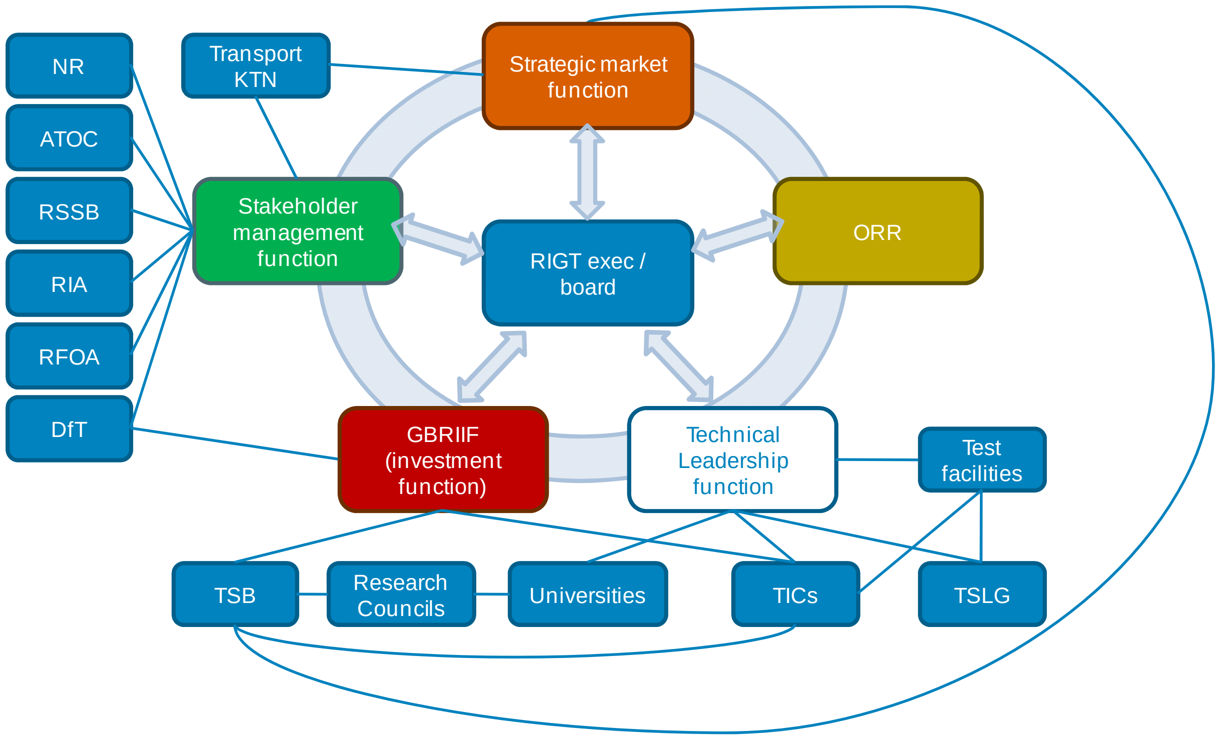


Figure 43: A proposed structure for the RIGT

Therefore, an issue such as determining what EU innovation platforms should be supported and commissioned at national level and what decisions should be made about innovation interoperability should ultimately be determined by the appropriate function of the RIGT. Where a major systems decision is made requiring competence across the entire system, the appropriate decision-making body is likely to be the RIGT executive / board. Where an issue is a matter of resolving a deadlock between stakeholders or technical authorities, at component, project or functional interoperability level, these should be resolved by the relevant RIGT function with the aim of clear avoidance of doubt. An example of a functional interoperability-type problem might be a debate about what national platforms should be commissioned from “the industry”, or when discussing lift-and-drops, technology transfer and conduit activities from other industries, or for example resolving the “air gap” between a technical specification and the first set of rolling stock fitments, or ensuring that a train can be run elsewhere after it is retired from its first network.

The sort of leadership the RIGT should be able to display can be shown through the example of the system-level commissioning of the TPWS. There was a clear ministerial mandate and a clear system need, there was a clear technical gap in terms of a solution for SPADs. One person took the leadership role as a systems authority and the design ended up being handed to industry with a clear mandate to develop launchable applications:

Case study: Redifon / MEL (now Thales) and TPWS

TPWS is an excellent example of a cost-effective, innovative system using low-technology components. In some aspects TPWS broke new ground – the design is non-fail-safe, but offers affordable levels of safety. Its commercial, off-the-shelf nature was viewed as alien by some in the signalling fraternity, but the compelling safety / business case was so compelling (driven on by societal expectations and regulation) that implementation was progressed with alacrity. The project resonates with several aspects of the innovation model, there was clear industry leadership, there was supplier-driven innovation, and a focussed project team driving the testing and evaluation of operational application in a demanding EMC environment (Thameslink testing). For such an innovative system, it proved capable of development to protect against train collision risk at much higher speeds that those for which the original design was conceived.

Supplier-led innovation will generally be a component-type problem but will sometimes need leadership at the level of interoperability. Component-level interfaces, for example dealing with issues arising from innovation in a subsystem on a piece of rolling stock must be minimised. For the RIGT to be most effective in decision-making, each function should ideally be able to make decisions based on 3-5 members, up to an absolute maximum of 7.

The proposed structure for the RIGT above assumes that the existing explicit and implicit R&D / Innovation roles and functions of DfT, TSAG and RSSB are subsumed; there is clearly an opportunity here to drive operational efficiency into the future structure. Furthermore, on the assumption that the RVfM work will also recommend the creation of a Rail Systems Authority, we recommend that the RIGT functions could be discharged under its remit. This obviates the need for separate management overheads that would exist should the RIGT be separately established. In the event that the Systems Authority is not created, it would obviously be necessary to understand how the capabilities of the RIGT could be worked into the various industry parties that currently have a role in innovation, including Network Rail, RSSB, Rail Research UK Association, TSAG, SICs, Operations Focus Group, TOM Standards Committee etc, suppliers, RIA and RFOA – this would have to form the basis of further investigative work.

It is also worth mentioning at this point that the introduction of a RIGT should resolve the issue of governmental leadership on innovation in the industry. The DfT is not prepared to act as a system authority, nor is this an optimal solution for a supposedly privatised industry. However, it certainly has a role to play at arm's-length as an innovation enabler and the proposed structure for the RIGT provides adequate interfaces to keep civil servants informed and appropriately involved in the industry's research and innovation agenda. The RIGT therefore needs to be able to use its relationship to lead innovation for the industry, thus removing any governmental propensity to try and micromanage. However, the RIGT does also need to be aware that the DfT sees itself as the voice of the customer, speaking on behalf of the taxpayer. However, this relationship is made explicit by the DfT's anticipated role in providing funding for collaborative investment. And where regulatory considerations are an issue in innovation, the RIGT needs to have the ability to raise this at the appropriate level with the ORR via an appropriate interface. Similarly, when the government, the regulator or the taxpayer wishes to directly raise the issue and priority of innovation, the RIGT will provide a forum and mechanism to do so in a practical manner.

A senior stakeholder's view:
"There is a deficit in the ability of the industry to innovate – necessary conditions to address this include:

1. greater clarity, consistency and stability of government objectives
2. stability in terms of organisation
3. greater alignment of incentives and timescales, and
4. some investment in filling the gap between ideas/research/technical development and industry exploitation
5. improvements to procurement arrangements in Network Rail, based on a partnering approach.

The first and second of these conditions are for government to deliver, and the third can be delivered by some focussed investment along the lines being developed by Department for Business Innovation and Skills through the TSB."

An important area of concern for the RIGT is likely to be raising the visibility of windows of opportunity for the “insertion points” for new technology to be introduced to the industry. Essentially, each insertion point has a lead time, but the interdependencies of these insertion points are not easily visible at an industry level. An example of this type of challenge is the interface between points of operator refranchising and the technical overlay for HS2, which will come in about year 8 of a 15-year franchise, or, similarly, the issue of the lead time for new on-track equipment raised by Network Rail. We therefore propose the creation of a matrix of insertion points to enable the agendas of industry stakeholders to be linked to technical road-mapping and anticipate that this would enable a reduction in supplier-determined variation orders. We suggest that the regulatory function, via the interface between the RIGT and the ORR, take the guardianship role in terms of incentivising the industry to meet these insertion points and ensuring compliance with a stated and clear requirement to innovate.

Group-Think
The tendency of a unchanging or insular group of people to converge their thinking. If taken to far the group-think behaviour will tend to “shut-out” new ideas or different solutions and remain in familiar comfort zone thinking.

The matrix of insertion points should be detailed at regional map level and show the functions that can be altered at the insertion point concerned. This should assist in resolving the sort of problems that occur when there is an insertion point for a platform a business case that runs over the end of an operator franchise or control period, where track access charges will normally be renegotiated, thus affecting the viability of the business case. The interface between the RIGT and the ORR should facilitate the standardisation of a process for such situation, where the resolution might be to negotiate a percentage reduction in access charges, with the percentage discount carrying over the end of the period even though the overall charges are changed, or perhaps by mandating the use of residual value for franchise owners, rather than an abrupt cessation in asset value.

The RIGT must be “cognisant of the economic consequences” of its decisions; it must be possible to determine who are the winners, who are the losers and how the incentives work. This will be achieved by a market system function, which can provide a sounding board for business case robustness and take a whole-system view to align commercial drivers and build common purpose. An example of this kind of challenge might come from resolving an issue between NR and a TOC where the existing commercial arrangements between the NR grant and the TOCs’ Track Access Offsets are not sufficient to incentivise a resolution.

The RIGT should be able to take a leadership role in innovation research. Whilst the need for tactical and operational research is met by the existing RSSB programme, the RIGT’s technical leadership function must be able to specify, trigger and manage research to test 10-15 year innovation horizons. Equally, the technical leadership function must, as mentioned above, have an extremely strong interface with the TIC / network of TICs envisaged by the Department for Business, Innovation and Skills and industry testing facilities, as well as being able to help with “learning for the industry” and creating knowledge that is valuable to other railways and sectors – for example, wheel rail interface knowledge is transferable to any instance of rolling contact bearings, which are common in helicopters, for example.

An important consideration in terms of staffing for the RIGT is the danger of industry “group-think”. The stakeholder group are abundantly aware of this as a challenge, as the same group people tend to be involved in technical leadership across the industry, thus perpetuating and institutionalising existing personal and organisational relationships and permitting the development of “comfort zones”. We therefore propose that membership of RIGT functions be periodically refreshed, on a 2-3 year basis. Ideally, the industry should seek to develop innovation leaders that are capable of effective participation in any one of the RIGT’s functions. We consequently recommend that innovation skills are explicitly included in GB rail’s new National Skills Academy programme, which is effectively an embryonic industry platform.

It is also important to mention the role that funding has in the demonstration of authority. With funding comes responsibility to show leadership. This will be achieved by the provision of a collaborative investment mechanism. The funding function will also require an interface with the UK plc best practice for innovation funding via the TSB, the research councils and established academic routes. By following the matching practice of the ETI, industry stakeholder will also be able to have a strong voice on this issue. When an innovation platform is commissioned at industry level, the collaborative investment mechanism will be able to own the business case as the funding sponsor when it is handed over by the platform developers and then present it to the prospective application developers for launch.

6.1.1 Research and Development Capability

The team was tasked with identifying specific enablers that will facilitate an improved approach to research, development, testing and innovation, as well as enhancing and focusing the GB rail industry's research capability. Because this is so intrinsically linked to progressing early-stage TRL activities to later development tracks, the approach is described in detail in section 6.1.2 but it is worth mentioning the success of the SBRI approach implemented by the TSB and extensively and successfully emulated in the Defence sector and urging the adoption of this model for early-stage research. The current research model implemented by RSSB and the programmes running internally at stakeholders such as NR already produces quality research particularly at tactical level, but the industry faces significant difficulties progressing this research into development and tracking its benefits beyond GB rail application due to the lack of clear innovation leadership from the industry – we believe this leadership will be effectively provided by the IGT. We also envisage that a key enabler of R&D capability will be the establishment of the TICs, in particular the proposed Transport TIC, which will be investing in R&D infrastructure and capability that can be called on by the RIGT via the collaborative investment approach outlined below to accelerate the development and testing of new technology. We additionally note the concern expressed by a senior stakeholder that existing industry initiatives should be comprehensively assessed for inclusion in the programme of the IGT – the concern here is to avoid the "orphaning" of activities that are catered for within the existing structure.

6.1.2 Collaborative Investment Approach

The project team were tasked with identifying practical ways to stimulate all industry parties and suppliers to develop cost saving or efficiency generating new products and processes and bring them to the market. To address the issue of funding and support open IPR models, we propose the establishment of a **GB Rail Innovation Investment Fund (GBRIIF)**, funded similarly to the Energy Technologies Institute (but avoiding its mistakes in IPR management) by "the industry":

- Suggested funders would include NR, RIA (and its members), ATOC (and its members), RFOA (and its members), RSSB, ORR and the academic institutions involved in RRUK, who should be prepared to create a substantial investment fund
- Matching funding should be provided by the public sector including DfT and, ideally, the TSB if the investment criteria permit
- The introduction of a Transport TIC should provide additional opportunities for collaborative investment, particularly if the platform has cross-sectoral application and requires access to high-end shared development facilities
- The GBRIIF should also attempt to attract external funding from other private sources as well as UK plc – at an EU level, other member states may also participate if the developed platform can be delivered across the EU.

> **Application Launch Undertakings (ALUs)**
> ALUs are organisations or consortia that would purchase the right to develop and launch applications based on an agreed industry-sponsored platform. As the platform would already have been considerably derisked, the ALUs would benefit from decreased time to market and an increased level of assurance that their application would succeed, They would consequently pay a royalty to the early stage platform developers, although they would retain the majority of profits from launching their applications to the market.

The GBRIIF should be incorporated to hold the IP of platforms developed for the industry and be able to bear risk in a similar way to a private fund. The platforms proposed by the RIGT for development should be developed by collaborative consortia to an agreed TRL level (probably 6-7) and the results delivered to the RIGT. Development consortia should be 50% funded by GBRIIF to the agreed level of technical readiness to de-risk the innovation process. Upon delivery to the RIGT an appropriate decision-making body should act as system authority to approve the platform's franchising for development to launch-readiness in line with the relevant standards.

Development to launch-readiness should be carried out by **"Application Launch Undertakings"** (ALUs, which can be either individual organisations or consortia as appropriate), who pay a "**platform franchise fee**" for the right to do so. A condition of ALU readiness to participate will be a guarantee of timely approval of compliance with relevant standards, failure to meet which should result in a part-refund of the platform franchise fee. Upon launch, ALUs will pay an **ongoing royalty** to the original development consortia but will be able to keep the rest of the profits from launching the systems in GB rail and in external worldwide markets.

This process, hereafter referred to as **"Value-Added Reimbursable Launch Investment"** (VARLI), is based upon the principle of "Reimbursable Launch Investment[26]" already in use for funding the development of Airbus by multiple European member states and known in the United States as "launch aid". The key feature of VARLI that allows collaborative investment to take place is the separation of the "research and develop" funding phase from the "build and launch" funding phase. This aims at an alignment of the commercial drivers of the various stakeholders so that both those who have the ability to research the problem and scope out potential innovative solutions are able to be incentivised despite their inability to implement the solutions and that those who have the ability to implement innovative solutions are able to obtain workable and practical platforms to implement in a cost-effective way.

Although the use of a Value-Added Reimbursable Launch Investment process is recommended here, we have received differing stakeholder perceptions as to how well such an approach has performed in the aerospace sector. On balance, therefore, we recommend that whilst this approach is pursued with appropriate caution, that lessons are learned from aerospace as to how to develop better performance from such an approach.

Value-Added Reimbursable Launch Investment (VARLI)
VARLI is a collaborative investment model which aims to address the uneven distribution of costs and benefits between early stage TRL developers and later stage launchers of mature innovation.

Traditional research grant funding as provided through the Research Councils, KTPs and SBRI should continue, but with the establishment of the RIGT they will have an ability to offer the results of research to the entire industry rather than offering it individually to each downstream stakeholder, each of whom will have their own agenda that is not aligned with the agenda of other downstream stakeholders. Of course, there is nothing to prevent any stakeholder, should it be willing, to participate across both research and develop and build and launch phases, if it is prepared to undertake the platform-building uncertainty gap in TRLs 4-6. The application of matched funding at this phase (up to 50%) should enable this process to be significantly de-risked, enough to prevent stakeholders from losing confidence and traction at this point and improving launch rates.

There should be nothing to prevent VARLI from alignment with the innovation management processes of individual stakeholders such as operators or Network Rail; the major change to collaborative innovation investment will be that the stage gates will be managed by the RIGT, in which the stakeholders will already be participating both as funders and approvers, rather than by individual stakeholders' stage gate processes. This should significantly increase transparency in decision-making and therefore prevent any party, particularly the larger stakeholders, from gaining undue influence over the timeliness of innovation.

[26] http://trade.ec.europa.eu/doclib/docs/2010/september/tradoc_146485.pdf

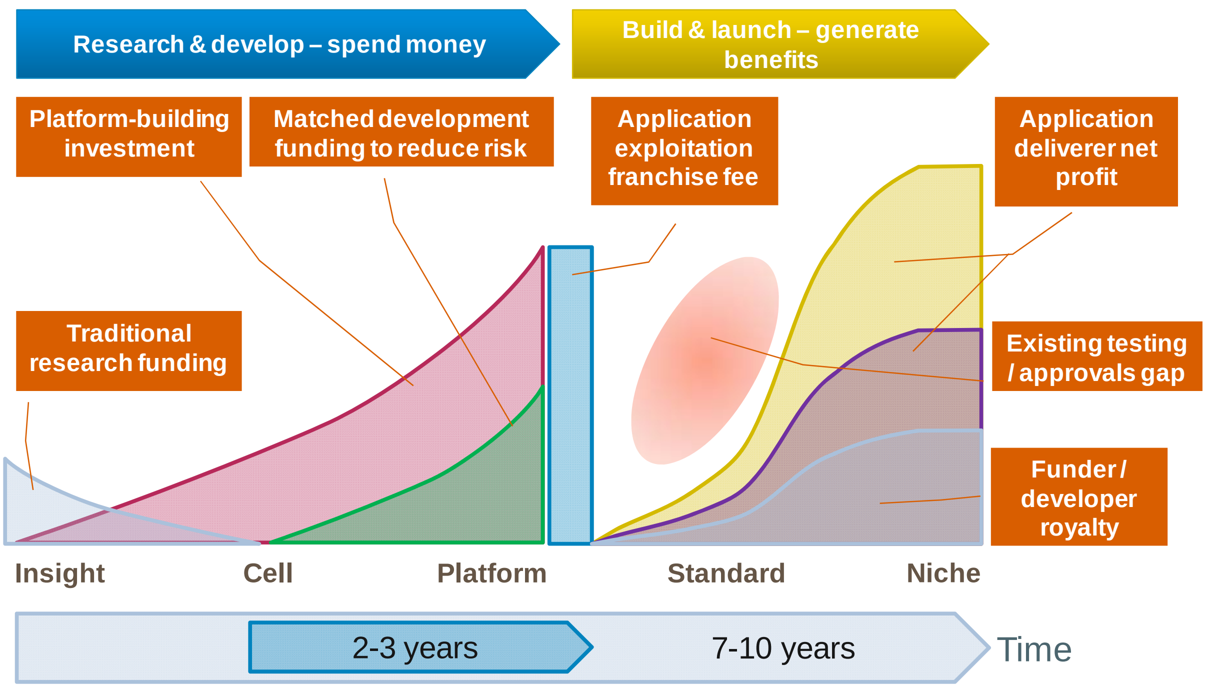


Figure 44: Visualisation of the proposed VARLI system for industry platforms

Rigorous best-practice process and examples of administrative systems to support this method of open innovation can be provided by the TSB. Technology Innovation Centres (TICs) will also be used by both development consortia and ALUs within the UK to support specific technology expertise and testing facilities, along the lines of the Fraunhofer Institutes. But development consortia and ALUs should be permitted to use whatever sources of technology and testing expertise they see fit.

We recommend that further work be undertaken to understand in detail the validity and viability of the VARLI model for use in developing GB rail industry innovation platforms, although the experiences of both Niteworks and the ETI and the best practices used by the TSB in implementing the TICs should provide clear lessons both in what to do and what to avoid.

6.1.3 The relationship between the RIGT and the proposed System Authority

The project team have been asked to outline how the proposed set of innovation enablers such as the RIGT and GBRIIF interface with the Systems Authority that is the subject of the parallel report "Achieving VfM From A Railway Systems Authority" by Risk Solutions and Steer Davies Gleave and align our recommendations, The systems authority is to be charged with identifying and facilitating the implementation of systems solutions that improve value for money from GB rail and, clearly, innovation will in many cases involve some of the same capabilities as regards value for money particularly in the field of new system solutions, hence our focus on innovation platforms as outlined above,

Although we have been asked to assume that a systems authority will be created, we feel it is fair to point out that in many cases the most effective enabler of value for money for the industry from innovation will be the introduction of specific innovation-related objectives and performance regimes to the existing organisations, as Network Rail and much of the supply base have begun to do. Nonetheless, the proposed systems authority as described appears to be able to fulfil the role in with our systems implementation model (described in section 7.1.1) of specifying 'measures of performance effectiveness' for RIGT and consequently to be able to perform primary monitoring activity.

A key risk to the establishment of both the RIGT and the systems authority is the accusation of "moving the deck chairs around" without bringing in new perspectives and sources of expertise from outside the "railway club". Similarly, the lessons of the Strategic Rail Authority – namely, that driving change requires real teeth, a systems view and independent leadership – must be seen to have been learned. A similar risk arises from the vested commercial and performance interests of stakeholders and suppliers of every sort – one of the most effective barriers to innovation is the conflict between “the day job” and “value-added” activity. If this occurs, it is inevitably the “day job” and “our commercial drivers”, as a more immediate call on time and resources, that will crowd out more uncertain or shared benefits from innovation. We therefore note the arguments made in the Systems Authority Report with regard to the location of the systems authority and suggest a model that is independent both from Network Rail, operators and RSSB as they are at present, but directly accountable to the regulator and the taxpayer (via ORR and DfT). This would ensure that focus would remain at industry level and moreover, sufficiently on the medium to long term benefits, both internal / domestic and external / overseas as opposed to more immediate concerns.

By the same token, the systems authority must not act as an “industry club” – it must not only permit but explicitly be tasked with leveraging knowledge, best practice and innovation in and seeking to build value by leveraging domestic innovation into global markets. Consequently, staffing at both systems authority and RIGT must be free to take “the industry view” (as opposed to a view which benefits one or more groups of stakeholders) and, where innovation is part of the solution, RIGT people, process, structure and culture must be free to act in the interests of both GB rail and UK plc with the specific end of becoming a net contributor to GDP through inward investment and global sales and value for money – through the consequent ability to reduce public subsidy. Innovation should therefore be seen as an enabler of economic self-sufficiency for the industry, not merely a vehicle for the reduction in local costs.

The Systems Authority Report makes prominent mention of the “Systems Mind” concept and we suggest that this approach is very much supported by the way the ISS and IPMS frameworks function. ISS and IPMS provide a picture of “what is going on in the system” and embrace the multiple perspectives implied by the Systems Authority Report’s vision of a system authority which can draw on a cross-functional resource pool of engineers, operators, economists, regulators, government specialists and industry consultants. The Systems Authority report suggests that innovation and growth from the point of view of the systems authority will require a “systems intelligence function” which will look at opportunities and challenges, covering futures and horizon scanning, legislative change, franchise renewal, major projects, new methods and RUSs. The RIGT is designed precisely with these functions in mind.

The structure of the RIGT is designed to facilitate changes to the current behaviour of the industry in order for this improved approach to innovation to be realised. The principal change will be that of transparency leading to clear accountability for each aspect of the innovation system. The RIGT structure has been conceived with a view to achieving this accountability and hence the responsibility for leadership. Leadership will be most manifest in the ability to exercise judgment through informed decision-making (particularly in cases where it will be required to resolve systemic issues arising from innovation) and we therefore specify the capabilities which will be required.

The full set of critical success factors determining decision-making capabilities required for a complete industry innovation system are described above in Table 6 and the systems authority will have need of all of them at the appropriate junctures. The specific subset likely to be required for system-level innovation decisions by the RIGT, particularly when it is acting to progress issues across TRLs 4-6, are those in the “traction” and “launch-readiness” stages and are reiterated in the following table:

	Traction	Launch-readiness
Strategy, policy & leadership	Strategic maturity & urgency	Mandate for launch
Sectoral & theoretical trends, regulatory & environmental changes	Directed research & investigation	Scenario planning & competitive analysis
Organisational structure & stakeholder relationships	Prioritisation of resources, silo-busting	Alignment of initial go-to-market structure
Technical excellence, creative insight, R&D	Technical deep-dive, proof of concept	Prototyping, testing, dry running
Systems, processes & operating models	Business case & process development	Go / No-go “hard” decision-making
Cross-functional integration: culture, people, teamwork, synergies & skillbase	Upskilling, partnering, cross-functional links	Defined go-to-market or execution team

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	Traction	Launch-readiness
Delivery, quality & risk management	Risk mitigation & quality measurement	Performance reliability & process stability
Marketing, communications, reputation, competitive threats	Value proposition development, channel identification	Competitive positioning, channel access planning
Relationship management, channels, suppliers & partners	Partnering, target segment piloting, strategic procurement	Launch strategy, key segment planning, commercial decisions
Users & customers	Beta testing, key user groups, influencing	Key adopters, first-movers, power-brokers

Table 9: Areas of leadership and decision-making competence likely to be required by the RIGT when acting a Systems Authority in GB rail

These areas can be analysed in further detail according to the granularity of the subsystems, systems and super-systems affected by the innovation that is being considered by the systems authority in its decision, depending upon the stage of the process in question. The suggested appropriate functional areas of the RIGT are shown in the matrices below:

	Traction	Component / supplier	Project	Functional interoperability	GB rail	EU / international
Strategy, policy & leadership	Strategic maturity & urgency	**Strategic market function**				
Sectoral & theoretical trends, regulatory & environmental changes	Directed research & investigation	**Technical leadership function / ORR interface**				
Organisational structure & stakeholder relationships	Prioritisation of resources, silo-busting	**Stakeholder management function**				
Technical excellence, creative insight, R&D	Technical deep-dive, proof of concept	**Technical leadership function, GBRIIF**				
Systems, processes & operating models	Business case & process development	**GBRIIF**				
Cross-functional integration: culture, people, teamwork, synergies & skillbase	Upskilling, partnering, cross-functional links	**Stakeholder management function, strategic market function**				
Delivery, quality & risk management	Risk mitigation & quality measurement	**Technical leadership function**				
Marketing, communications, reputation, competitive threats	Value proposition development, channel identification	**Strategic market function**				
Relationship management, channels, suppliers & partners	Partnering, target segment piloting, strategic procurement	**Strategic market function, stakeholder management function**				

	Traction	Component / supplier	Project	Functional interoperability	GB rail	EU / international
Users & customers	Beta testing, key user groups, influencing	**Strategic market function, stakeholder management function**				

Table 10: Specific capabilities for systemic and systematic decision-making likely to be required by RIGT functions at "traction" stage

	Launch-readiness	Component / supplier	Project	Functional interoperability	GB rail	EU / international
Strategy, policy & leadership	Mandate for launch	**Strategic market function**				
Sectoral & theoretical trends, regulatory & environmental changes	Scenario planning & competitive analysis	**Technical leadership function / ORR interface**				
Organisational structure & stakeholder relationships	Alignment of initial go-to-market structure	**Stakeholder management function**				
Technical excellence, creative insight, R&D	Prototyping, testing, dry running	**Technical leadership function, GBRIIF**				
Systems, processes & operating models	Go / No-go "hard" decision-making	**GBRIIF**				
Cross-functional integration: culture, people, teamwork, synergies & skillbase	Defined go-to-market or execution team	**Stakeholder management function, strategic market function**				
Delivery, quality & risk management	Performance reliability & process stability	**Technical leadership function**				
Marketing, communications, reputation, competitive threats	Competitive positioning, channel access planning	**Strategic market function**				
Relationship management, channels, suppliers & partners	Launch strategy, key segment planning, commercial decisions	**Strategic market function, stakeholder management function**				
Users & customers	Key adopters, first-movers, power-brokers	**Strategic market function, stakeholder management function**				

Table 11: Specific capabilities for systemic and systematic decision-making likely to be required by RIGT functions at "launch-readiness" stage

It should therefore be clear that the proposed RIGT structure can be mapped onto the required functions as outlined above and thus the leadership role of the various functions along the different dimensions of the system can be clarified. The next section describes how this leadership could function strategically, tactically and operationally within the RIGT.

6.1.4 The RIGT, industry leadership and issue resolution

Industry leadership for innovation is required at the following five levels:

Level	Principal challenge
EU / international	How should the innovation system factor in European & international considerations? What platforms should be commissioned at European level? How can GB provide innovation leadership at this level?
GB rail	How should the innovation system factor in considerations from other industry sectors? What platforms should be commissioned at GB level and how can the industry provide leadership? How can innovation be derisked at a regulatory level?
Functional interoperability	How should the innovation system provide leadership when considering industry-level questions of interoperability?
Project	How (if at all) should the industry innovation system affect activity and provide leadership at project level?
Component / supplier	How (if at all) should the industry innovation system affect activity and provide leadership at component level?

Table 12: Proposed set of capabilities required for the industry to enable innovation leadership

At component level, the industry's principal challenge is to show a clear technical strategy to influence R&D in the supply chain and clear barriers to approval of innovation. This is best achieved by having recourse to a system-level authority in a case where approval for innovation is proving problematic. The challenge is already being tackled from the point of view of Network Rail, with a view to improved output and more user-friendly standards. This process must continue and must, going forward, provide more transparency and clear timescales. Approval bodies cannot be allowed to simply play it safe when faced with either ambiguity or requests for derogation because of lack of knowledge or understanding, or lack of clarity in terms of systemic interdependencies. Where a product or service is deemed non-compliant, clear, timely feedback must be given, together with a resolution path and / or a way to challenge the opinion of the approval body. A systemic list of types of non-compliance and suggestions for how they might be resolved is shown in the table below.

ISS dimension	Reason for non-approval	Resolution route	Challenge route
Strategic / policy fit	Contravenes policy or industry strategy	Rework business model or whatever aspect is unacceptable	Refer to strategic market function of RIGT
Sectoral, environmental & regulatory benefits & compatibility	Incompatible with environmental or other regulatory considerations	Rework whatever aspect is unacceptable & / or engage in strategic R&D	Refer to ORR or to systems authority
Acceptability to industry stakeholders	Unacceptable to industry stakeholders	Rework management system & business model for the innovation	Refer to stakeholder management function of RIGT
Technical viability & achievability	Fails to meet technical output performance standards	Rework technical issue & / or engage in tactical R&D	Refer to technical leadership function of TSLG / RIGT or to systems authority
Value for money & cashflow model	Not cost-effective	Rework business case & operating model	Refer to GBRIIF

Compatibility with industry culture, skillset & structure	Clashes with industry culture, structural boundaries, skillset unavailable	Rework management system for the innovation	Refer to stakeholder management function of RIGT
Supply & delivery capability, riskiness	Fails to meet quality standards, unacceptable delivery risk	Rework technical issue & / or engage in tactical R&D	Refer to technical leadership function of TSLG / RIGT or to systems authority
Industry competitiveness	Locks competition unfairly out of the market	Rework business model	Refer to strategic market function of RIGT
Impact on industry relationships & channels	Incompatible with established industry relationships & channels	Rework management system for the innovation	Refer to stakeholder management function of RIGT
User & customer appetite	Unacceptable to users & customers	Rework whatever aspect is unacceptable	Refer to strategic market function of RIGT

Table 13: Innovation-enabling routes for providing leadership across the GB rail system

6.1.5 The relationship between the RIGT and the proposed Transport TIC

Although TICs have been mentioned at various points in this report, it must be noted that at this time, although high-level industry discussions are under way, it is by no means certain that the Government will opt to prioritise the creation of a Transport TIC. Even if it does, the remit and function of the TIC is not yet clearly defined or agreed by the stakeholders of the various industries involved. What can be said at this point is that its focus will not be on the benefits of GB Rail exclusively and within its purview, Rail will be in competition with other modes.

Although we have not been directly included in the discussions to date, at the very least, from our study of the Fraunhofer institutes and other intermediate institutions ("translational infrastructure" in Hauser-speak), it may be possible to suggest where at this point the line may be drawn and the distinctions and interfaces made clear between the RIGT and the TIC. The table below sets out these issues in as much detail as they can be presently described and we recommend that this is studied further in some detail.

ISS Dimension	RIGT (proposed)	TIC (indicative)
Policy, strategy & objectives	Focusing on the innovation objectives and strategy of GB rail and what it contributes to UK plc, for the travelling public and the movement of freight. Setting goals for innovation capability that are aligned with industry strategy.	Focusing on the challenge of [surface] transport across road, rail, marine and supporting innovation arising from multimodal issues such as congestion or last-mile delivery. Responding to transport strategy at UK level.
Trends (social, cultural, political, economic, regulatory)	Leveraging knowledge, best practice, research and insight from other rail industries around the world and determining innovation priorities and portfolio content, as well as monitoring global markets for developments that GB Rail can exploit or benefit from.	Leveraging knowhow and technology between transport modes and opportunities to benefit from shared challenges and solutions. Bringing insights across different transport markets and looking for synergies and trends that can inform multiple modes.
Stakeholders & funding	Aligning the interests and resource commitments of GB Rail stakeholders to meet industry value priorities. Liaison with stakeholders from other railways. Setting the investment programme of the GBRIIF. Providing a stakeholder interface for GB Rail (which should include the TIC).	Providing a mechanism whereby the investment priorities of multiple different industries can be met through shared facilities. Informing investment programme at the level of the Transport KTN. Providing a multi-modal stakeholder interface (which should include the RIGT) for UK transport.

ISS Dimension	RIGT (proposed)	TIC (indicative)
Technical capability, skills & best practice	Deep technical / technological expertise in rail applications and system-level thinking, compatibility with standards and processes. Determining the innovation platform components of industry technical strategy, generating shared industry IP.	Drawing upon the expertise of multiple transport modes and providing cross-industry insight, technical synergies and shared IP. Determining shared components and platforms for multiple modes (e.g. informed logistics, informed passenger travel).
Value for money & operating models	Managing the cost-benefit analysis of innovation and measuring the tangible and intangible value generated for GB Rail internally and by GB Rail externally. Leveraging public funding for rail.	Measuring the costs and benefits of addressing technology and innovation issues that affect multiple modes of transport and its relationship to UK plc. Leveraging public funding for transport.
Organisations, people & collaboration	Providing a forum and models for collaboration between academia, consultancies, infrastructure, operators, suppliers and industry bodies. Determining workable platform models for collaboration within the industry and sharing foreground IP and agreeing the distribution of benefits.	Providing a forum and models for collaboration between academia, consultancies, infrastructure, operators, suppliers and industry bodies from multiple transport modes. Determining workable models for collaboration across industry borders, sharing IP and agreeing benefits distribution.
Competition & communication	Communicating the value and benefits of innovation to the industry and from the industry to UK plc. Determining global target market entry strategies and competitive positioning against innovative platforms, products and services from other railways in the global supply chain as well as other domestic modes of transport.	Providing a route to exploitation and dissemination of IP and technology generated within the TIC to adjacent markets and industries. Competing with (or collaborating with) "intermediate institutions" (e.g. Fraunhofer, Carnot) from other countries for contract research, testing and prototyping business.
Delivery, standards & risk	Sourcing and procuring [local?] facilities for testing and prototyping for the GB Rail supply chain from wherever is most appropriate (e.g. AAR/TTCI, the TIC)	Providing prototyping and testing facilities that can be used by multiple transport modes both locally and internationally, including the RIGT.
Internal & external relationships	Building relationships with purchasers in domestic and global markets to maximise the value for money from commercialising innovative products, services and platforms, leveraging GB Rail capability (e.g. global engineering consultancies)	Building a network of networks to ensure that value-added prototyping, testing and technology development facilities can be delivered to and commercialised by UK transport stakeholders in a cost-effective and collaborative way.
User & customer needs	Gaining deep insight into the needs of existing and future GB rail users and customers, both domestic and global, ensuring that this informs industry strategy and platform development priorities.	Gaining deep insight into the needs of existing and future transport users and customers, ensuring that this informs industry strategy and development priorities.

Table 14: ISS comparison of the similarities and differences in the focus, functions and remits of the proposed RIGT and Transport TIC

6.1.6 Converting research into technology via cost-effective provision of testing facilities

Innovation Enablers
The components of the proposed industry innovation management system, comprising the RIGT, GBRIIF, relevant functions of the SA, the TICs and industry-focused improvements to and interfaces with the innovation management processes of industry stakeholders. The Transport KTN, and TSAG/TSLG should also act as innovation enablers.

The project team was tasked with making recommendations as to how to provide testing facilities such that the cost is not prohibitive and development can be effectively undertaken before bringing the product to the market. A review of how the industry's future needs for testing facilities to support innovation can best be met provides the following conclusions:

i) A facility comparable with Wegberg-Wildenrath or Velim is unlikely to be commercially viable in the GB rail market. The former cost €105M to build (in the late 1990s) and has to be maintained to all intents and purposes as an operational railway; the level of demand from the industry is unlikely to enable those costs to be recovered.

ii) Use of European test tracks and related facilities must be carefully evaluated to ensure that they are practicable for UK industry stakeholders due to financial, logistical and capacity constraints.

A stakeholder view:
"The examples quoted…from British Rail days, show the benefit of having a research capability with testing facilities and the development of TICs and other similar solutions should begin to plug the gap that most people recognise."

iii) The Network Rail Innovation and Development Centre at High Marnham is an excellent facility for evaluating innovation in plant, equipment, processes and people associated with the maintenance and upgrading of rail infrastructure. However, its capabilities for testing rolling stock and interactions between the various elements of the rail system are limited at present. There is undoubted potential for development of the site, but even if it were to be upgraded it is questionable whether all stakeholders would be able to access it when required.

iv) The British Rail Board Residuary Asfordby Test site already accommodates all types of UK rolling stock and is capable of a degree of integrated, 'whole system' testing, e.g. compatibility of rolling stock with signalling. Its principal limitation is its 'end to end' layout which precludes continuous running, but in view of its length (21 km) this may not be a significant barrier to 'accelerated life' testing.

v) An engineering development workshop facility, accessible to a wide range of industry stakeholders, would be of great benefit in supporting prototyping, development, validation and static testing of novel technology to build confidence in the product before commencing on-track testing.

vi) The team notes the significant investment in synthetic environments made by the defence industry and the benefits that are thereby gained from enabling the testing of interoperability as well as the cost reductions to be gained. A similar investment in synthetic environments for railways would be able to leverage the knowledge and experience of the defence industry as well as providing an opportunity for costs to be further reduced by shared resources with, say, automotive or aviation environments.

Further work is required to substantiate the above conclusions and to make substantive recommendations for the provision of rail industry test facilities in the UK. This should include:

- Discussions with representatives from key industry stakeholders including ROSCOs, TOCs, and test facility operators;
- Investigation of the potential for upgrading the two UK test track facilities to meet current and future industry needs;
- Benchmarking rail test facilities with those in related industries, particularly Defence and Aerospace;
- Detailed Investigation of funding models.

6.2 Quantification of Innovation Benefits

The project team was asked to quantify innovation benefits by reference to

(a) Existing GB rail industry projects
(b) Rail industry projects in other countries
(c) Innovations in other industries

6.2.1 Our Approach to Benefit Quantification

The extent to which the value for money of innovation could be improved, by reducing costs and / or increasing returns, due to the implementation of innovation enablers, needs to be estimated based on two considerations:

- To what extent could existing issues such as barriers to innovation success be resolved due to the role played by the innovation enablers, enhancing the performance of projects that have been put forward under the existing industry set-up?
- To what extent could innovation enablers enhance the performance of the GB rail industry's innovation performance by stimulating activities and improvements that are beyond what could be foreseeable within the current industry set-up?

With respect to the first consideration, if it is found that costs overruns are common on GB rail innovation projects or that the realised benefits are typically smaller than envisaged, then the innovation enabler should be capable of reducing cost overruns and improve benefit realisation on the sort of projects have been implemented in the past. For this exercise, data from GB rail organisations are required, in terms of:

- What were the forecast costs and returns?
- What have been (or realistic to be) actual costs and returns?
- What have been the factors that have led to the differences between the forecasts and the actual?

Based on past project data, a picture of the benefits and costs can be established, the gap between the actual and the forecasts is one which the innovation enablers could help to close. The extent to which they could close this gap depends on the extent to which they could resolve the issues that have led to the differences between the forecasts and the actual. Such analysis is undertaken in section 6.2.2.

It needs to be recognised that the analysis based on past projects could only offer part of the picture in terms of the extent to which the innovation enablers could improve GB rail innovation performance. This is because the set-up of the industry to an extent determines the activities that are undertaken. Therefore, the sort of activities that would be undertaken with innovation enablers in place in the future could be different from those that are currently done. This is the second consideration – the ability to stimulate new activities and growth which would not have been considered under the status quo.

The analysis of stimulated activities due to innovation enablers cannot depend on data from the current GB rail industry. Instead, examples from other sectors and organisations are required to provide a benchmark, which suggests that if the innovation enablers function as well as these comparators, then certain levels of returns could be generated at given cost inputs. Such analysis is undertaken in section 6.2.3.

Overall, the use of the two approaches help to establish the extent to which existing issues could be resolved and future growths could be stimulated due to innovation enablers. A fuller explanation of the approach used can be found in Appendix G.

6.2.2 Analysis based on past and existing GB rail projects

Overview of how innovation enablers could resolve existing project issues

In chapter 5, it was established that at industry level, there is a gap between how the GB rail industry is performing now compared to the ideal, as well as compared to the target performance level that could be achieved with innovation enablers. This is illustrated in the figure below:

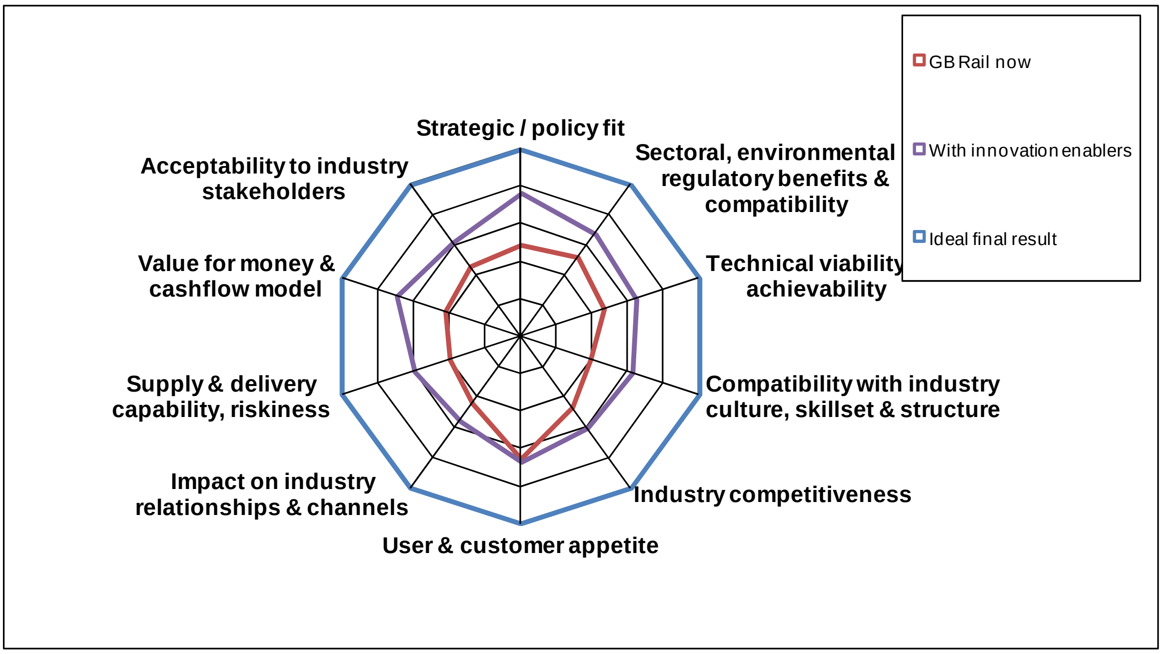

Figure 45: Benefit performance level that could be achieved with innovation enablers

As shown in the figure above there are some gaps between "now" and "target", indicating the levels of improvement that could be achieved with innovation enablers in place. It should be noted that not all aspects are likely to improve by the same extent. For example, innovation enablers are likely to improve the issue of strategic and policy fit to a greater extent compared to improvements that are likely on the issue of industry culture compatibility. The table below presents the numerical values, comparing "now" and "target". The numbers are rounded to one decimal place.

Issue	Ideal	Now	Now gap vs ideal	Target	Target gap vs ideal
Calculations	*a*	*b*	*c = a - b*	*d*	*e = a - d*
Strategic / policy fit	5	2.4	-2.6	3.8	- 1.2
Compatibility – sector, environment, regulations	5	2.6	-2.4	3.4	- 1.6
Stakeholder acceptability	5	2.3	-2.7	3.2	- 1.8
Technical viability & achievability	5	2.0	-3.0	3.1	- 1.9
Value for money & cashflow model	5	2.3	-2.7	3.0	- 2.0
Compatibility – industry culture, skillset, structure	5	3.3	-1.8	3.3	- 1.7
Supply & delivery capability, riskiness	5	2.2	-2.8	2.8	- 2.2
Industry competitiveness	5	2.0	-3.0	3.0	- 2.0
Impact on industry relationships & channels	5	2.1	-2.9	3.5	- 1.5
User & customer appetite	5	2.3	-2.7	3.1	- 1.9

Table 15: Gaps between current situation and ideal by ISS dimensions

If the industry is at its "ideal" state, then there should not be any major system-level problems. With respect to the projects that have been undertaken under the current industry set-up, all projects would be delivered on budget and generating the envisaged returns. However, even with the envisaged innovation enablers, such an ideal state is unlikely to be achievable. Nevertheless, the gap between the “target” and the “ideal” is narrower compared to the gap between “now” and the “ideal”. The table below shows that with innovation enablers, the gap is likely to be narrowed.

Issue	Now gap vs ideal	Target gap vs ideal	Target : now factor percentage	% of problems resolved
Calculations	*c*	*e*	*f = e / c*	*g = 1 - f*
Strategic / policy fit	-2.6	- 1.2	45%	55%
Compatibility – sector, environment, regulations	-2.4	- 1.6	67%	33%
Stakeholder acceptability	-2.7	- 1.8	67%	33%
Technical viability & achievability	-3.0	- 1.9	62%	38%
Value for money & cashflow model	-2.7	- 2.0	75%	25%
Compatibility – industry culture, skillset, structure	-1.8	- 1.7	95%	5%
Supply & delivery capability, riskiness	-2.8	- 2.2	80%	20%
Industry competitiveness	-3.0	- 2.0	67%	33%
Impact on industry relationships & channels	-2.9	- 1.5	52%	48%
User & customer appetite	-2.7	- 1.9	70%	30%

Table 16: Likely effect of innovation enablers on the industry by ISS dimensions

As shown in the table above, different issues are likely to move closer to the “ideal” under the “target” state (i.e. with innovation enablers), some more so than others. For example, in terms of industry culture, skillset and structure compatibility, the move from “now” to the “target” will not remove much of the gap to the “ideal”, as the “target” gap to the “ideal” is 95% of the “now” gap. Here, it is derived that only 5% of the problems relating to this issue could be resolved by the introduction of innovation enablers. By contrast, the gap to the “ideal” is narrowed significantly with respect to strategic / policy fit, resolving 55% of the problems relating this issue.

It has already been discussed in chapter 5 that the issues listed in the table above cover the most important dimensions related to innovation, and all problems could be categorised accordingly. Therefore, depending on the nature of the problems faced by past projects, the introduction of innovation enablers could help to varying extents (according to the table above) to overcome such problems, helping to ensure that projects are delivered according to forecast costs and returns.

Past project data

In order to establish the extent to which innovation enablers could improve the performance of GB rail projects initiated under the existing set-up, it is necessary to gather data and information on past projects. This section summarises the data collected from GB rail organisations, including infrastructure owner and operator, train operators, manufacturers, rolling stock leasing companies and government organisations. This version of the report uses data supplied by a number of rail organisations, made available up to 20th January 2011. The data have been supplied on a strictly confidential basis, and therefore all references to the organisation, project, detailed financial data have been omitted from this report.

It should be noted that data collection has not been an easy process. The source organisations typically found it difficult to supply detailed data within a short notice period. Sometimes data is not stored and managed at a senior level or, while some views about innovation exist at a senior level, there is a lack of immediate and direct access to detailed data. In addition, with respect to certain projects, there has been a lack of monitoring data and review information. This is not unsurprising as this issue is also observed on major infrastructure projects world-wide.

Case study: SMART Pensions
To drive efficiencies in a large organisation's internal operations, the HMRC-approved SMART ("Save Money and Reduce Tax") initiative was introduced to enable both the organisation and its employees to reduce NI payments on their pension contributions. IT systems were developed to process the financial deductions concerned and the project was supported by a change management communications programme. At 40% take-up, this project would save about £3.6m p.a. If the project delivered to the forecast cost of £0.8m, the ROI would break even within three months. Actual cost was £0.6m and £4m was saved in the first eight months by the organisation (employees saving £3m over this period), returning the investment within **six weeks** of launch. Actual takeup was 60% and ongoing benefits are expected.

Overall, "visibility" and "control" could be problematic issues within the GB rail industry with respect to innovation. Data supplied often has to be interpreted, adjusted and prepared as inputs to the model before analysis is possible. Timing is also an issue with some innovations potentially taking a long time before generating returns, hence presenting unclear outcomes at this time. It has to be acknowledged that many data providers have been very helpful, but the provision of detailed historical data can be a challenge. In addition, the set-up of some organisations (indeed the industry as whole to an extent) has not had an overt focus on innovation performance. Nevertheless, it is observed that those organisations that perform a coordination / oversight role with respect to innovation have helpful "elevated" views on innovation performance. These observations suggest that the introduction of the innovation enablers could indeed help to provide that coordination / oversight role for the industry as a whole, helping to overcome some of the "visibility" and "control" issues so far observed.

Case study: "Plug-and-play" signalling
This is an example of an innovation that is under way at a number of different stakeholder organisations, based on the insight that it costs more to carry out work trackside than it does to carry out the equivalent work in the factory. If work is transferred to the factory the cost of signalling can be reduced and safety increased. The project covers the update of processes around signal testing and the standardisation of the use of plug couplers for equipment, which will henceforth be fitted with plug couplers and fully tested in the factory, transported to site, then connected ready for a correspondence test and commissionings. The result is quicker installation and reduced signal testing trackside. The challenge is to embed Plug & Play in signalling projects and get to a position where it is "business as usual" within the next 18 months, thus reducing testing, commissioning, installation and project management costs as well as reducing construction and commissioning time. In this instance, it was forecast that this project would cost £1.38m and has in fact cost £2.2m and has, to date, achieved £3.6m in cost savings expected to amount to £6.7m in year two, achieving payback within this timeframe.

Despite the challenges, an initial analysis has been produced in this section, based on usable high-level information. It should be noted that the monetised estimates need to be viewed with caution given the issues already discussed.

Overall, the usable data suggests that the organisations sought to invest £362m with a view of gaining £1,483m – a return-on-investment of nearly 4 : 1, and a net surplus of £1,120m. In reality, this level of return-on-investment has not been realised, due to a number of reasons. A few examples are given below:

- Difficulties with identifying stakeholders and decision-makers
- Difficulties with the agreement and approval process
- The cost of materials was significantly higher than anticipated, with a misalignment in the production chain

This picture aligns with the industry-level picture given by the various stakeholders. Due to various reasons, overall, the usable data suggests that the organisations spent or would realistically spend £385m and gain £1,061m. The cost increase does not appear to be substantial, but the shortfall of benefit-realisation is almost £422m against forecast. This results in a lower than intended return-on-investment of approximately 2.8 : 1 and a net surplus of £676m.

It should be noted that there is substantial variation between projects in terms of the comparisons between forecast and actual costs and returns. While on some projects, increased costs have been the main problem, on others, the under-realisation of benefits is the key issue.

In the data collection (completed on 20th January 2011), over half of the intended investment cost value comes from two organisations. One of these organisations supplied their 2008/09 forward looking programme. The data from this organisation suggests that while the benefits estimated are large, this organisation judges that the probability of realisation is low, due to the range of factors that could stop research findings from being implemented or implemented at a scale that is smaller than could be envisaged. There is no single reason behind this under-realisation. The gap between what could be achieved and what is likely to be achievable (considering the low probability), is therefore substantial. Any percentage closure of this gap would mean significant gains.

It is interesting to note that one supplier organisation, which has received national awards for innovation, worked mostly on highway innovation projects, with only two rail projects, and one of these was in Southern Europe.

The reasons for variation are classified using the ISS dimensions as shown in the tables shown at the start of this section. Numerically, if a project was mainly been troubled by the issue of strategic / policy fit and hence had lower return levels compared to forecasts, then with innovation enablers, that shortfall in the levels of returns would be reduced by 55%.

Using this approach, it is estimated that with innovation enablers, the overall cost would be similar to the levels that have been incurred at £382m. Here, the savings from some projects is balanced with the implementation of some other projects which were not implemented. The return is estimated to be in the region of £1,198m. The resulting net surplus is £816m. Compared to the £676m net surplus currently gained, this £816m net surplus constitutes an increase of £140m. Therefore, as calculated, it is estimated that based on the usable data available, the contribution of the innovation enablers to GB rail would be in the region of £140m, as summarised in the table below.

£ million	Current	With innovation enablers	Change
Spend	385	382	-3
Return	1,061	1,198	+137
Return-on-investment ratio	2.8 : 1	3.1 : 1	+ 0.4
Net surplus	676	816	**+140**

Table 17: Contribution of innovation enablers to GB rail using sample data

The organisations that supplied the data have indicated how representative their project examples are of their own organisations' innovation activities, ranging from 5% to 100%. Also, the organisations have indicated over what period these types of activities are undertaken, from these sorts of projects being undertaken every year to approximately every seven years. Weighted by forecast project costs, on the whole, the sample data represents 20% of the overall innovation activities of the organisations that supplied data, with such projects occurring approximately every five years. Mathematically, therefore, the same numbers suggested in the table above can be taken as the annual figures for the organisations.

While the calculations above have provided the annual innovation performance for the organisations that provided data, a picture of the industry as a whole needs to be established. Judging by the organisations that have supplied data, an initial view is that the sample could represent a good proportion of industry-level activities.

According to a report, the average spending on innovation per employee in the transport and communication sector is approximately £4,000 per annum[27]. This level of spending is low compared to many other sectors including retail and wholesale trades. It is estimated that 187,000 people work directly (i.e. in the movement of people and goods, and the management of infrastructure) or indirectly

[27] *Taking services seriously*, NESTA, 2008

(engineering and equipment suppliers) for the rail industry[28]. If the rail industry spends as much as the generic transport and communications sector on a per employee basis, then the industry spends approximately £748m on innovation. The sample data, therefore, represents approximately 50% of the industry's activities.

Assuming that the sample data does represent 50% of the industry's activities, **then the GB rail industry as a whole is likely to benefit by approximately £280m a year in net surplus with innovation enablers in place**.

At a higher level, beyond project examples, issues expressed by the various organisations are again in significant agreement with the issues identified by our industry analysis. These include:

- The lack of joined-up thinking in the rail industry
- The lack of leadership or strategic vision for cross-industry investment projects
- The lack of a mechanism for sharing benefits across companies, making business cases with shared benefits impossible (or very difficult) to justify.

While the project-level difficulties have hindered the progress at that level, the higher-level issues exampled above mean that there are constraints even before projects are envisaged, developed and implemented. The set-up of the industry plays a role in the sort of projects that could go forward in the first place, as well as influencing the successes of these projects. Therefore, if the industry-set up changes, then it is not only the successes of projects that could be affected, but at a more fundamental level, the generation of projects could be affected, for example leading to certain projects being envisaged, developed and implemented which would not be under the existing set-up. This issue of "stimulation" is discussed in section 6.2.3.

6.2.3 Analysis based on comparator organisations

The previous section has discussed the extent to which innovation enablers could help to resolve some of the issues faced by the GB rail industry, based on past projects. It needs to be noted that the types of projects undertaken, with their costs and returns, analysed in the previous section were initiated under the existing industry set-up. With the introduction of innovation enablers, the industry-level set-up of GB rail will change. Following this change, it is likely that while some of the existing types of projects will continue to be undertaken, it is also likely that new projects will be stimulated that could be different. This is the simulation effect of innovation enablers, which could not be numerically analysed using past data, but could be analysed using information from comparator industries and organisations, where there exist overall coordinator bodies covering the issue of innovation.

The most appropriate comparator to the combination of innovation enablers is the TSB. It has plans for a range of investments over the coming years. The table below provides a set of examples, courtesy of the TSB:

Programme	TSB investment over 5 years per programme	Expected direct returns (increase in UK market turnover)	Return : investment ratio
Low Carbon Vehicles	50	500	10 : 1
Programme 1	100	300	3 : 1
Programme 2	29	100	3.5 : 1
Programme 3	6	30	5 : 1

Table 18: Return : investment ratios from TSB programmes

As shown in the table above, overall, depending on the project, the return-to-investment ratio is above 3: 1, with the best-case of Low Carbon Vehicles achieving 10 : 1.
In the UK's energy generation and supply sector, the "Innovation Funding Incentive" (IFI) was set up as a mechanism with the objective of incentivising distribution network operator (DNO) companies to invest in appropriate R&D activities that focus on the technical aspects of network design, operation and maintenance, enhancing efficiency in operation costs and capital expenditure. It is estimated that

[28] Memorandum from Invensys Rail to the Commons Select Committee on Transport, Session 2010-11, UK Parliament

the cost of IFI measures is approximately £71 million, with an expected benefit of £372 million if cross-initiative benefits are excluded, generating a benefit cost ratio of approximately 5 : 1.

In the aerospace manufacturing sector which is recognised as a key UK innovation industry, BAE Systems is a major player. Although there are many contributing factors to profit and R&D is not necessarily the same as innovation (only covering TRLs 1-6), the figure below shows that there appears to be a delayed trend between R&D spend and profit levels for BAE Systems (Data source: TSB dataset on R&D investment).

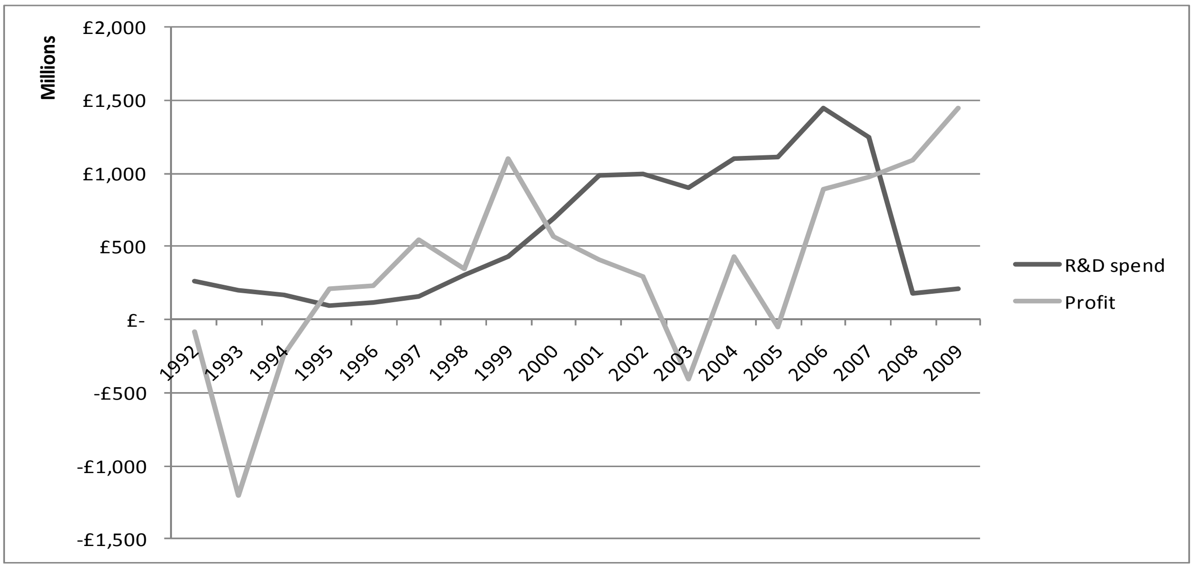

Figure 46: Delayed trend between R&D spend and profit levels (BAE Systems)

Meanwhile, in general, according to the TSB, the KTNs operated by the TSB help to provide the benefits of £3.5m increase in annual profit before tax per £1m government spend. From our empirical experience in innovation and following industry best practice, innovation projects are best managed as a portfolio, with projects classified into three generic categories:

- High risk – high return;
- Medium risk – medium return; and
- Low risk – low return.

The low risk – low return projects generate the basis upon the higher-end innovation, most important in providing competitive advantage and reputation, could be undertaken. The table below provides an illustrative example of portfolio management following in a 20-30-50 rule in the split between high and low return-risk projects.

Category	Return-to-cost ratio	Probability of occurrence	Proportion in the portfolio	Expected return from portfolio
High risk – high return	1000 : 1	1 in 300	20%	3 : 1
Medium risk – medium return	10 : 1	1 in 3	30%	
Low risk – low return	3 : 1	90%	50%	

Table 19: Innovation portfolio split showing probable return BCR

Given the analysis above, a 3 : 1 ratio may be considered as realistic. Using past project data, it has already been estimated that the current return ratio is approximately 2.8 : 1. The analysis in the previous section has already suggested that the innovation enablers could improve this ratio to 3.1 : 1. Therefore, with the stimulation effect that is likely under a new industry set-up, an overall 3 : 1 at portfolio level may be considered as achievable, although this might not be considered ambitious.

Overall, it can be assumed that at a given investment level, through the GBRIIF, the GB rail industry should be able to generate a substantial return on investment. Depending on the nature of the projects, different returns could be expected. **Overall, it may be appropriate to assume that a return-cost ratio of between 3 : 1 and 5 : 1 could be manageable at the portfolio level**. The absolute size of investments and returns depends on the level of project activity that could be managed by the innovation enablers. The appropriate size of the innovation enablers (as indicated by resource levels, or operating cost) and the level of manageable project investment are discussed in Section 7.2 on funding.

6.3 Global growth markets accessible to innovation from GB rail

If it is accepted that the Hauser principles of **global growth based on building world-class capability in sections of an industry value stack** are fundamentally the correct approach to exploiting the expertise of UK plc, then the real "size of the prize" from innovation comes not only from its application to home markets, but particularly from its leverage through exports to global markets. Certainly the "Blueprint for Technology" document and £200m government investment in the TICs, not to mention the focus on the importance of the TSB, would appear to provide clear evidence that this is considered to be the case. Therefore, it is important to understand in some detail the characteristics of the world market for exporting GB rail expertise, with a view to answering the following key questions:

- How big are the markets by rail product sector?
- Where are key regional markets?
- Where are the key regional markets for each rail product sector?
- Which are the mature and emerging markets that could be targeted by GB rail for export-led growth?

Once these overall issues are understood, the key questions for target markets are:

- What is the size of the target market by region and product sector?
- What is the size of the market opportunity for GB rail?

Approach

The data for this section is based upon the "World Rail Market Study" (report published by UNIFE. This report provides data from 2007-09 and forecasts for 2015-16 in terms of market sizes by rail product sector and region. Analysis of world markets is undertaken using a size-growth matrix, as illustrated below:

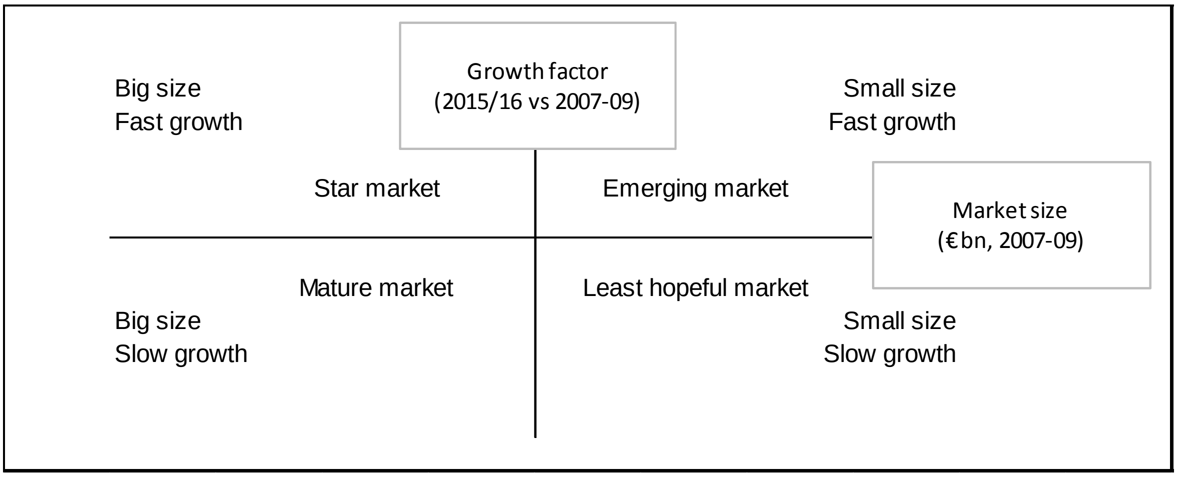

Figure 47: Size-growth matrix showing taxonomy of market types

As illustrated above, there are four types of markets:

- **Star markets** – these are large markets that are forecast to grow rapidly as well, potentially allowing GB rail to expand its presence and / or make entry more easily.
- **Mature markets** – these are large but slow-growing markets. The potential to expand is more limited and entry could be more difficult.
- **Emerging markets** – although the sizes of these markets are relatively small, they are fast growing. Expansion or entry to these markets could be easier than in mature markets. In addition, holding a steady position in the emerging markets could potentially lead to further benefits, for example if these markets continue to grow to become mature or even star markets.

- **Least hopeful markets** – small in market size and slow in growth, these markets do not compare favourably with the other markets. Expanding or entering these markets may not be easy and may not be as beneficial compared to emerging or star markets.

While there is a stark contrast between star and least hopeful markets, from a purely demand-led market point of view, it is possible to be indifferent in respect of a position in a mature market (where one could gain through size) or an emerging market (where one could gain through growth). A dotted line is therefore drawn across the matrix, representing "a line of indifference". The further away from this line a market is represented, the more or less promising that market is concluded to be.

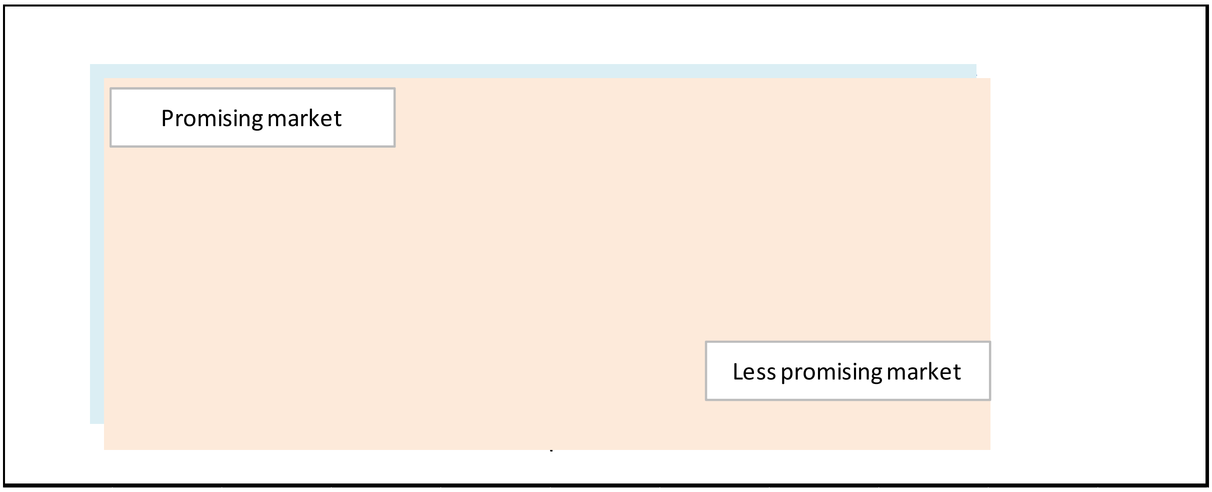

Figure 48: Taxonomy of promising and less promising market types with "line of indifference"

In this market analysis, the following should be noted:

- The markets analysed, in terms of size and growth, are accessible markets, which could be receptive to GB rail exports.
- When discussing the different types of markets, from star to least hopeful, such discussions are based on the **relative positions** of these markets. If we say that a certain market is "mature" it does not literarily mean that this market has reached a certain stage of development, but only that in terms of size and growth, it appears more mature than some other markets.

Market by rail product sector

The report groups all products into the category "rail equipment". Under this label, there are four product sectors:

- Service
- Rolling stock
- Rail control
- Infrastructure

The figure below shows that, in terms of world-wide rail market by product sector, "service" (s) is set to grow the fastest, whereas "infrastructure" (i) shows the least promise. As illustrated in the approach section, the x-axis represents the market size in 2007-09 €bn, and the y-axis represents the growth factor between 2007-09 and 2015/16.

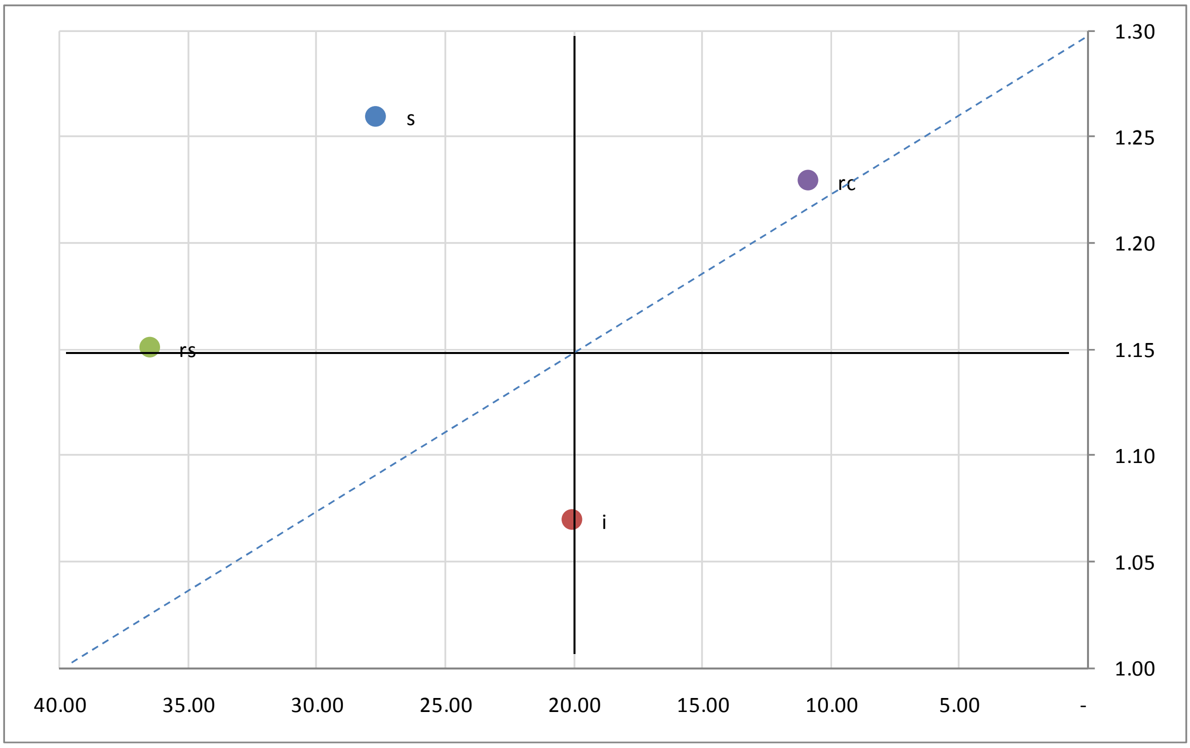

Figure 49: Size and growth rate of world-wide rail market by product sector

The table below presents the overall market size (2015/16) by product sector. A ranking order is provided indicating the preference between the markets.

Product sector	Market size (€bn, 2015/16)	Market type	Ranking / preference / comment
Service (s)	35	Star	1
Rolling stock (rs)	42	Star / Mature (borderline)	2
Rail control (rc)	13	Emerging	3
Infrastructure (i)	22	Least hopeful	Last

Table 20: Overall market size 2015/16 by product sector

Market by region

The report classifies the world market into the following regions:

- NAFTA (n)
- Rest of America (ra)
- Western Europe (we)
- Eastern Europe (ee)
- Africa / Middle East (a/m)
- CIS
- Asia / Pacific (a/p)

Using the size-growth matrix, the figure below illustrates that Western Europe (we) appears to be a promising market. CIS, although small in market size, is fast-growing, which also presents an opportunity.

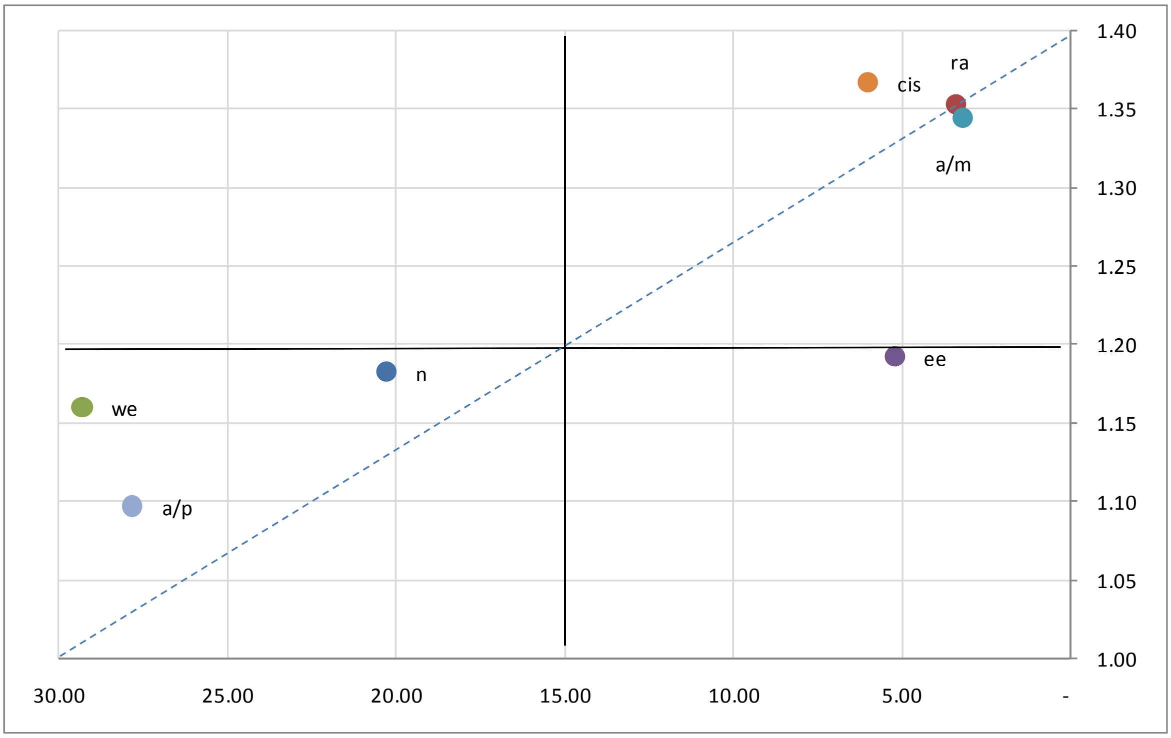

Figure 50: Size and growth rate of world-wide rail market by region

The table below presents the overall market size by region. A ranking order is provided, indicating the preference between the markets.

Region	Market size (€bn, 2015/16)	Market type	Ranking / preference / comment
NAFTA (n)	24	Mature	2
Rest of America (ra)	5	Emerging	3
Western Europe (we)	34	Mature	1
Eastern Europe (ee)	6	Least hopeful / emerging (borderline)	Last
Africa / Middle East (a/m)	4	Emerging	4
CIS	8	Emerging	2
Asia / Pacific (a/p)	31	Mature	2

Table 21: Overall market size 2015/16 by region

Service by region

Service is the most promising product sector. The figure below illustrates the position of different regional markets in terms of size and growth.

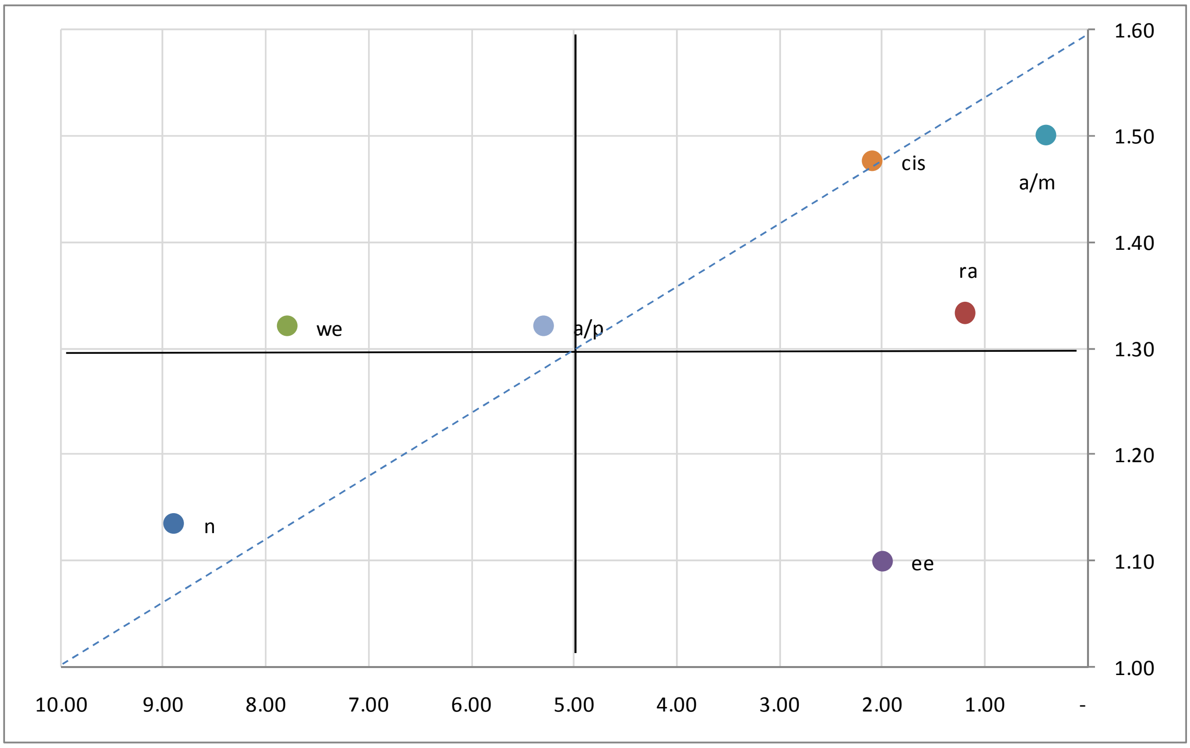

Figure 51: Size and growth rate of world-wide service market by region

As shown, above, Western Europe (we) appears to be the most promising market and Eastern Europe (ee) the least. The table below presents the overall market size by region. A ranking order is provided indicating the preference between the markets.

Service	Market size (€bn, 2015/16)	Market type	Ranking / preference / comment
NAFTA (n)	10	Mature	2
Rest of America (ra)	2	Emerging	Poor
Western Europe (we)	10	Star	1
Eastern Europe (ee)	2	Least hopeful	Last
Africa / Middle East (a/m)	1	Emerging	3
CIS	3	Emerging	2
Asia / Pacific (a/p)	7	Borderline	2

Table 22: Ranking of worldwide service market by region

It is worth noting some of the sub-sectors of the service sector. In Western Europe, rolling stock services on heavy rail is a large and relatively fast growing sub-sector, growing to €8.2bn in 2015/16 representing an annual growth of 4.5%. In terms of heavy rail infrastructure services, Asia / Pacific and Rest of America are fast growing, at 2.6% per annum. However, the accessible markets here are small, at less than €1.5bn combined. On light rail and metro, rolling stock service is the fastest growing in Africa / Middle East, at 17% per annum, followed by the Rest of America, at 12%. Again, the sizes of these markets are very small.

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Rail control, by region

In contrast to rail equipment, rail control is a small market but is fast growing. The figure below shows that the fastest growing of all regions is NAFTA (n). Western Europe (we) appears to be a promising mature market with large size but slow growth.

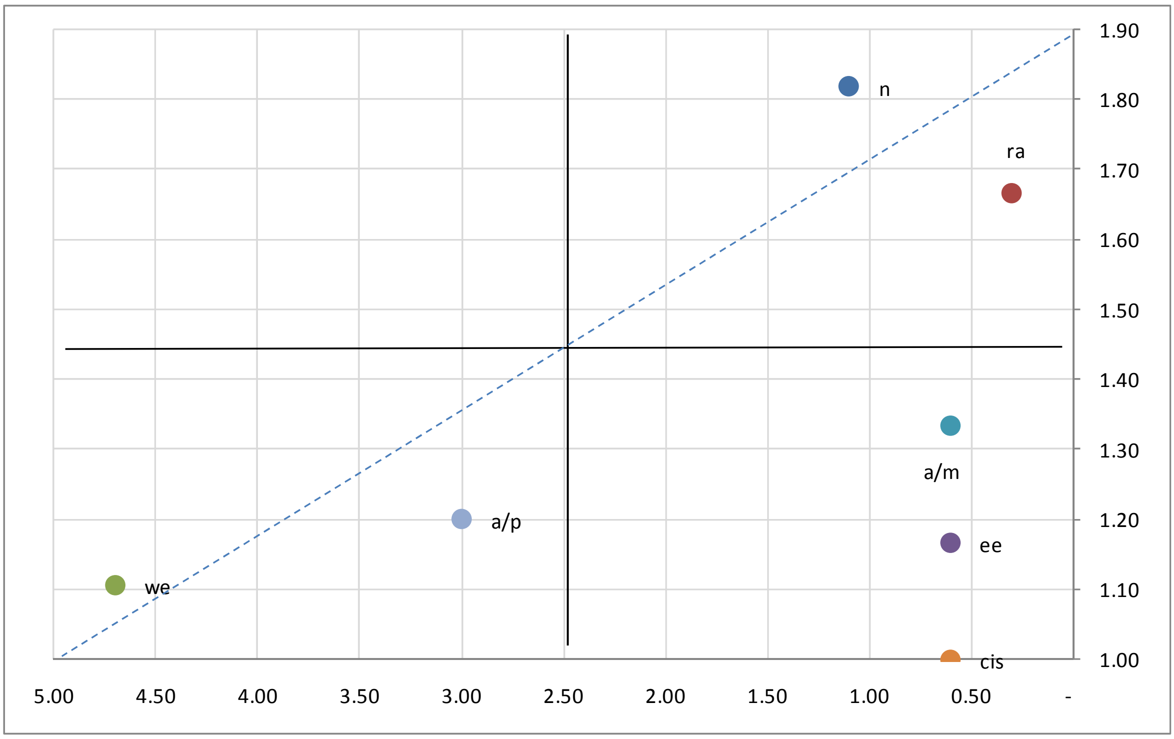

Figure 52: Size and growth rate of world-wide rail control sector by region

The table below presents the overall market size by region. A ranking order is provided indicating the preference between the markets.

Rail control	Market size (€bn, 2015/16)	Market type	Ranking / preference / comment
NAFTA (n)	2	Emerging	1
Rest of America (ra)	1	Emerging	3
Western Europe (we)	5	Mature	2
Eastern Europe (ee)	1	Least hopeful	Poor
Africa / Middle East (a/m)	1	Least hopeful	Poor
CIS	1	Least hopeful	Last
Asia / Pacific (a/p)	4	Mature	3

Table 23: Ranking of worldwide rail control sector by region

In NAFTA, heavy rail is fast growing, with a forecast market size of €1.3bn by 2015/16, with an annual growth rate of 12% from 2007-09. In terms of light rail, the Africa / Middle East and the Rest of America are emerging markets, with a forecast market size of €0.2bn and €0.3bn respective by 2015/16, with an annual growth rate of 5.6% and 5.5%, the fastest among the regions. NAFTA is also a promising market, with a market size of €0.7bn with a growth rate of 3.9%. Overall, the exporting of rail control innovation to NAFTA could be the most promising of all markets.

Rolling stock, by region

Rolling stock is a product sector characterised by medium market size and relatively slow growth. Here, as illustrated in the figure below, Eastern Europe (ee), CIS and Africa / Middle East (a/m) are the clear emerging markets (small size, fast growth), in contrast Asia / Pacific (a/p) and Western Europe (w/e) are large in market size, but slow in growth.

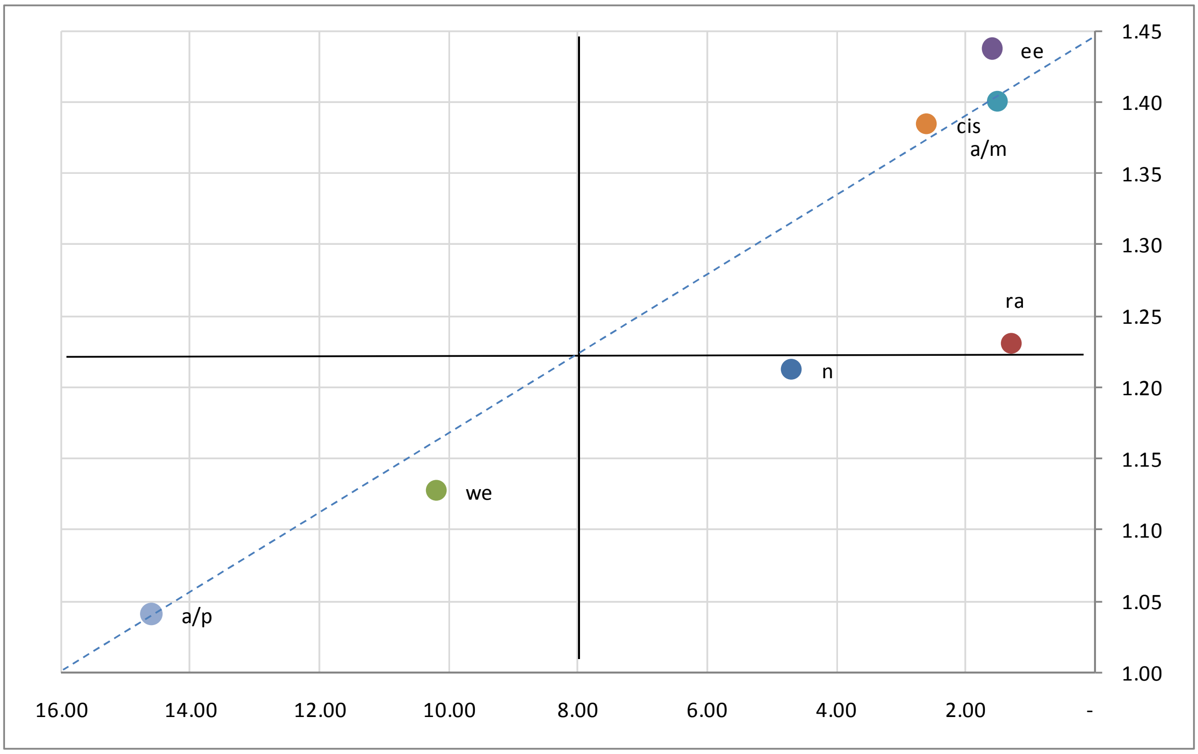

Figure 53: Size and growth rate of world-wide rolling stock market by region

The table below presents the overall market size by region. A ranking order is provided indicating the preference between the markets.

Rolling stock	Market size (€bn, 2015/16)	Market type	Ranking / preference / comment
NAFTA (n)	6	Least hopeful / emerging (borderline)	Poor
Rest of America (ra)	2	Emerging / least hopeful (borderline)	Last
Western Europe (we)	12	Mature	3
Eastern Europe (ee)	2	Emerging	1
Africa / Middle East (a/m)	2	Emerging	2
CIS	4	Emerging	2
Asia / Pacific (a/p)	15	Mature	3

Table 24: Ranking of worldwide rolling stock sector by region

In the emerging market of Eastern Europe, the fastest growing sub-sector is diesel locomotives, growing at 26% per annum. On the whole, Western Europe is a mature and steady market, but its intercity multiple unit sub-sector is particularly fast growing, at 25% per annum. Although NAFTA does not appear to be the strongest market, its regional multiple unit sub-sector is set to grow rapidly, at 38% per annum.

Infrastructure

Although infrastructure appears to be the weakest of the four product sectors, there are some distinct regional variations, as illustrated in the figure below, with the small market Rest of America (ra) growing rapidly whereas Asia / Pacific, a large market, forecast to shrink. Meanwhile, there is no growth estimated for the Eastern Europe (ee) market.

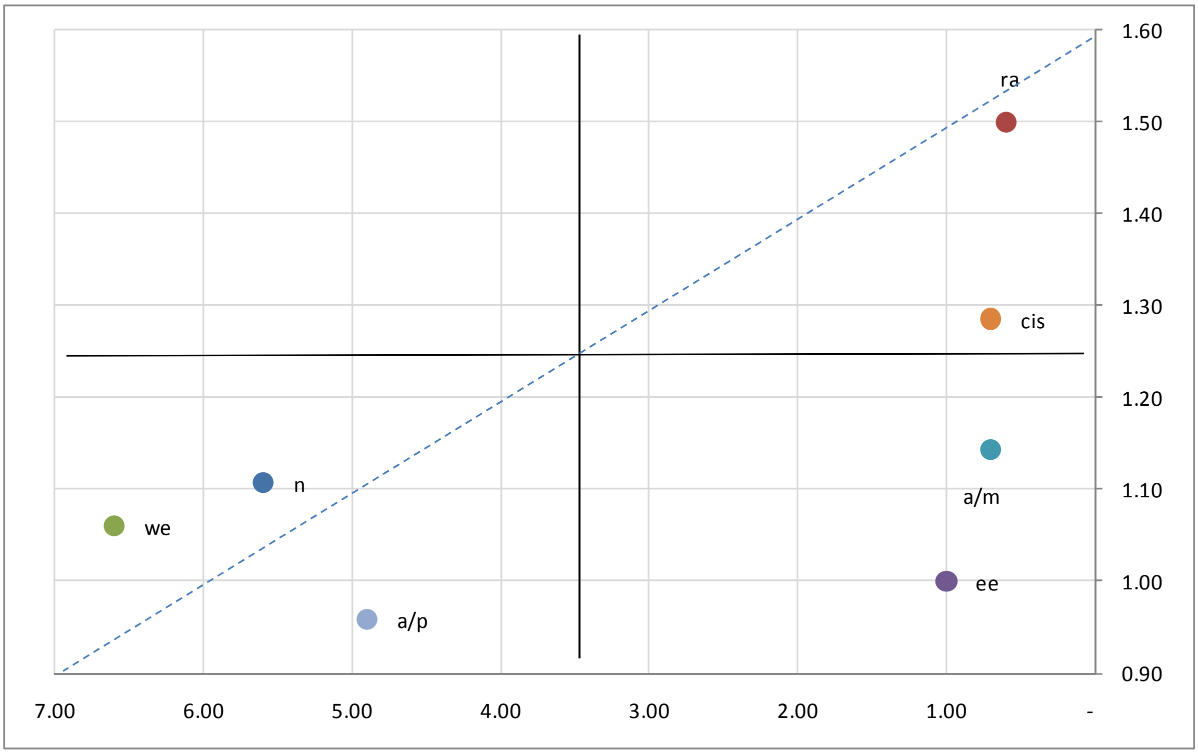

Figure 54: Size and growth rate of world-wide infrastructure market by region

The table below presents the overall market size by region. A ranking order is provided indicating the preference between the markets.

Infrastructure	Market size (€bn, 2015/16)	Market type	Ranking / preference / comment
NAFTA (n)	6	Mature	2
Rest of America (ra)	1	Emerging	3
Western Europe (we)	7	Mature	1
Eastern Europe (ee)	1	Least hopeful	Last
Africa / Middle East (a/m)	1	Least hopeful	Poor
CIS	1	Emerging	Poor
Asia / Pacific (a/p)	5	Mature	Last

Table 25: Ranking of worldwide infrastructure sector by region

The promising markets

Based on the discussions above, the table below presents the markets by market type. The least hopeful and borderline markets are in *italic*.

Region	Service	Rail control	Rolling stock	Infrastructure	Overall
NAFTA (n)	Mature	Emerging	*Least hopeful / emerging*	Mature	**Mature**

			(borderline)		
Rest of America (ra)	Emerging	Emerging	*Emerging / least hopeful (borderline)*	Emerging	**Emerging**
Western Europe (we)	Star	Mature	Mature	Mature	**Mature**
Eastern Europe (ee)	*Least hopeful*	*Least hopeful*	Emerging	*Least hopeful*	***Least hopeful / emerging (borderline)***
Africa / Middle East (a/m)	Emerging	*Least hopeful*	Emerging	*Least hopeful*	**Emerging**
CIS	Emerging	*Least hopeful*	Emerging	Emerging	**Emerging**
Asia / Pacific (a/p)	Borderline	Mature	Mature	Mature	**Mature**
Overall	**Star**	**Emerging**	**Mature / star (borderline)**	***Least hopeful***	

Table 26: Overall assessment of market size and growth by product sector

The table below presents the accessible market size (€ bn) in 2015/16 of the mature markets:

Mature markets	Service	Rail control	Rolling stock	Infrastructure	*Overall*
NAFTA (n)	10			6	***16***
Rest of America (ra)					
Western Europe (we)	10	5	12	7	***34***
Eastern Europe (ee)					
Africa / Middle East (a/m)					
CIS					
Asia / Pacific (a/p)	7	4	15	5	***31***
Overall	***27***	***9***	***27***	***18***	***81***

Table 27: Accessible size of mature markets by product sector

As shown in the table above, Western Europe represents the strongest market by size by 2015/16, with a range of product sectors that are open to suppliers. The table below presents the accessible market size (€ bn) in 2015/16 of the emerging markets:

Mature markets	Service	Rail control	Rolling stock	Infrastructure	*Overall*
NAFTA (n)		2			***2***
Rest of America (ra)	2	1		1	***4***
Western Europe (we)					
Eastern Europe (ee)			2		***2***
Africa / Middle East (a/m)	1		2		***3***
CIS	3		4	1	***8***
Asia / Pacific (a/p)					
Overall	***6***	***3***	***8***	***2***	***19***

Table 28: Accessible size of emerging markets by product sector

As shown in the table above, CIS offers the largest emerging market, with key product sectors in rolling stock and service. The Rest of America is an emerging market for service. Overall:

- Western Europe presents the largest mature market with a 2015/16 value of €34 bn;
- CIS is the largest emerging market with a 2015/16 value of €8 bn.

GB rail's export potential in terms of innovation

The previous sections have established the relative maturity of the different markets by product sector and by region, as well as the sizes of these markets. This section estimates the potential size of the innovation market which GB rail could target. One of the key strengths of the UK is in early stage research, as identified in the Hauser report and stakeholders indicate that rail is no exception to this general rule. There are other leading capabilities in the UK which are already tapped by GB rail, in particular top universities such as Cambridge, Imperial, Loughborough, Sheffield, Southampton and Birmingham.

If one of the key purposes of the RIGT as an innovation enabler is to bridge the gap between early stage innovation (insight and cell) and later stage realisation (standard and niche), then the creation of this organisation should be judged against not only the strengthening of existing UK capability, but also the targeting of world-wide rail markets.

A report by NESTA[29] has previously established that the UK private sector invests approximately 14% of its Gross Value Added in innovation. If a similar proportion represents the value of the rail market in terms of innovation, then the size of the market that could be targeted by GB rail innovation is approximately (2015/16):

- €11bn in mature markets
- €3bn in emerging markets
- The largest mature market (Western Europe) is approximately €5bn
- The largest emerging market (CIS) is €0.2bn

Of course, it is unlikely that, in a competitive environment, all such innovation markets could be captured by GB rail, especially given that other countries such as Germany (operators and control systems), France (high speed rail) and Japan (rolling-stock) have already, in effect, successfully adopted the Hauser principles and indeed the level of industry-level market that is attributable to innovation could differ by product sector and region. Nevertheless, the approximate magnitude of the size of the innovation market, overall, is still likely to be worth approximately **€14bn annually**. Even if GB rail could capture a relatively small proportion of this market, that would still mean substantial earnings to GB rail.

By way of an example, the UK aerospace industry is "one of the most successful sectors… [with] a consistent positive trade balance… [of a] long run average £2,6bn…" The turnover of this industry was £17bn in 2003, capturing 10% of the world aerospace product market[30]. In 2005, 67% of the industry's sales was for export[31]. It should be noted that a large presence in the world market has been supported by substantial investments in research and development, approximately £2bn a year (11% to 13% of annual turnover).

If GB rail could emulate the success of the aerospace industry, then the industry could gain millions of pounds annually of export earnings and inward investment to GB rail, which would certainly justify the existence of the RIGT; any benefit to the home market would then effectively be free. However, the experience of defence systems, energy generation and supply and aerospace manufacturing sectors would tend to indicate that the benefits from implementing innovation enablers are far greater than those measurable by financial means alone.

Further investigation

While the above analysis has established the overall rail market and the potential market for GB rail innovation export, such analysis has been purely from a **demand** point of the view – what the market might want. The extent to which GB rail could fulfil the market demand is a separate question but certainly at this stage it seems clear that a lack of an innovation enabler such as the RIGT is certainly an existing barrier which can be addressed.

[29] NESTA, "The Innovation Index", 2009
[30] UK aerospace industry report to the Trade & Industry Committee of the House of Commons in 2005,
[31] Memorandum submitted by the Society of British Aerospace Companies to the Parliament Select Committee on Treasury, Minutes of Evidence, 2006,

At the next stage of works, it is recommended that the following issues are investigated, to establish the likely extent to which GB rail could take advantage of the world rail market, especially in relation to innovation:

- What are the current advantages of the UK in the world rail market, in which product sector and in which region?
- From what aspects of GB rail might competitive advantage be derived?
- What could, with the introduction of innovation enablers, be improved based on current advantages and hence be adjusted in the matrix? How should the “strategic market” function of the RIGT perform so that world market share could be captured by GB rail?

7 GB Rail Innovation Solution Implementation

7.1 Implementation Plan

As stated in the solution definition section 5.2.6, the innovation management system must enable the effective development and implementation of new platforms as well as embracing supplier-led and lift-and-drop innovation. The **system requirements** of a successful industry innovation management system (which are consistent with and referenced back to the SSM functional requirements described in Table 7 in section 5.2.6 above) should comprise the following:

- **(SSM requirement #A) An understanding of how innovation works:** In other words, the whole GB rail industry should appreciate what innovation means through a common understanding
- **(SSM requirement #B) An appreciation of the scope of innovation:** the boundaries of innovation should be clearly defined relative to the industry, for example:
    - o that there is a supporting vehicle that coordinates UK Rail innovation from platform conception through to platform exploitation.
    - o That innovation value / prioritisation mechanisms / TRL scopes need to be defined.
    - o That roles, responsibilities, beneficiaries and contributors need to be defined.
    - o That decision-making capability needs to be defined to ensure the intended outcomes are met
    - o That the formal range of interfaces (channels) both internal and external to the rail sector need to be defined
- **(SSM requirement #C) An appreciation of the activities involved in running the innovation system:** Rail industry processes for enabling innovation need to be determined. Engagement protocols need to be defined and made visible e.g. commercial terms of engagement and model contracts for enabling and sharing the benefits from platforms
- **(SSM requirement #D) Availability of resources to operate the innovation system:** Resources should be made available to operate the innovation supporting vehicle and each body / platform stakeholder involved with innovation should appreciate and implement their own commitment with, and dedicate their own resources to the innovation system.
- **(SSM requirement #E) Visibility of innovation system operation:** The innovation management system should be seen to be in operation.
- **(SSM requirement #F) Effective monitoring of the performance of the innovation system:** management activities need to be set up. The innovation system should be capable of monitoring the performance impact of the innovation management system to determine if the innovation system is operating against targets, can be seen to be delivering value, is supporting platforms that are effective within the rail sector and is enabling collaborative networking relative to the successful delivery of platforms through their lifecycle.
- **(SSM requirement #G) Measures of 'innovation performance' should be decided:** For example, an appreciation of the value of the TRL benefit through the lifecycle, an intended platform's global market share and hence value per annum, the status of the technical leadership on a global basis, the proportion of the value chain (from research to manufacturing) that can and has been anchored within the UK, or the proportion of dependent research based in the UK.
- **(SSM requirement #H) Improvement and control actions must be made to improve the innovation system if the innovation system is not performing as expected:** A body also needs to be in a position to intervene if the innovation system is not performing against measures or protocols have been ignored.

To understand the innovation management system, additional **dependencies** should be recognised in terms of the GB rail sector playing its part within the wider UK economy:

- **(SSM requirement #I) The GB rail innovation management system should be seen to be delivering benefits to wider UK industries and wider UK economy:** For example:
    - o The value of innovation in helping to bring platforms to market that have a direct or indirect impact on industry cost and performance efficiencies

- The value of additional employment in supporting regional and UK-wide industries and sectors
- The value of exporting platforms to other regional or global economies

- **(SSM requirement #J) The value of these benefits should have measures of performance effectiveness:**. For example, the value of the proportion of GB rail industry exports relative to other UK sector exports (proportion of UK GDP) and the proportion of GB rail global market share relative to other UK sector global market share.
- **(SSM requirement #K) These measures need to be monitored:** a body must have the responsibility of monitoring these performance measures.
- **(SSM requirement #L) If the targets are not being met, improvements / control actions need to be made to improve the effectiveness of the GB rail industry:** therefore, a body must be given powers to intervene and change the way in which the industry works.

Given the requirements of the innovation management system, it is important to then compare these requirements with the current rail organisation within the UK. When gaps in capability are identified, these can be turned into projects representing parts of an overall improvement programme.

7.1.1 Tasks required for the innovation management system to function effectively

The tasks required for the innovation management system to reflect understanding of the industry relative to the requirement, describe project scope, define intended project outcomes, describe measures of success or capability and estimate activity duration are shown in the table below. The sequence is not representative of the sequence the actions should be undertaken. In addition, other enabling actions are identified as part of the plan sequencing outlined in the next section:

1.0	**Establish core team and develop detailed programme**
	As an RIGT does not exist, a core team needs to be established and tasked with developing the organisation.
	Activity scope
	Recruit suitably experienced, qualified and knowledgeable staff that are capable of establishing a new organisation to meet the expectations of the industry
	Intended outcome
	A core business development team comprising 6-8 staff
	Measure of success or capability
	Completion of the detailed development plan incorporating scopes of work Approval of the detailed development plan up to stage gate 1
	Estimated task duration
	6 weeks
	SSM check: [#A] resources that appreciate innovation [#D] resources – people to do the work

2.0	**Develop terms of reference and business operation model for RIGT**
	Whilst innovation occurs within a number of industry organisations, innovation needs to be placed into a management system. The current organisations do not manage innovation at a systemic level. We recommend that a supporting vehicle is established; the RIGT. Therefore, the business operating model for the RIGT needs to be defined so that its business can be understood, put into action and its outputs monitored.
	Activity scope
	Establish an emergent team that develops the RIGT business operating model.
	Intended outcome
	Within the context of managing innovation within the UK Rail sector: • Defined business terms of reference • Defined roles of intervention • RIGT Business Management System / Quality Management System
	Measure of success or capability
	An organisation that is accountable for providing the visibility of and enabling the leveraging / gearing of rail innovation in the UK and wider global rail economies, i.e. able to express values of platforms, value to industry, changes in states and so on.
	Estimated task duration
	12 weeks

	SSM check: [#B] scope of work of RIGT [#C] actions to be undertaken as an RIGT business internally

3.0	**Define roles and responsibilities and engagement systems / stakeholder engagement**
	The new organisation needs to define and establish roles, responsibilities, channels and protocols.
	Activity scope
	Establish the RIGT business model as regards roles, responsibilities, channels and protocols.
	Intended outcome
	Within the context of managing innovation within the UK Rail sector: • Defined interface with Department for Business, Innovation and Skills • Defined interface with DfT • Defined roles of responsibility • Defined interfaces with the Systems Authority • Defined interfaces with the Technology Strategy Board • Defined interfaces with the Technology Innovation Centres • Defined interfaces with research in the rail sector • Defined interfaces / channels with the UK plc value chain
	Measure of success or capability
	A business model that represents an organisation that is accountable for providing the visibility of and enabling the leveraging / gearing of rail innovation in the UK and wider global rail economies, i.e. able to express values of platforms, value to industry, changes in states and so on.
	Estimated task duration
	12 weeks
	SSM check: [#B] scope of work of RIGT [#C] actions to be undertaken as an RIGT business internally

4.0	**Design organisation structure and resources**
	Given the current GB rail organisation, the roles and responsibilities of the existing organisations need to be adjusted / aligned to enable the success of innovation. It is widely recognised that there are a range of barriers in place that constrain innovation. Barriers are seen as industry inaction and lack of clear or inappropriate directives. In order for the innovation management system to work change is required 'outside' or at the organisational interfaces of the RIGT. Ultimately, organisations wishing to engage in the inputs or outputs of innovation will have to continually adapt to enable innovation to succeed. However, in the first instance a baseline must be established so the innovation system can work. For example, model terms of engagement must be established so that innovation stakeholders can support platform development and other modes of innovation.
	Activity scope
	Given the business operating model developed in task 2.0, engagement protocols need to be established between RIGT and stakeholders. For example, model articles would have to be developed that manage relationships between stakeholders, distribution of responsibilities and value tracking.
	Intended outcome
	Innovation stakeholders can commit and are held to account for the development, success, implementation and benefit of innovation, including innovation platforms.
	Measure of success or capability
	Smooth transition of the innovation lifecycle, enabling benefits to be gained in the shortest possible time, effective rail business change to realise benefits.
	Estimated task duration
	12 weeks, but possibly much more subject to testing
	SSM check: [#B] scope of work of RIGT / external organisations [#C] actions to be undertaken by RIGT and other organisations to allow RIGT interfacing

4.1	**Define budget**
	An operational RIGT needs to be sustainable; therefore, a budget needs to be defined through the lifecycle of the organisation.
	Activity scope

	Develop RIGT implementation budget from 1-5 years, incorporating return on investment based upon 1-5 year objectives.
	Intended outcome
	Visibility of scope of financial investment in relation to return on investment.
	Measure of success or capability
	Workable and operational budget for RIGT.
	Estimated task duration
	9 weeks
	SSM check: [#D] resources – funding [#F] measures of performance

4.2	**Transfer / recruit resources**
	The RIGT will need personnel to operate the organisation, to produce the intended outcomes of the organisation.
	Activity scope
	Recruit suitably experienced and qualified personnel.
	Intended outcome
	Suitably experienced and qualified personnel working for RIGT.
	Measure of success or capability
	The RIGT is capable of working within the terms of reference.
	Estimated task duration
	14 weeks
	SSM check: [#D] resources – personnel

5.0	**Development and publication of the GB rail innovation management system**
	There are a wide range of terms, tools and techniques available for managing and understanding innovation. Innovation is carried out in different ways in different organisations. Whilst it is recognised there is no single best methodology and that each methodology has advantages and limitations, the industry also needs to understand how innovation is managed at industry level. The GB rail sector should ideally adopt a common system or approach to interpreting innovation through its lifecycle. This way, metrics and value systems at rail sector level can be developed and applied. This will enable a common understanding of how innovation is applied at industry level and will help stakeholders understand how their own innovation systems interface with the UK-wide rail innovation system.
	Activity scope
	To develop the processes, standard terms, tools and techniques that manage the innovation lifecycle and to publish the rules of engagement. Made available to all suppliers and platform stakeholders wishing to engage in the GB rail sector, for example via the development of a 'GB Rail Innovation Handbook' or collaborative web portal, following the example of the _CONNECT platform used by the TSB.
	Intended outcome
	The innovation lifecycle (incorporating platforms) will be defined, roles and responsibilities and interfaces of the innovation management system will be defined. For example, TRL maturity levels, stakeholder types, types of technology etc.
	Measure of success or capability
	Any party wanting to explore / develop / exploit the GB rail sector will be able to understand the route to enabling the development of products / services that enable platform success, via the handbook or web portal which provides visibility of how interfaces work, how benefits are measured, research / suppliers can engage with industry effectively.
	Estimated task duration
	14 weeks
	SSM check: [#D] instructions

6.0	**Launch and operate the RIGT**
	The industry needs to be aware at what time and at what state the RIGT vehicle will be functional. In this case this does not necessarily need to be fully functional covering every aspect of innovation and could only refer to aspects of innovation that are most appropriate to apply first. A decision should be made as to which specific components of innovation management have end-to-end continuity such that the RIGT establishes a 'critical mass' at launch i.e. RIGT is in itself a platform. The TSB is in an excellent position to provide best

	practice and indeed resource in terms of both systems and process to administer innovation platform development and the management of funding, via SBRI and open platform development competitions, particularly the more risky ones which the industry will find more challenging and is indeed keen to support this activity.
	Activity scope
	Define the most appropriate launching scope/prioritisation aspects of RIGT and launch using the most appropriate method. Operate RIGT as defined in the business operations model.
	Intended outcome
	RIGT exists and is operable as an entity.
	Measure of success or capability
	RIGT is operable, within the terms of the launch criteria.
	Estimated task duration
	4 weeks (launch programme e.g. road show)
	SSM check: [#A-E]

7.0	**Establish monitoring activity of RIGT**
	The RIGT's performance must be monitored within the rail sector to ensure the performance of the RIGT is meeting industry expectations. It is envisaged that a range of organisations would have an interest in RIGT monitoring activity within the sector, including: • Department for Transport, in the context of monitoring the effective application of the GB Rail Innovation Investment Fund (GBRIIF) • The Systems Authority, in the context of understanding the value and progress of innovation activities relative to platform delivery • The Transport KTN, in the context of understanding the activity of the sector in terms of collaborative innovation and knowledge generation • The ORR in the context of understanding the value of the platforms so that innovation platforms can be accommodated through regulatory / organisational adjustment
	Activity scope
	Establish terms of reference and reporting channels, determine roles and responsibilities within each respective monitoring organisation. Implement the continuous reporting activity.
	Intended outcome
	• The DfT can understand the effectiveness and application of the GBRIIF. • The Systems Authority can understand the progress being made in innovation relative to sponsored activities. • The ORR have visibility of platform status and impact in order to plan or influence regulatory / organisational adjustment
	Measure of success or capability
	Visibility of RIGT performance.
	Estimated task duration
	8 weeks
	SSM check: [#G] monitoring activity

8.0	**Establishing measures of innovation performance of RIGT**
	Considering the management of innovation is not integrated at present, with the exception of a few cases, there is no evidence to suggest that there is a current coordinated approach to applying and optimising innovation as a management system. RIGT will therefore be responsible for managing the innovation management system. Consequently, the operation and outputs of the RIGT must be seen to provide value to the rest of the industry. A range of key performance indicators need to be developed that articulate the RIGT performance value.
	Activity scope
	To develop a range of KPIs that the RIGT will be measured against. For example; • Visibility of an accurate innovation road map and TRL status so that the UK research and supply chain can readily engage with innovation • Credit assigned to enabling opportunities i.e. business development and influence this has on market share • Return on research investment relative to TRL status and TRL value
	Intended outcome
	Key performance indicators for RIGT performance.
	Measure of success or capability
	Visibility of RIGT performance and return on investment of the GBRIIF.

	Estimated task duration
	12 weeks
	SSM check: [#F] measures of performance

9.0	**Implementation of authority to intervene with the operation and organisation of RIGT**
	In the event that the RIGT is underperforming or there is an opportunity to improve the way in which the RIGT operates, a governing body should be able to intervene to improve/change RIGT operations. In this context it is thought that the Systems Authority / ORR / DfT would represent the primary stakeholders or governing body and therefore a process needs to be developed that will allow these parties to intervene in the operation of RIGT.
	Activity scope
	Develop a management process that enables the primary stakeholders i.e. the Systems Authority / ORR / DfT to change the way in which the RIGT operates.
	Intended outcome
	The ability to change the way in which RIGT operates.
	Measure of success or capability
	Effective and efficient changes can be made to RIGT operation.
	Estimated task duration
	4 weeks
	SSM check: [#H] take control action

10.0	**Development of GB rail economic values relative to RIGT measures of performance**
	An appreciation needs to be gained of the performance of the sector compared with other sectors, not only within the UK but on a global basis.
	Activity scope
	To determine a UK sector performance league within the global economy.
	Intended outcome
	The performance of the sector(s) is appreciated so UK aspirations can be managed.
	Measure of success or capability
	An clear understanding UK sector global performance.
	Estimated task duration
	27 weeks
	SSM check: [#I] appreciating aspirations for the rail innovation management system compared with innovation in other sectors within the global economy

11.0	**Development of GB rail economic values relative to RIGT contribution**
	Industry is appreciated on a sector basis (high level function/system basis) i.e. Rail, Aerospace, Automotive etc. In this case, industry sector is represented as its contribution to overall UK GDP. Therefore, in the wider context, an appreciation is needed of the value the RIGT contributes to the sector as a whole. When this is established comparisons can be made of the effectiveness of RIGT in the GB rail sector against other innovation growth teams, for example, the Automotive Innovation Growth Team or Aerospace Innovation Growth Team. Given this visibility, meaningful and purposeful comparisons can be made across innovation growth teams enabling improved decision making. i.e. increase / decrease funding, making step changes etc
	Activity scope
	Determine a range of KPIs that measure the performance effectiveness of innovation growth teams.
	Intended outcome
	An understanding of innovation growth teams effectiveness per sector .
	Measure of success or capability
	A meaningful ‘innovation growth team performance league’ on a sector basis.
	Estimated task duration
	27 weeks
	SSM check: [#J] defining measures of performance effectiveness

12.0	**The measurement of GB rail economic values relative to RIGT measures of performance**
	The RIGT’s performance should be monitored in the wider context and compared with other sectors. It is envisaged that a range of organisations would have an interest in RIGT monitoring activity:

	• Department for Transport, in the context of monitoring the effective application of the GB Rail Innovation Investment Fund • The Technology Strategy Board, in the context of understanding and supporting the application of technology and innovation across sectors • The Department for Business, Innovation and Skills, in the context of understanding and exploiting business growth
	Activity scope
	Develop a range of processes that the DfT / TSB / Department for Business, Innovation and Skills operate to monitor the innovation sector performance effectiveness.
	Intended outcome
	The DfT / TSB / Department for Business, Innovation and Skills are able monitor the effectiveness of industry sector innovation.
	Measure of success or capability
	KPI production.
	Estimated task duration
	27 weeks
	SSM check: [#K] monitoring tasks #A-H

13.0	**Intervention of the organisation of the UK sector (not shown on the plan)**
	This activity already exists i.e. the DfT has intervened with the railway management system. It is assumed that this intervention is part of an external management system that may incorporate other wider external influences. However, the DfT may consider the responsiveness in which it reacts to intervening activities.
	Activity scope
	Not applicable; part of an external system that already exists.
	Intended outcome
	Not applicable, part of an external system that already exists.
	Measure of success or capability
	Meeting aspirations of the government for value for money of the railway system and the travelling public.
	Estimated task duration
	Not applicable
	SSM check [#L] take control action

Table 29: Tasks required for the innovation management system to function effectively

7.1.2 Outline programme and milestones for the implementation of the innovation management system

We would envisage the overall programme for setting up the RIGT from start-up to launch to be 11 months. We would suggest the following stage gates for the programme:

Stage gate	**1**
Description	Core team and initial terms of reference
Intended outcome	Setting up the core start up team and establishing basic business operations
Stage gate	**2**
Description	RIGT Build
Intended outcome	• Mature terms of reference and operational model • Roles and responsibilities defined • Organisational structure defined • Budget, resources, instructions agreed developed and in preparedness • Measures of performance established • Monitoring activity established
Stage gate	**3**
Description	RIGT Launch
Intended outcome	• Operational RIGT • Return on strategic benefits
Stage gate	**4**

Description	RIGT evaluation
Intended outcome	• Understanding of RIGT's performance and the impact 12 months operation has on the management of innovation in the rail sector

Table 30: Proposed stage gates for implementing innovation management system

The scope of work for the development of the innovation management system managed by RIGT could be extensive. Nonetheless, this work needs to be prioritised in order to be objective and, to optimise return on investment, the project must develop the most relevant parts of the business first in relation to a viable portfolio and only focus on workable outcomes in the short, medium and longer term. The development of a workable portfolio should be defined and refined between stage gates 1-2 prior to launch. Developing this foresight will require wide consultation and strategic thinking.

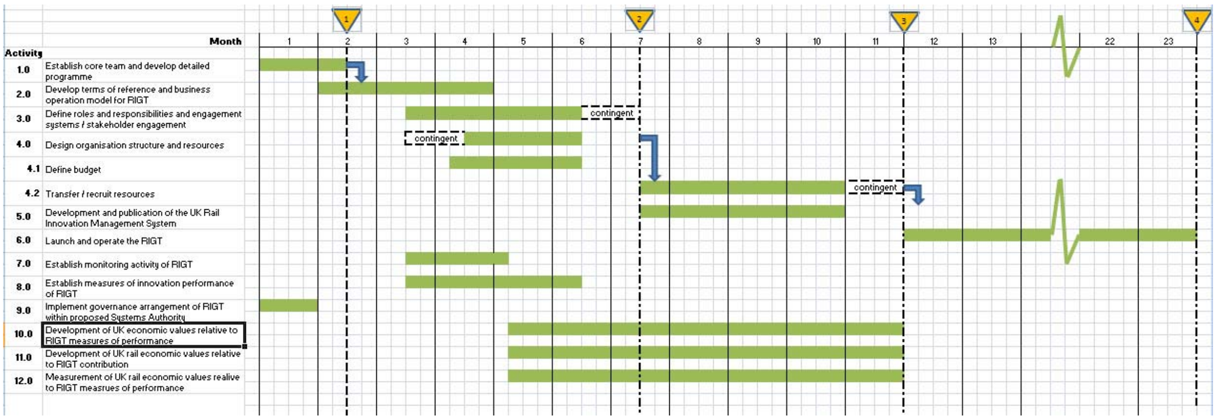

Figure 55: Indicative sequential programme for developing the industry innovation management system – a full sized version can be seen in Appendix D

7.2 Funding

In order to build a realistic funding strategy based on the financial analysis conducted in section 7.4 there are two high level questions to be answered:

- How much funding should be invested?
- Who should fund this investment?

The question of how much funding is required would be answered based on comparator study from other countries' railways and other industries, with those that are advanced innovators setting a benchmark for the GB rail industry.

The level of funding would be subject to a view on affordability. This would be established based on our preliminary, informal and non-committal interviews with industry partners and using our own knowledge of the industry.

The question of who should fund on a year-on-year basis is complex. At one extreme, all parties can be asked to contribute the same fee level; the agenda for pursuing what innovations will then be determined on a periodic basis. At another extreme, a minimal fee is charged to each party to cover the day-to-day overhead costs, while funding for innovations is determined at a project-by-project basis, with those who are likely to benefit the most from certain innovations contributing the most to their developments. There are pros and cons with all options.

A number of plausible funding arrangements can be established to recommend option(s) that forms a robust argument based on our analysis and review of best practice in other railways and industries. This recommendation incorporates our informal and non-committal discussions with industry partners and stakeholders.

The key funding questions are **how much funding should be invested** and **who should fund this investment**. In answering the two questions, clarity is required over the items of funding and the two questions need to be answered with regard to set-up costs, operating costs and project costs.

Amount of funding

It is important to distinguish the three elements of the costs associated with the establishment of an industry innovation management system, especially that set-up and operating costs need be distinguished from project costs. Set-up and operating costs, by themselves, do not generate real benefits to the industry, whereas project costs are directly associated with the benefits that could be realised through the projects. Overall, the general thrust is that:

- Set-up and operating costs should be controlled and minimised, so long as such minimisation is not to the detriment of project delivery
- Project costs should also be controlled, but it is important to recognise that the existence of the innovation enablers is justified by the benefits that these costly projects generate and therefore should not be treated using the same perspective as set-up and operating costs.

Set-up cost

The ADL report provided an estimate that the set-up cost of an organisation responsible for safety, standards and innovation could cost between £5 million to £10 million. The cost of the innovation element of this organisation is not separately identified. Nevertheless, it is reasonable to assume that the innovation element would constitute only a proportion of the cost estimates. A third of the costs are assumed to be associated with the innovation element:

- Set-up cost high estimate: £3.3 million (33% of £10 million);
- Set-up cost low estimate: £1.7 million (33% of £5 million).

Operating cost

The ADL report suggests that the Systems Authority is likely to cost between £30 million to £45 million per year in total to run, based on a per full-time equivalent staff cost of £128,000 using RSSB data (£32 million a year, 250 staff) and savings from NR and RSSB on standards governance and management. In effect, the ADL report suggests that the staffing level of the Systems Authority would be between 234 and 352 full-time equivalent staff.

If the 33% split of the innovation role is used, as per set-up cost, then the year-on-year cost of the would be between £9.9 million and £14.85 million, with staffing levels of between 77 and 116. This level of staffing may be too high in view of the RIGT structure proposed in section 6.1.

The RIGT executive function is to be predominantly provided by three public sector organisations – DfT, ORR and TSB. A core team from these three organisations is required to operate this function. Other organisations, such as NR and ATOC, are not necessarily envisaged as providing the executive function but fulfilling a supporting role. Time and resource requirement from such supporting organisations are unlikely to be high, when support is required on a more ad hoc basis.

The tables below provides two levels of staffing, high and low cases, with staff predominantly coming from the core members of the executive, i.e. from DfT, ORR and TSB.

High	Number	Salary (2010 prices)	National Insurance	Pensions	% of staff time spent working in RIGT	SUM
Senior staff	15	£80,000	10%	12%	50%	£732,000
Technical staff	30	£40,000	10%	12%	50%	£732,000
Support staff	5	£30,000	10%	12%	50%	£91,500

SUM	50				Full time equivalent staff: 25	£1,555,500

Table 31: High level staffing costs breakdown

Low	Number	Salary (2010 prices)	National Insurance	Pensions	% of staff time spent working in RIGT	SUM
Senior staff	3	£80,000	10%	12%	100%	£292,800
Technical staff	6	£40,000	10%	12%	100%	£292,800
Support staff	1	£30,000	10%	12%	100%	£36,600
SUM	10				Full time equivalent staff: 10	£622,200

Table 32: Low level staffing costs breakdown

The above cost estimates are based on staff cost only. The operation of an organisation often requires additional expenditure. Of course, if non-staff costs constitute a large proportion of the overall operating cost, then the operating cost will be significantly larger than the staff cost.

The Fraunhofer Institutes of Germany spends 35% of its operating cost on staff salaries, 29% on rent and lease, 8% on maintenance, 3% on investments (capital). If rent and lease, maintenance and investments are excluded, items which the RIGT will seek to minimise or even avoid, then staff cost of the Fraunhofer Institutes constitute approximately 60% of overall operating expenditure (non-staff cost constituting 40%[32]).

It should be noted that the Fraunhofer Institutes is a very large organisation and is properly compared to the proposed network of TICs, whereas the RIGT is envisaged to be significantly smaller in organisational size and hence should be able to avoid most of the non-staff cost often associated with large organisations. For example, if the Systems Authority is in place, taking on the safety and standards role, then most of the innovation enablers can be accommodated with the SA (subject to the arguments made in section 6.1.3) instead of being housed separately elsewhere. Indeed, it is possible to explore remote working and "virtual" teams, making the full use of the advances in office technologies in recent times, and hence further reducing the need for spending on non-staff cost items. The table below uses the high and low staff cost estimates previously discussed, and presents the overall operating cost assuming different levels of non-staff cost.

		Likelihood of the level of non-staff costs	High	Low
Staff cost			£1,555,500	£622,200
Operating cost	If no non-staff cost / non-staff cost is negligible	**Possible**, given the small size of the organisation	£1,555,500 and not much more	£622,200 and not much more
	If non-staff cost constitutes 25% of the overall cost	**Likely** to be no more than 25% of the overall operating cost	Not more than £2,074,000	Not more than £829,600
	If non-staff cost constitutes 50% of the overall cost	**Unlikely** to be more than 50%	£3,111,000	£1,244,400

Table 33: Overall operating cost estimates

Although most organisations have some non-staff costs, the small organisation implied by the innovation enablers should have very low non-staff costs, if not negligible then perhaps no more (or not much more) than 25% of the overall operating cost. This means that the annual operating cost is

[32] Achievement and Results, Annual Report, 2009, Fraunhofer ISIT

likely to be in the region of just over £2 million in the high case and just under £830,000 in the low case. Sensitivity tests are undertaken in the section on financial analysis (where quantified benefits and costs are brought together), to assess the effect on the value-for-money case if the non-staff cost rises to 50% of the overall operating cost.

It is useful, at this point, to compare the above operating cost levels to equivalent functions of the RSSB as discussed in the ADL report. The table below shows that the proposed operating cost levels of the innovation enablers are smaller than RSSB per-staff cost.

Innovation enablers operating cost scenario	High 25 FTE	High % vs RSSB	Low 10 FTE	Low % vs RSSB
If no non-staff cost / non-staff cost is negligible	£62,200 per staff	49%	£62,200 per staff	49%
If non-staff cost constitutes 25% of the overall cost	£82,960 per staff	65%	£82,960 per staff	65%
If non-staff cost constitutes 50% of the overall cost	£124,440 per staff	97%	£124,440 per staff	97%

Table 34: Cost comparison for innovation enabler operating cost scenarios

As shown in the table above, on a per full-time equivalent staff basis, as proposed, the innovation enablers are likely be cheaper to run than equivalent functions of the RSSB. This is primarily based on the assumption that innovation enabler non-staff cost will be small, especially if such cost is to be kept at no more than 25% of the overall annual operating cost. This may be reasonable, given the innovation enablers are much smaller than the equivalent functions of the RSSB and hence should be able to reduce and avoid some of the cost items associated with large organisations.

Project investment

The level of spending on projects in the future, managed by the RIGT / GBRIIF, is a function of:

- What the projects are;
- How much they require;
- If they are accepted and should be progressed forward; and
- If they can be managed by the staff at the RIGT / GBRIIF.

The first three questions cannot be answered from the outset, as they are project case-dependent. The last question can be discussed by reviewing the relationship between staff capacity in conjunction with operating expenditure, and the scales of projects managed.

In 2008/09, according to its annual report and accounts, TSB's staff cost was £7.29 million. It had 84 employees, 55 of whom were permanent staff. In its annual review, TSB announced that between 2008 and 2011, it is seeking to channel £2 billion of investment in programmes, from both public and private sectors. On an annual basis, this means that every pound spent on staff helps to manage £91 worth of programme.

It should be noted that this 91:1 ratio of project manageable against staff cost reflects that TSB is not in itself a "hands-on" institution, but provide an overall management and co-ordination role. The actual work on technical projects is undertaken by other organisations. For the more "hands-on" organisations, their ratio of project managed against staff cost is much smaller. For example, according to its 2009 annual report, the Fraunhofer Institutes work on an annual research budget of approximately €1.6 billion, with €697 million spent on personnel expense, providing a ratio of 2.30:1.
Overall, the innovation enablers proposed under the structure of RIGT are far more similar to TSB than the Fraunhofer Institutes, in that this organisation will not take on a "hands-on" role but to manage and co-ordinate activities in GB rail, providing the system-level function, rather than detailed technical inputs to the projects it manages.

Given the 91:1 ratio of project scale manageable by TSB against its staff cost and given that TSB will form one of three members of the RIGT executive, it is reasonable to assume that this executive will be able to manage a similar scale of projects given its staff capacity (i.e. as reflected by its staff cost). A rounded 90 : 1 ratio is used in the financial analysis as the central case, with sensitivity test of 50 : 1.

Given the level of operating cost discussed previously, a high case of £2 million and a low case of £0.8 million (with staff costing being £1.56 million in the high case and £0.62 million in the low case), using a multiplier of 90 on the staff costs, the innovation enablers should be capable of managing project spends of approximately £140 million in the high case and £56 million in the low case, increasing in line with real operating cost rises. In effect, under this set-up, each full-time equivalent senior staff is set out to manage approximately £18 million worth of project per annum. On a per-staff level, considering all full-time equivalents, £5.6 million worth of project will need to be managed a year. It should be noted that by "manage" it is not meant detailed and "hands-on", but providing a system-level input.

Summary inputs for testing in financial analysis

This section describes the estimates of the following:

- Potential set-up costs of innovation enablers, high and low cases, drawing on recommendations from the ADL report and using an on-cost methodology based on operating cost estimates
- Potential operating cost estimates, high and low cases, based on estimates of staff and non-staff costs
- Potential magnitude of aggregate project size, high and low cases, manageable given the operating capacities (i.e. operating cost).

The above estimates are summarised in the table below, which are used in the financial analysis, in combination with the quantification of benefits discussed under Section 6.2 of this report.

Cost estimates	**High (£million, 2010 prices)**	**Low (£million, 2010 prices)**
Based on 33% of ADL estimates of all-encompassing organisation	3.30	1.65
Annual operating cost (assuming 25% of it being non-staff cost), increasing at 1% per annum in real terms	2.07	0.83
Annual project cost (size) that could be managed, increasing at 1% per annum in real terms	140.00	56.00

Table 35: Summary of the cost estimates

Sources of funding

When discussing funding arrangements, it is necessary to clarify who should fund what aspect of the innovation enablers, i.e. who should provide the funding to cover set-up costs, operating costs and project-level investment.

Set-up cost

The Hauser report notes that core funding from the public sector appears to be most in need at start-up for infrastructure and capacity building, and on-going support is required from the public sector to provide functions in strategic research of medium to long-term duration, competence development, and the acquisition and maintenance of large-scale facilities and specialist equipment. The setting up of the innovation enablers fits with the Hauser report's comment on the need for public sector funding. As an example, in the UK, the Technology and Strategy Board was set up by the Government. Given the assumption that the Government is planning on setting up the Systems Authority, with a remit at least covering safety and standards, it is timely to set up the innovation enablers concurrently, so that some of the costs of the set-up can be shared between the two initiatives and the overall costs minimised.

Based on the Hauser report, the successful set-up of the Technology and Strategy Board and the planned set-up of the Systems Authority, **it is recommended that the Government fund the set-up cost of the innovation enablers**.

Operating cost

In chapter 6 of this report, it has already been discussed that the innovation enablers should be structured involving the organisations in the table below, to form the RIGT.

Organisation	Strategic market function	RIIF (investment function)	Stakeholder management function	Technical leadership function	RIGT Executive / board
ORR					Direct membership
DfT		Direct membership	Direct membership		Via stakeholder management function and GBRIIF
NR			Direct membership		*Via stakeholder management function*
ATOC			Direct membership		
RSSB			Direct membership		
RIA			Direct membership		
RFOA			Direct membership		
TSB	Direct membership	Direct membership		Via TICs	Via strategic market function, and GBRIIF
Research Councils		Via TSB			
Universities		Via Research Councils			
TICs				Direct membership	Via technical leadership function
TSLG				Direct membership	
Test facilities				Direct membership	

Table 36: Industry organisations mapped to innovation enabling functions

Overall, the key organisations forming the executive of the RIGT are ORR, DfT and TSB. Other organisations' contributions towards the executive are less direct, via one of the functions of the executive. ORR, DfT and TSB are all public sector bodies funded by the Government. Therefore, the innovation enablers could be entirely funded by the Government in terms of covering its day-to-day operational costs, in a similar way to TSB being funded primarily by the Department for Business, Innovation and Skills (BIS).

Although public sector funding is likely to be important, it is not necessarily the case that all on-going funding has to come from the public sector. The Advanced Manufacturing Research Centre was originally set up primarily funded by the central government with supplement contribution from Yorkshire Forward, the University of Sheffield, European Regional Development Funding and Boeing. It now has a large number of private sector partners, including Rolls-Royce and BAE Systems, who pay annual membership fees as well as contracting research.

While in principle on-going funding could be secured from the private sector, this principle needs to be sense-checked. Given that the state is likely to have significant involvement in GB rail, the industry is likely to be heavily influenced by the government and hence public sector presence is likely to be dominant, even though there are some moves by the Coalition Government to hand greater roles to the private sector. Therefore, public funding for the operating cost of the innovation enablers should reflect the public sector's role in GB rail.

On an organisational level, in the RIGT, ATOC, RFOA, and RIA (and, to some extent, NR) represent the private sector. Some funding could be sought from them (or from the TOCs and FOCs and manufacturers via them). However, given that most of the functions are to be performed by the public sector, it may be more practicable for the public sector to cover the operating costs, as it is in the case of the TSB which is funded by the Department for Business, Innovation and Skills (BIS). A small level of subscription fee could be charged to the industry via NR, ATOC, RFOA and RIA.

Based on the level of involvement and the successful example of existing organisations such as TSB, **it is recommended that the Government fund the operating cost of the innovation enablers, with a small subscription fee charged to NR, ATOC, RFOA and RIA.**

Project-level investment

While the initial set-up and the on-going operating costs are recommended to be paid for by the Government, project-level funding should not be entirely paid for by the Government. In the UK, the Advanced Manufacturing Research Centre leverage funding from a range of organisations, through winning competitive calls for research from organisations such as the TSB and the Research Councils, and undertaking research projects commissioned by businesses.

The table below shows that the distribution of funding between the public and private sectors for Technology and Innovation Centres (TICs) – which overlap in some functions with the innovation enablers discussed – varies by country[33]. Although the figures in the table below do not differentiate between spending on projects and operating costs, typically, it is the funding for projects that often constitute the largest component of on-going spending (if the operating cost exceeds project-level investment, then arguably one is spending too much on operations while managing too little in terms of value generation).

Organisation	Govt. / State	Other public sector	Private sector	Licensing and others	*Govt./ State + other public sector*
Fraunhofer Institutes (Germany)	35	23	34	7	*58*
Carnot (France)	59		41		*59*
TNO (Netherlands Organisation for Applied Scientific Research)	33	15	37	15	*48*
GTS (Denmark)	10	10	78		*20*
AIST (Japan)	70	21			*91*
Industrial Research Institutes (Sweden)	7				*7*
ETRI (South Korea)	26		74	0.2	*26*

Table 37: Distribution of funding between public and private sectors for TICs

As shown in the table above, the extent to which funding for TICs is provided by the government, the state and other public sector bodies varies from 20% in Denmark to almost all in Japan. To a certain extent, the differences between funding sources between TICs reflect the focus of these organisations. For example, GTS (Denmark) is mostly focused on supporting Small and Medium Enterprises, over shorter-term projects. In Sweden, only 7% of funding comes from the government / state, with the organisation's focus mostly on short-term projects and services to businesses.

In the UK, as noted in the Hauser report, the gradual withdrawal of public funding from Research Associations played a role in the change of the business models, reducing generic research and

[33] The Current and Future Role of Technology and Innovation Centres in the UK, Dr. Hermann Hauser for the Department for Business Innovation & Skills, 2010

development activities in favour of more routine and commercially lucrative laboratory and technical consultancy services.

If the innovation enablers focus primarily on short-term projects, that could benefit the private sector quickly and directly, then arguably, the private sector should contribute to the cost of these projects, whereas the more “blue-sky” and long term projects would be of lesser interest to the private sector immediately, and hence require greater public funding.

Often, for an immediate gain to be achievable, the “blue-sky” thinking had to be done in the first place. In relation to the IPMS, to achieve the niche stage, the earlier stages of insight, cell, platform and standard have to be achieved first, or delivery risk increases to a potentially unstable level.

As the Hauser report noted, universities and other research-focused institutions are often concentrated on projects of the earlier stages, between Technology Readiness Levels (TRL) 1-4, whereas the industry (private sector) is mostly focused on the later stages, entering at around TRL 6 (with TRL 7 being prototype demonstration in operational environment). Therefore, while the “blue-sky” focusing organisations have their activities tailing off towards TRL 4 and the quicker-gain focused private sector not picking up until gradually after TRL 6, there can be a gap, which means that potentially hugely beneficial ideas are not developed to a stage by which it is “launch-ready”, let alone achieving standard and niche status.

The innovation enablers could bridge the gap discussed above. If the early stages (TRL 1-4) often involve substantial public funding, and the later stages (TRLs 6-9) often involve more private funding, then where the innovation enablers seek to act, between TRLs 3-8 as per Hauser report illustration for TICs, but primarily between TRLs 4-6, then the funding for projects should come from a mixture of public and private sources.

TRL	IPMS	Public involvement	Private involvement
1	Insight	✓✓✓✓✓✓✓✓✓	✓
2	Insight to Cell	✓✓✓✓✓✓✓✓	✓✓
3	Cell	✓✓✓✓✓✓✓	✓✓✓
4	**Cell to Platform**	✓✓✓✓✓✓	✓✓✓✓
5	**Platform**	✓✓✓✓✓	✓✓✓✓✓
6	**Platform to Standard**	✓✓✓✓	✓✓✓✓✓✓
7	**Standard**	✓✓✓	✓✓✓✓✓✓✓
8	Standard to Niche	✓✓	✓✓✓✓✓✓✓✓
9	Niche	✓	✓✓✓✓✓✓✓✓✓

Table 38: Involvement of public and private sectors at various TRL levels

Indeed, the relationship between public and private funding should not be considered as contradictory – it is far from the “either or” relationship. In France, the Carnot Institutes can receive up to €60 million in supplementary funding from the government in proportion to the volume of funding generated through their contract work with the private sector.

In principle, the party that is set to benefit from a project should pay for it. In the rail industry the benefit split between the public and private sectors is not straightforward. This is because there is a huge level of interaction between the public and the private sector organisations. However, it is sufficiently to say that depending on the exact nature of the project, beneficiaries are unlikely to be the same between all projects. Nevertheless, it is likely that both the public and the private sector will benefit from innovation as invested under the innovation enablers given their key role over TRLs 4-6, bridging the potential gap between cell and standard in the IPMS framework. Moreover, project-level investment should be shared between the public and the private sectors on a case-by-case basis. For example, if more “blue-sky” initiatives are to be undertaken, then project-level investment is likely to require greater public funding (as a proportion of the overall funding level), whereas if the innovation enablers are to focus more on “quick-gain” initiatives, then more private funding could potentially be secured. There are a number of ways by which the transaction of funding could take place. For example, the Value-Added Reimbursement Launch Investment (VARLI) process (see section 6.1.2) could be adopted.

Summary

This section discussed the issue of who should fund the innovation enablers, and recommends that:

- The set-up cost should be paid for by the Government, based on the Hauser report, the past experience of setting up the TSB and bearing in mind the cost advantage of being set-up in conjunction with the planned establishment of the Systems Authority, whether or not it becomes part of the Systems Authority.
- The operating cost should be paid for by the Government, given that under the proposal for RIGT the main representatives are to come from ORR, DfT and TSB, although some relatively small amount of funding may be securable from the private sector via ATOC, RFOA and RIA.
- Project-level investment should be shared between the public and private sectors via the GBRIIF. The exact split should be considered on a project-by-project basis. The mechanism for transactions can also be considered on a project-by-project basis, using processes such as the VARLI.

7.3 Financial Analysis

Section 6.2 has established the likely quantified benefits which the innovation enablers could bring, and section 7.2 puts forward a set of cost estimates. This section brings together findings on benefits and costs and provides a high-level discussion on the financial performance.

Using data from past GB rail projects, section 6.2 has established that £280m could be gained as result of introducing innovation enablers. This is the value of the new set-up when assessed using past projects. With a new industry set-up, it is likely that new projects and potentials could be materialised which would otherwise have been put aside under the existing set-up.

The analysis in section 6.2 has also indicated that a well-managed new set-up of the GB rail industry could deliver a return-to-cost ratio of between 3 : 1 and 5 : 1.

Section 7.2 established that between £56m (low case) and £140m (high case) worth of project investment could be managed by the innovation enablers annually. Using the ratios of 3 : 1 and 5 : 1, this means that the level of returns that could be generated is between £168m (low case investment on 3 : 1 ratio) and £700m (high case investment on 5 : 1 ratio) per annum.

The set-up cost, estimated in section 7.2, is between £1.7m (low case) and £3.3m (high case), and the operating cost between £0.83m (low case) and £2.07m (high case) if staff cost constitute 75% of the operating cost. It has already been discussed in section 7.2 that it should be possible to keep the non-staff elements of the operating cost to a minimum given the organisation's small size, the advent of modern office technology, and the nature of it being an executive-led (small core team) but functionally-based (wider team in existing GB rail organisations) collective as per RIGT set-up.

The table below summarises the financial information discussed above:

£ million	Code	High cost set-up		Low cost set-up	
Cost of innovation enablers					
Set-up cost (one-off)	a	£3.3		£1.7	
Operating cost (annual)	b	£2.07 (25 FTE staff)		£0.83 (10 FTE staff)	
Project annual net surplus based on existing GB rail projects					
Net surplus	c	£280			
Project annual net surplus based on benchmarks					
Project investment manageable	d	£140		£56	
Return ratio of	e	5 : 1	3 : 1	5 : 1	3 : 1
Return	f=d*e	£700	£420	£280	£168
Net surplus	g=f-d	£560	£280	£224	£112
Overall annual net surplus					

£ million	Code	High cost set-up		Low cost set-up	
Based on existing GB rail projects	h=c-b	£278		£279	
Based on benchmarks	i=g-b	*£558*	*£278*	*£223*	*£111*

Table 39: Cost-benefit analysis of innovation enablers

As discussed in section 6.2, the innovation enablers should be capable of addressing some of the existing issues facing projects initiated under the existing set-up of GB rail. As shown in the table above, it may be possible that innovation enablers could improve existing types of projects by £280m a year, in the industry as a whole.

Also as discussed in section 6.2, innovation enablers could open up new opportunities as well as addressing issues on existing problems. Clearly, as shown in the table above, if the benchmarked level of project investment could be made and the benchmarked levels of return could be gained through that investment, then hundreds of millions pounds' worth of project-level (excluding operating cost) net surplus could be derived, vastly dwarfing any set-up and operating costs envisaged. The key therefore is to ensure that the innovation enablers are sufficiently resourced and can perform to the designed level in terms of project investment and returns.

In any case, based on past projects or benchmarked performance, through the considerable level of benefits that it could help to generate, the innovation enablers should have little problem in recovering one-off set-up costs and covering annual operating costs.

While the above analysis focuses on the UK domestic rail industry, as suggested in section 6.2.2, there is a sizeable international rail market, which the GB rail industry could seek to capture. The annual innovation market size of mature and emerging markets could be as large as €14bn (by 2015/16) combined across product sectors. As noted in section 6.2.3, the UK aerospace sector captures approximately 10% of the world product market. If GB rail could perform even half as well, capturing 5% of the mature and emerging rail markets in terms of innovation, then the annual export gain could be €0.7bn. It should be noted that the world and the UK markets are not mutually exclusive – the returns on project investment gained in the UK could be repeated abroad at limited additional cost. Whether this €0.7bn export potential could be realised is beyond the scope of this report. The GB rail industry will need to assess in which areas it could be best placed to compete in the world market. Nevertheless, the performance of the GB rail industry could be enhanced by inducing an element of export-led growth.

8 Conclusion and Recommendations

We conclude that the key priority for the industry is the establishment of a **Rail Innovation & Growth Team** (RIGT) to emulate best practice from aerospace manufacturing and automotive and to develop an industry vision for innovation (as opposed to technology) similar to that outlined in the National Aerospace Technology Strategy (NATS).

We also conclude that further detailed study should be considered into the functioning of both aerospace and automotive Innovation and Growth Teams and the defence industry's Niteworks partnership as well as other innovation enablers like the NHS Innovation & Improvement Agency.

The RIGT's technical functions could be sourced from the existing TSLG and RSSB, but this should only form a part of its makeup as it must be able to cover all dimensions of the Innovation System Structure and be cost-effective. Its technical capabilities must also go far beyond core rail technical skill-sets, to cover validation for software controls. The RIGT should be responsible for setting (via output-driven specifications) and managing the response to industry-level innovation challenges and also function as a systems authority to make stage-gate decisions on behalf of the industry concerning collaborative investment funding as well as a referral body for difficult-to-resolve systemic innovation issues down to component level.

However, the rest of the industry needs to continue along the trajectory for improving the fitness for purpose and user-friendliness of standards and the commitment made by Network Rail in this area is critical. The fitness for purpose of standards where innovation is concerned is a two-way street. Standards owners must be open to challenge and those who seek approval for innovation must engage at an early stage with other stakeholders in the approval process and work to resolve issues in a productive, collaborative fashion. Here, the provision of RIGT would function as 'deadlock-breakers'; a critical step to improve the introduction of new products and systems both from the existing UK supplier base and to improve "lift-and-drop" from other railways and other industries. We conclude that further work be undertaken to develop and disseminate best practice guidelines for systemic and systematic innovation decision support for the industry.

The RIGT will fail if it simply adds another layer of bureaucracy or becomes an "industry club". Its effectiveness will flow from its ability to make good systemic decisions. The capability to achieve this needs to be built explicitly within the industry and we note with approval a commitment to a national training academy which could perhaps develop into a platform for the industry to develop innovation skills. We envisage the transformation of the industry's innovation systems from being primarily driven by technical strategy and technology roadmaps (however valuable) to being led by strategic vision and challenges that flow from that vision.

> **A stakeholder view:**
> "The RIGT structure has worked in other industries and I endorse its establishment, provided that this is consistent with other VfM theme recommendations. [With reference to the call] for resourcing via part-time support from the industry: there are too many pulls on people to support these initiatives already, so full time support should be considered. The remit of RIGT needs to be clear, if part of the Systems Authority, to ensure that value is generated, and that it is not just another industry cost."

To that end, we envisage the RIGT being the custodians of a map of output-driven insertion points to drive all three modes of innovation for the industry, from supply chain product evolution through transfer from other industries to system-wide innovation platforms. This should improve visibility of the approaches to these systemic insertion points and encourage early engagement with stakeholders of the sort that is most likely to lead to innovation success. A proper understanding and commitment to innovation in its truest systemic sense is the most likely to enable it to contribute to value for money within GB rail.

The original linkage between innovation and safety and standards still exists and an outstanding issue therefore remains to take regulatory action to de-risk innovation. The industry remains risk-averse and committed to providing world-class safety and if innovation is perceived to increase liability then that will be a hard barrier to overcome. The risk to innovation delivery, by contrast, is relatively straightforward to resolve and it is for this reason that we propose the formation of a **GB Rail**

Innovation Investment Fund (GBRIIF) to provide joint public and private funding to bridge what is known as the “valley of death” between Technology Readiness Levels 4 - 6. We anticipate that the introduction of “Clerk Maxwell Centres”/TICs, in particular one for Transport, would facilitate and provide extra impetus to this drive to institutionalise the delivery of innovation. We consider that the interface between RIGT and the TIC will enable GB rail to bring industry-level strategic clarity about its innovation priorities to the TIC so that the industry will be able to commit to developing and delivering everything from innovative offerings from the supply chain to new industry capability platforms. We would expect the TIC to be an active participant in the agenda and functioning of the GBRIIF.

The most pervasive problem in the industry is the perceived difficulty in finding the skills and capabilities needed to develop systemic innovation and those needed to launch it into the market and to manage it to fruition. We propose that this be addressed through the introduction of a Value-Added Reimbursable Launch Investment (VARLI) model, which is based on the established and fairly successful aerospace models from the EU and US used by Airbus and Boeing.

We note that the stakeholders have reacted to this proposal with some trepidation, citing possible complexity, but we are confident that an industry which has in its time coped with PPP and operator franchises can find a way to make the model work, particularly with the introduction of the RIGT and the GBRIIF. However, we do suggest that more detailed work is carried out to examine VARLI in detail with a view to gaining stakeholder buy-in and learning the lessons from other industries, particularly that of aerospace manufacturing and the ETI. An important piece of subsidiary work will be to develop draft partnership and collaboration agreements which align the profit drivers of the various stakeholders and provide safeguards to prevent undue pressure being brought to bear by the more powerful stakeholders. In this respect, the examples of the TSB’s SBRI programmes will be useful, as will a closer look at the pharmaceutical industry’s experiments in IPR models.

We note the difficulty of building a financial case for the benefits of innovation, given the commercial sensitivities and difficulty of quantifying benefits across the industry, particularly if the distribution of costs and benefits is uneven and system-level data is not measured. Nevertheless, even a conservative view of the benefit-cost ratios achievable to the industry gives cause for optimism if the barriers to innovation can be removed by a change in the industry’s attitude to collaboration and shared value creation. Similarly, individual organisations are able to build convincing and robust business cases within their own span of control, as suppliers, Network Rail and we ourselves can confirm. However, the “domestic” benefits from innovation pale beside the real size of the prize that we believe to be available from the global exploitation of GB rail products, services and above all know-how and which, in some cases, GB rail organisations are already individually active in pursuing.

It has long been the conventional wisdom – not without justification – that railways do not earn money (with the possible exception of India, where industry turnover is said to rival tax receipts). However, the UK is now strongly committed to the dissemination of the “Hauser Principles” by which parts of the industry value stack with the capability to demonstrate world-class capability focus on becoming dominant players in the global market. Our analysis of what we believe to be a €14bn p.a. world market for rail products and services suggests that there is a substantial opportunity to be exploited if UK plc is able to gain market share. The RIGT / GBRIIF should enable the industry to build this growth strategy with a view to building a significant source of cross-subsidy for the domestic market whilst at the same time providing further incentive for the industry to focus on innovation. With this in mind, we recommend that the industry as a whole commit to the Hauser principles as offering the greatest potential to overcome barriers to innovation. Other British industries can demonstrate capabilities that are the best in the world and we believe that the same will be true of GB rail, given the right sort of clarity, focus and leadership.

The full derivation of our recommendations is shown in Table 40 below. This is followed by a full list of our recommendations.

Recommendations

Barrier to Innovation – Identified Problem / Barrier to Innovation
Impact – Clear Understanding / Assessment of Impact of Identified Problem / Barrier on GB rail Industry
Impact Evidence – Evidence to Support Impact Claims; Previous research, current research, case studies, surveys etc
Recommended Solution – How to Overcome Identified Problem / Barrier
Benefit – Anticipated Benefits from Implementing Recommended Solution
Benefit Evidence – Evidence to Support Benefit Claims; Previous research, current research, case studies, surveys etc
Innovation Enabler Role – Anticipated role of Innovation Enabler (Systems Authority) to Implement Recommended Solution

Barrier to Innovation	Impact	Evidence	Recommendation	Benefits	Facts and Case Study	Innovation Enab'er's Role
Lack of coherent leadership of GB rail industry innovation	• Lack of effective capacity to introduce tried-and-tested innovation from other rail industries • Lack of effective ability to assess & adapt technology, processes & insights from adjacent transport sectors & other industries	• ISS / IPMS Survey • Stakeholder input • Hauser report • Comparison with EGS & AM industries	Establishment of Rail Innovation & Growth Team (RIGT)	• Improved capacity to leverage innovation from other [rail] industries	• Aerospace IGT • Automotive IGT • Aerospace, Transport KTNs • Space Technology Transfer programmes	• Technical capability of RIGT is already available via RSSB / TSAG, although non-technical capability is not
Bureaucratic & non-transparent approvals regime	• New technologies & practises difficult to implement • Slow & time-consuming process • Discouragement of investment in innovation by SMEs, large concerns including major consultancies	• ISS / IPMS Survey • TSAG • ADL • Case Studies • Stakeholder input	Dissemination of best practice for approvals	• Efficient approvals process with clarity in strategy & objectives • Early engagement with approvals stakeholders • Encourage research investment & innovation • Enable easier technology transfer from other safety-critical systems	• Other Industries • Cost Benefit Analysis (?)	• Network Rail innovation programme • Ongoing work by NR & TSAG to improve standards quality • Establishment of RIGT, which should enable the definition of appropriate approval strategy, authority and process for innovation to align with industry objectives & strategy
Lack of industry-level leadership, collaboration & investment, poor commercial driver alignment across organisational boundaries, particularly at TRLs 4-6	• Lack of effective capacity to research, investigate, propose & commission the development of industry platforms.	• ISS / IPMS Survey • Stakeholder input • Hauser report • Comparison with EGS & AM industries	Establishment of GB Rail Innovation Investment Fund (GBRIIF)	• Creation of capacity to develop industry & capitalise the commercial competitiveness of GB rail	• AAR/TTCI • ETI • TSB "Intelligent Information Systems" & "Informed Logistics" competitions • EPSRC & SBRI	• Establishment of Rail Innovation & Growth Team (RIGT)

Barrier to Innovation	Impact	Evidence	Recommendation	Benefits	Facts and Case Study	Innovation Enab'er's Role
					programmes	
Ineffective implementation of Hauser Principles to support effective innovation at national level	• Unsustainably low levels of innovation • High public subsidy • Inability to utilise of industry interfaces • Inability to tap into high quality research & spin-offs or converting it into practical utility.	• TSAG • ADL • ISS / IPMS Survey • Stakeholder input	Explicit dissemination of Hauser Principles	• Successful funding strategy for high quality research • Reduce public subsidy by utilising industry interfaces • Sustainable innovation growth • Increased support from UK plc via UKTI	• Experience of Fraunhofer Institutes • Experience of global EGS & AM industries • Experience of US, German & Japanese railways	• Establishment of Rail Innovation & Growth Team (RIGT) & GB Rail Innovation Investment Fund (GBRIIF) • Inclusion of Hauser principles in industry strategy & objectives for sustainable growth • Develop implementation plan to encourage industry collaboration & adoption of Hauser principles.
High capital investment to convert innovation into practical applications (TRL 4-6)	• Discouraging of innovation • High uncertainty in investment returns	• TSAG • ADL • Stakeholder input • ISS / IPMS survey	Regulatory action to derisk innovation liability, matched funding availability from GBRIIF	• Encourage private investment • Reduce public subsidy • Reduce risk & uncertainty	• TSB BCR for transport investment	• Use of ISS / IPMS innovation index approach to assess risk profile & manage innovation liability risk
Inadequate & non-uniform incentivisation plan for innovation growth due to non-alignment of organisational commercial considerations	• Costs & benefits not realised in same context • Compartmentalisation of industry • Reduced collaboration • Inadequate innovation • Short-term perspective • Unconvincing business cases	• TSAG • ADL • TSB • Stakeholder input • ISS / IPMS survey • Case studies	Introduction of business model for VARLI (Value-Added Reimbursable Launch Investment) together with further investigation into optimal system-level IPR models to support it.	• Alignment of commercial incentives • De-risking of investment platform development • Uniform incentivisation mechanism • Longer-term perspective • Improved business cases • New revenue streams	• Airbus • ETI / SBRI Case Study ISS / IPMS survey • Experience of global EGS & AM industries	• Establishment of Rail Innovation & Growth Team (RIGT) & GB Rail Innovation Investment Fund (GBRIIF) • Define and implement an incentivisation plan to stimulate innovation growth • Dissemination of Hauser principles

Barrier to Innovation	Impact	Evidence	Recommendation	Benefits	Facts and Case Study	Innovation Enab'er's Role
No safeguard to ensure profitability through industry partnerships & collaborations	• Centralisation of benefits without clear benefit dissemination • Reduced collaboration • Inadequate innovation • Short-term perspective • Unconvincing business cases	• TSAG • ADL • Stakeholder input • ISS / IPMS survey • Case studies	Develop draft partnership & collaboration agreements which align profit drivers and provide suitable IPR models; safeguards to avoid gaming of system by major players e.g. NR or ToCs	• Improved industry partnerships & collaboration • Uniform incentivisation mechanism • Longer-term perspective • Improved business cases • New revenue streams	• Airbus • ETI / SBRI Case Study • ISS / IPMS survey • Experience of global EGS & AM industries	• Establishment of Rail Innovation & Growth Team (RIGT) & GB Rail Innovation Investment Fund (GBRIIF) • Introduction of VARLI model
No clearly defined role or global growth strategy for GB rail expertise, knowledge, products & services.	• Non-exploitation of international export market • Innovation strategy not aligned with industry objectives • Lack of capability to convert scientific knowledge into commercial innovation of practical utility • High reliance on imports • High public subsidy	• ISS / IPMS Survey • Stakeholder input • Comparison with EGS & AM industries	Explicit commitment of GB rail to the economic benefits of the global opportunity & appropriate alignment of drivers with safeguards to prevent interference with local delivery. May require alteration of NR licence.	• Ongoing commitment to innovation • Reduced asset cost through increased competition & international demand • Increased international market share • Reduced public subsidy through increased private investment • Additional revenue streams	• Experience of Fraunhofer Institutes • Experience of BR Transmark / Halcrow • Experience of global EGS & AM industries	• Establishment of Rail Innovation & Growth Team (RIGT) & GB Rail Innovation Investment Fund (GBRIIF) • Ensure that innovation objectives are aligned with overall industry strategy & objectives • Support from RIA &RFG
Lack of availability, poor implementation & risk management of testing facilities	• Limited or no integrated testing capability • Disruption to 24/7 operating railway • High risk of testing on operating railw • High public subsidy • Limited role in technology innovation	• TSAG • Case Studies (PCW, Pueblo, High Marnham) • ADL Report • Stakeholder input • Atkins research	Steps to be taken to improve provision of testing facilities & industry engagement with TICs	• Improved access to testing facilities • Increased capability to test integrated systems • Opportunity to test novel, state of art systems • Encourage independent testing by manufacturers • Less disruption to existing railway • Improved risk management	• Siemens, Germany • Pueblo, USA • High Marnham, UK • Experience of Fraunhofer Institutes	• Define strategy, role & responsibilities for provision of testing facilities • Define funding strategy and incentivisation programme to encourage collaborative approach • Investigate co-location of testing facilities with other transport modes

Barrier to Innovation	Impact	Evidence	Recommendation	Benefits	Facts and Case Study	Innovation Enab'er's Role
Unclear role for the TSB / KTN role including strategy to support industry innovation objectives	• Ineffective industry strategy • Limited effect of best practice • Inability for industry to to drive change	• TSAG • ADL • Stakeholder input • ISS / IPMS Survey	Define the role of the TSB / KTN & improve official terms of engagement with GB rail	• Effective & efficient utilisation of existing resources • Improved industry partnerships & collaboration • Longer-term perspective • Leverage of cross-industry benefits	• Survey • Case Studies • Atkins engagement with TSB • Experience of UK EGS & AM industries	• Establishment of Rail Innovation & Growth Team (RIGT) & GB Rail Innovation Investment Fund (GBRIIF) • Define the role & strategy for 'SB's terms of engagement with Industry segments
Complex internal & external interfaces between industry partners & vertical segments of value chain	• No transparency in processes & liabilities • Inefficient communication • Increased bureaucracy • Adversarial relationships	• TSAG • ADL • Stakeholder input • ISS / IPMS Survey	Provision of matrix of propos'd 'Innovation Enab'er' interfaces at different levels (using the "5 worlds" model)	• Clarity with regard to industry interfaces • Efficient & accelerated processes • Effective risk management & transparency • Reduction of bespoking	• Survey • Case Studies • Atkins engagement with TSB • Experience of UK EGS & AM industries	• Establishment of Rail Innovation & Growth Team (RIGT) & GB Rail Innovation Investment Fund (GBRIIF) • Define & manage core industry interfaces & communication processes • Increased engagement with TSB & KTN
Lack of visibility of introduction window for innovation, particularly in terms of new technologies	• Complex procurement regime • Lack of alignment of product development processes • Complex & bureaucratic approvals process	• TSAG • ADL • Stakeholder input • ISS / IPMS survey • Case studies	Provision of "Insertion Points" map to be made for technology	• Efficient approvals process with clarity in strategy & objectives • Early engagement with approvals stakeholders • Encourage research investment & innovation • Enable easier technology transfer from other safety-critical systems	• Other Industries • Cost Benefit Analysis (?)	• Establishment of Rail Innovation & Growth Team (RIGT) & GB Rail Innovation Investment Fund (GBRIIF) • TSAG technology roadmapping exercise
Lack of innovation skills in the industry	• Lack of effective capacity to research, investigate, propose & commission innovation • Poor business cases • Reduced collaboration	• TSAG • ADL • Stakeholder input • ISS / IPMS survey • Case studies	Commitment to national innovation skills training programme	• Improved industry partnerships & collaboration • Longer-term perspective • Leverage of cross-	• Experience of Fraunhofer Institutes • Experience of global EGS & AM industries	• Establishment of Rail Innovation & Growth Team (RIGT) & GB Rail Innovation Investment Fund (GBRIIF)

Barrier to Innovation	Impact	Evidence	Recommendation	Benefits	Facts and Case Study	Innovation Enab'er's Role
	• Poor integration of R&D			industry benefits • Efficient & accelerated processes • Effective risk management		• NR national skills training programme

Table 40: Final Recommendations against barriers and showing enablers

The following recommendations for cost reduction, increased efficiency and increased revenue are identified:

- Innovation enablers must be able to act to research, investigate, propose and commission the development of innovation through:
    - Supplier innovation from the traditional value chain ("inside-out")
    - Leveraged innovation from other rail industries and indeed other industries ("lift-and-drop" / "outside-in")
    - Industry platforms (as described above)
- A **Rail Innovation & Growth Team (RIGT)** should be established, following the best practice of the long-established Aerospace and Automotive teams and the Niteworks partnership from the Defence sector.
- The RIGT should emulate best practice from aerospace manufacturing and automotive and develop an industry vision for innovation (as opposed to technology) similar to that outlined in the National Aerospace Technology Strategy (NATS).
- The RIGT's remit should cover the entire TRL cycle and enable the alignment of people, processes, structure and culture around the IPMS to identify, assess, develop, test, launch and leverage innovation.
- Existing explicit and implicit R&D/ Innovation roles and functions of DfT, TSAG and RSSB should be subsumed into the RIGT.
- On the assumption that the RVfM work will recommend the creation of a Rail Systems Authority, we recommend that the RIGT's functions could largely be discharged under its remit.
- The RIGT should fulfil the "systems intelligence function" which will look at opportunities and challenges, covering futures and horizon scanning, legislative change, franchise renewal, major projects, new methods and RUSs.
- The RIGT should be tasked with the identification of transferable innovation from external sources as well as reporting on it to the industry. If a piece of innovation is deemed applicable, then its porting and development into GB rail can be commissioned as a platform as described in IPMS.
- The regulatory function of RIGT, via the interface between the RIGT and the ORR, should take the guardianship role in terms of incentivising the industry to meet these insertion points and ensuring compliance with a stated and clear requirement to innovate.
- Best practice guidelines for systemic and systematic innovation decision support must be developed for the industry as a matter of urgency – these should include investigating the scalability and industry-level application of the Network Rail innovation management system.
- The location of the systems authority should be independent both from Network Rail, operators and RSSB as they are at present, but directly accountable to the regulator and the taxpayer (via ORR and DfT).
- Based on the Hauser report, the successful set-up of the Technology and Strategy Board and the planned set-up of the Systems Authority, the Government should fund the set-up cost of the RIGT and other enablers.
- Based on the level of involvement and the successful example of existing organisations such as TSB, the Government should fund the operating cost of the RIGT and other enablers, with a small subscription fee charged to NR, ATOC, RFOA and RIA.
- The RIGT must provide adequate interfaces to keep civil servants informed and appropriately involved in the industry's research and innovation agenda.
- The technical capability of the RIGT could be drawn in part from the established TSAG / TSLG, but the RIGT must be able to make an informed assessment in terms of not only technical issues, but all ten dimensions of innovation system structure as described in ISS.
- The technical capabilities of the RIGT must go far beyond core rail technical skill-sets, to cover, for example, validation for software controls
- The RIGT should be responsible for setting (via output-driven specifications) and managing the response to industry-level innovation challenges as well as functioning as a systems authority to make stage-gate decisions on behalf of the industry concerning collaborative investment funding.
- The RIGT must make a comprehensive assessment of existing industry initiatives for inclusion in its programme to avoid the risk of "orphaning" activities that are already being catered for within the existing structure.
- The RIGT should also act as a referral body for difficult-to-resolve systemic innovation issues down to component level.
- A matrix of insertion points should be created to enable the agendas of industry stakeholders to be linked to technical road-mapping.

- Membership of RIGT functions be periodically refreshed, on a 2-3 year basis.
- The industry should seek to develop innovation leaders that are capable of effective participation in any one of the RIGT's functions, so innovation skills should be explicitly included in GB rail's new National Skills Academy programme.
- To address the issue of funding and support open IPR models, a **GB Rail Innovation Investment Fund (GBRIIF)**, should be established, jointly funded by industry and government, to support collaborative investment in innovation, using suitable IPR models.
- The unequal distribution of development investment against launch revenue streams in the industry must be addressed by the development of collaborative investment models like a Value-Added Reimbursable Launch Investment (VARLI) vehicle.
- Project- and platform-level innovation investment should be shared between the public and private sectors via the GBRIIF with the exact split and the mechanism for transactions considered on a project-by-project basis using VARLI or a similar process.
- Draft partnership and collaboration agreements must be developed which align the profit drivers of the various stakeholders and provide safeguards to prevent undue pressure being brought to bear by the more powerful stakeholders.
- A "strategic market" function should be developed for the RIGT in order to drive a global growth strategy for GB rail to capture world innovation market share?
- The RIGT should develop an informed and detailed understanding of the world rail innovation market, GB rail's competitive position (both current and potential, by product sector and region) and construct a relevant set of market entry and exploitation strategies to drive the industry vision.
- The RIGT must define and establish clear and straightforward procedures for interacting and collaborating with other innovation enablers such as "Clerk Maxwell Centres"/TICs, in particular if one is established for Transport, as well as the Transport KTN and other industry IGTs. We consider that the interface between RIGT and the TIC will enable GB rail to bring industry-level strategic clarity about its innovation priorities to the TIC so that the industry will be able to commit to developing and delivering everything from innovative offerings from the supply chain to new industry capability platforms and we expect the TIC to be an active participant in the agenda and functioning of the GBRIIF.

9 Document Control

Notice

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This Report is for the benefit only of the Client and the other parties that we have agreed in writing to treat as addressees of the Report (together the Beneficiaries).

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Document History

Atkins Project Number: 5098555 DfT Project Reference RVFM10003		**DOCUMENT REF: 5098555-ATK-51-0030 Improving Management & Delivery of Innovation Final Report v1.7**			
0.2-0.3	Successive early drafts	M Jafri/ D Jonas	N Murphy	-	13-20 /12/10
1.0	First Issue for RVfM review; at Interim Report Stage	D Jonas	N Murphy	N Murphy	20/12/10
1.1	First draft of final report incorporating feedback from RVfM team and stakeholders.	D Jonas	N Murphy	-	04/01/11
1.2	Further draft of final report	N Murphy	D Jonas		07/01/11
1.3	Draft final report for RVfM review	D Jonas	G Stroud	N Murphy	14/01/11
1.4	Draft final report (including updated cost data) for RVfM review	D Jonas / E Zhao	G Stroud	N Murphy	21/01/11
1.5	Final report draft for quality review incorporating feedback from RVfM team and stakeholders	D Jonas	N Murphy	N Murphy	10/02/11
1.6	Issued Final Report	D Jonas	N Murphy	N Murphy	10/02/11
1.7	Publication of final report	D Jonas	N Murphy	J Elphick	25/05/11
Revision	**Purpose Description**	**Originated**	**Reviewed**	**Authorised**	**Date**

Appendix A: Glossary of Terms, Figures and Tables

Term	Meaning / Definition
AAR	Association of American Railroads
ADL	Arthur D Little
AAR	Association of American Railroads
ALU	Application Launch Undertaking
AM	Aerospace Manufacturing
DfT	Department for Transport
EDF	Electricité De France
ETI	Energy Technologies Institute
EGS	Energy Generation And Supply
GBRIIF	GB Railway Innovation Investment Fund
IE	Innovation Enabler
IM	Infrastructure Manager (as defined in ROGS)
IP	Intellectual Property
IPMS	Innovation Process Maturity Spiral
ISS	Innovation System Structure
KTN	Knowledge Transfer Network
NESTA	National Endowment for Science, Technology and the Arts
NR	Network Rail
OEM	Original equipment manufacturer
OJEU	Official Journal of the European Union
ORR	Office of Rail Regulation
RFOA	Rail Freight Operators Association
RIGT	Railway Innovation & Growth Team
ROGS	The Railways and Other Guided Transport Systems (Safety) Regulations 2006
RSSB	Railway Safety and Standards Board
RU	Railway Undertaking (as defined in ROGS)
RUS	Route Utilisation Strategies
RVfM	Rail Value for Money
SA	Systems Authority
SME	Small to medium enterprise
TIC	Technology Innovation Centres
TRL	Technology Readiness Level
TSAG	Technology Strategy and Advisory Group

Term	*Meaning / Definition*
TSLG	Technology Strategy Leadership Group
TSB	Technology Strategy Board
TTCI	Transportation Technology Centre, Inc
VARLI	Value Added Reimbursable Launch Investment
VfM	Value for Money

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Appendix B: Technical Readiness Levels (TRLs)

Technical Readiness Level	Readiness implied	IPMS quadrant
1	Basic principles observed	Insight
2	Technology concept and / or application formulated	Insight-to-Traction
3	Analytical & experimental critical function and / or characteristic proof-of-concept	Traction
4	Technology validation in laboratory	Traction-to-Platform
5	Technology validation in relevant environment	Platform
6	Technology demonstration in relevant environment	Platform-to-Standard
7	Technology prototype demonstration in an operational environment	Standard
8	Actual technology completed and qualified through test and demonstration	Standard-to-Niche
9	Actual technology system qualified through successful mission operations	Niche
Non-TRL	Technology concept and / or application identified as applicable in new environment	Niche-to-Insight

Table 41: Technical Readiness Levels mapped to IPMS quadrants

Appendix C: The Fraunhofer model

The Fraunhofer-Gesellschaft is one of the world's major international research organisations. An undertaking of this size and significance needs a decentralised organisational structure which nevertheless incorporates line functions that allow it to develop an efficient strategic orientation on the basis of centralized control mechanisms. This decentralised form of strategic planning at institute level, coordinated within the Fraunhofer research groups, is an important success factor in planning the association's research activities.

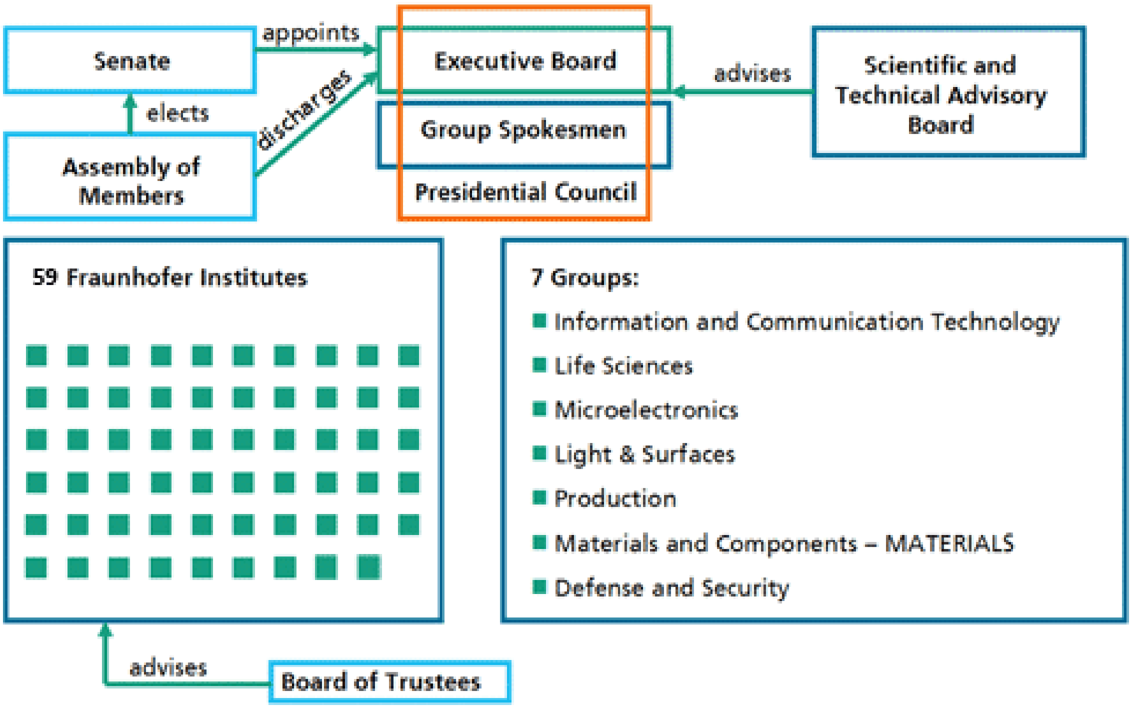


Figure 56:The FHG organisational structure (source: Fraunhofer ISIT)

The **Senate** is responsible for decisions concerning the basic scientific and research policy of the organisation and planning of its research activities and expansion. It comprises eighteen leaders from science, business, industry and public life, including members delegated by government institutions (four national, three regional) and three members selected from these who serve on the Scientific and Technical Advisory Board.

The **Executive Board** is responsible for managing the business activities of the Organisation and dealing with all other affairs of the organisation. Its principal duty is to elaborate the basic premises of the organisation's science and research policy and draw up its research, expansion, and financial plans in collaboration with the Scientific and Technical Council and the Alliance chairmen represented on the Presidential Council. The Executive Board supervises the Institutes and working groups of the organisation and collaborates with the scientific and technical council on the coordination and promotion of its work.

The **Presidential Council** participates in decision-making relating to the organisation's business strategy and assists with the implementation of Executive Board resolutions. It consists of the Executive Board and the chairmen of the Alliances.

The **Scientific and Technical Council** is composed of the management of the Institutes (3 yrs duty) and internally elected representatives of the scientific and technical staff on the organisation's Institutes. Its function is to assist the Executive Board in the coordination of the Institutes' research activities and the promotion of collaboration among the Institutes.

Each **Institute** is managed by one or more directors assisted by the heads of any branch institutes and independent departments. Members of Institute management manage the business activities of the Institute, bearing responsibilities towards the organisation. They draw up plans for the Institute's scientific work and organise their own scientific projects. They also endeavour to acquire contract research work. The management of each Institute is expected to observe the planned budget and to meet any obligations it has assumed relating to the execution of research projects. They submit proposals concerning employment to the Executive Board and report to the Scientific and Technical Council concerning the progress, planning and results of the Institutes' scientific activities on a regular basis.

The formation of alliances is subject to the decision of the Executive Board.

Performance-related funding

The Fraunhofer-Gesellschaft's research work is oriented toward concrete applications and results. Pure basic research, as practiced at universities, is funded to almost 100% by public grants. Industrial R&D, up to prototype level, is largely financed by private enterprise.

Fraunhofer is funded both from the public sector (approximately 40%) and through contract research earnings (roughly 60%) and operates in a dynamic equilibrium between application-oriented fundamental research and innovative development projects.

The institutes of the FHG work hand in hand, collaborating in groups and alliances or pooling different skills in flexible structures as and when needed. This secures their leading position in the development of system solutions and the implementation of comprehensive innovations.

The FHG has more than 80 research units, including 59 Fraunhofer Institutes in Germany

In addition to its locations in Europe, the FHG is engaged in a number of international activities in the USA, in Asia and in the Middle East. The Brussels office serves as a platform for dialog with European policy makers, with the additional functions of issuing public / official statements and providing information services.

FHG Institutes are continuously adapting their profiles to meet current demand, thereby responding to the present and predicted needs of the market. At the same time, they are influencing the development of promising new technologies through their own preliminary research.

There are an increasing number of technological and scientific challenges that can only be met if several disciplines work together. This is where the FHG has a unique strategy to offer: Where necessary, the association's various core competencies are efficiently pooled under the same roof – a strength that will be further developed in the context of the Fraunhofer frontline themes

FHG intends to actively contribute to finding new solutions (front line themes as health care, resources, climate change; this include Green powertrain technologies) with its twelve frontline themes, investing its own resources in preliminary research and cross-linking its distributed skills to facilitate the interface to industry.

In pursuing these frontline themes, Fraunhofer is strengthening its role as a driver of applied research in Germany. It is also **increasing its appeal as a research and development partner to industry, opening up new opportunities for businesses on tomorrow's markets.**

Internationalisation: Advancing the level of scientific and engineering know-how and exploiting the innovation potential of competing centres of excellence through local presence and involvement in:

- Penetrating new markets for research services and for the technologies offered by the Fraunhofer Institutes in Germany and their industrial partners.
- Offering wider opportunities for staff development by adding an international aspect, both in terms of scientific knowledge and with respect to the encounter with other management styles and business cultures, including foreign-language and social skills.

- Continuous improvement of problem-solving skills through a wider range of projects often based on other market dictates and other sets of customer requirements. This helps to raise the quality of the services offered to German industry and international competition forces them to develop a different attitude to quality

FHG believes that linking skills and pooling resources is the right way to meet the challenges posed by globalisation and the increasing dynamism of structural change. Knowledge-based industries, in particular, develop very successfully in regional clusters, which facilitate knowledge exchange and generate a critical mass of skills that complement one another. Geographical proximity between research organisations, investors and companies can produce networks that lead to new business ideas and the foundation of new enterprises.

Regional innovation clusters bridge the gap between industry and scientific research. Successful clusters can stimulate the competition on the market, and at the same time create fruitful collaborations which ultimately benefit everyone involved.

A key element of the German government's high-tech strategy is therefore to promote cluster initiatives. In the "Pact for Research and Innovation", the FHG has assumed the task of conceiving and implementing innovation clusters. Such collaborative ventures set themselves clear goals and define milestones for their development.

The purpose of innovation clusters is to pool the strengths of a region and activate them to solve demanding tasks. In addition to industry and universities, the networks include local non-academic research institutes that can make important contributions in relevant thematic areas, facilitated by regional partnerships between private companies, research institutes and universities. FHG clusters are real-life project clusters with concrete objectives that are clearly defined from the invention stage right through to the final product, financed jointly by industry, local government and FHG base funding.

Through this initiative, the FHG is providing impetus for the further development of regional centers of excellence, and is supporting the regions' skills and expertise. Innovation clusters will primarily serve as an instrument to help develop existing strengths. The collaborations will generally be restricted to within one federal state. Another important factor is how much money the industrial partners and the state are willing to invest in new projects within a region in addition to current expenditure.

Collaboration within clusters is intended to extend beyond that of a mere communication network. The clusters are built on mutual respect for one another's strengths and are prepared to take on specific tasks in an end-to-end chain from the invention to the final product. It is important to work together towards a shared objective, which can best be achieved through concrete projects. That is why the Fraunhofer innovation clusters are, first and foremost, project clusters. This means that the funds provided are used for particularly attractive projects that can only be implemented within a given network.

The distribution of tasks within each innovation landscape is maintained. While the public establishments create the basis for new products and services, the funds provided by industry are used to implement and market these innovations. This promotes collaboration in the development of concrete products. The positive effects of jointly achieved success on further cooperation are invaluable.

Joint, harmonised research and development at Fraunhofer Institutes, universities and in industry not only provides stimulation and helps to forge links within a cluster, but also has a financial leverage effect. Being able to mobilise equal funding from the regions and the industry involved is a prerequisite for setting up an innovation cluster, and ensures commitment on the part of all those concerned.

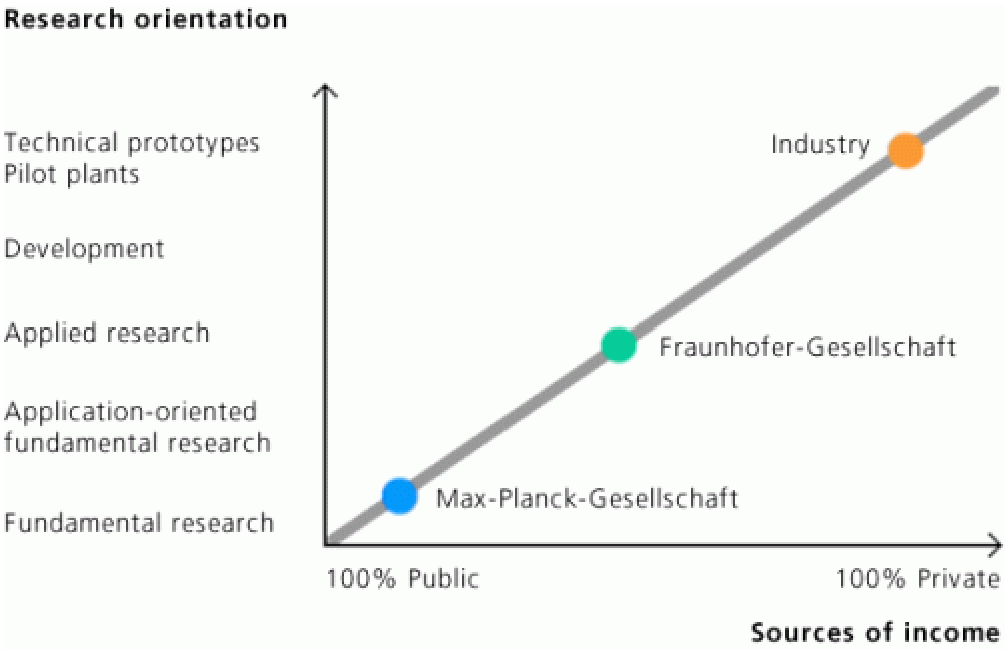


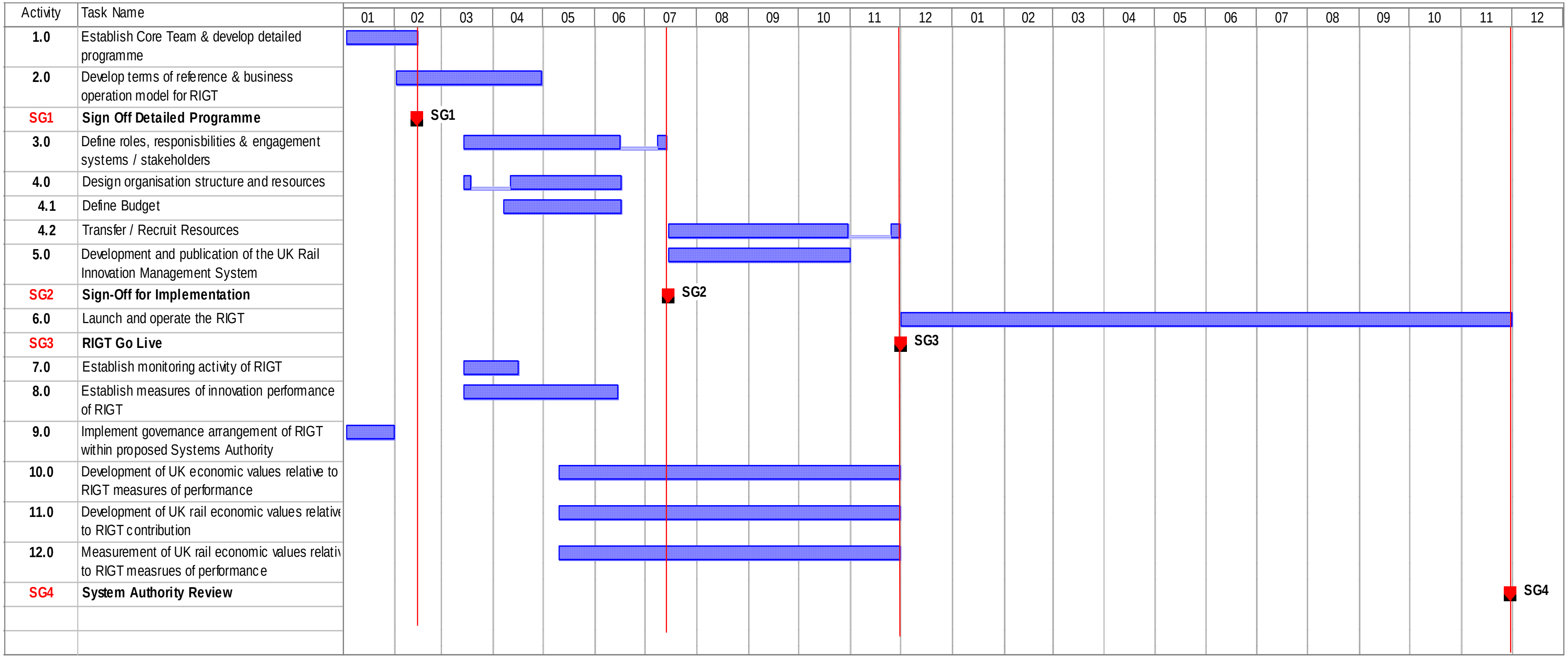
Figure 57: Positioning of Fraunhofer Institutes in terms of research orientation and sources of income (source: Fraunhofer ISIT)

Collaborating with the Max Planck institutes helps to bridge the gap between applied and basic research. A range of interdisciplinary research projects are driving innovative developments forward. One of these measures involves bridging the gap between applied and basic research by improving the co-operation between institutes of the FGH and the Max Planck Society. A wide range of project proposals has meanwhile been reviewed and approved by internal and external experts. Interdisciplinary networks are collaborating very successfully and are spurring on a great many innovative developments.

The German government has huge influence on the way FHG works, stating that "Innovation holds the key to economic growth in countries like Germany which are highly developed but lacking in natural resources." In its coalition agreement, the German government pledged to "boost R&D spending and legislate tax breaks for R&D in an effort to order to ramp up corporate spending in this area."

Appendix D: Draft Implementation Plan for Industry Innovation Management System

This indicative plan shows the timeline for implementing the industry innovation management system solution described in section 7.1.2 above.



Appendix E: Innovation System Structures and Dynamic Equilibrium

Whilst the ISS framework is primarily used as a checklist-style systematic method of assessing all aspects of an innovation system's structure, it also illustrates a more nuanced view of activity within an innovation system. This relates to considerations of strategic, tactical or operational effectiveness and the dominant modes of thinking and behaviour, which can be divergent, convergent or integrative:

Dimension	Typical level of engagement	Typically dominant mode of thinking & behaviour
Policy, strategy & objectives	Strategic	Integrative
Trends (social, cultural, political, economic, regulatory)	Strategic	Divergent
Stakeholders & funding	Strategic	Convergent
Technical capability, skills & best practice	Tactical	Divergent
Value for money & operating models	Tactical	Convergent
Organisations, people & collaboration	Tactical	Integrative
Competition & communication	Operational	Divergent
Delivery, standards & risk	Operational	Convergent
Internal & external relationships	Operational	Integrative
User & customer needs	Operational	Integrative

Table 42: ISS analysis of levels of engagement or dominant modes of thinking and behaviour in innovation systems

Like strategic, tactical and operational considerations, divergent and convergent modes of thinking and behaviour typically come into tension with each other and the provision of integrative modes of behaviours and thought is typically used to resolve this tension and move it into harmonious alignment. Thus, for example, research and development typically requires a level of comfort with divergence to allow practitioners to explore the realms of possibility, whilst system actors concerned with commercial operating models typically find themselves in conflict with this mindset, being constrained to employ more convergent modes of thought and behaviour.

A productive tension, or **dynamic equilibrium**, between all three modes is necessary for an organisational or industrial system to function effectively. For instance, a good idea is of little use in organisational terms without an application. The process of moving from potential through idea to reality requires evaluation and testing, both convergent modes, to ensure that the idea is feasible, robust and sustainable. Without careful, sober scrutiny of the development process, a half-baked idea will not survive in the real world.

Dynamic Equilibrium
Productive tension in an organisational system (particularly an innovation system) arising from the optimal balance of effort and focus involved in the performance of functions and modes of behaviour.

An innovation system with an over-reliance on divergent modes, however, is likely to be impulsive and exciting, but unable to function efficiently or effectively. Similarly, it is easy to see how an organisation with a corresponding over-reliance on convergent modes is likely to be bureaucratic, staid, hidebound and characterised by an adherence to routine and commitment to the elimination of risk. Divergence is too concerned with the quest for the new, convergence too concerned with conserving that which already exists. In an organisation where divergence overpowers convergence, value – particularly financial value – is unlikely to be maximised due to spiralling costs and wasteful use of resources. Likewise, in an organisation where divergence dominates convergence, resources will be so tightly controlled and competitively allocated on 'safe' projects that all imagination is stifled and the ideas that could create new markets are never developed, because of the suffocation of an atmosphere of prevailing wisdom, procedural fossilisation and monolithic complacency.

It is worth noting that many organisations have a strong bias towards convergent modes because of their association with quantification, predictability and structure. Convergent benefit is usually the most desired data to identify, as it is strongly associated with what is traditionally considered to be the essential business of management; namely, decision-making, discipline, supervision and the command-and-control functions of hierarchy.

What is particularly significant is that convergence also represents the most inflexible aspects of the system. Sometimes these aspects are procedural and cultural, such as the bureaucracy of public-sector organisations; sometimes they are technical, such as the manufacturing or IT infrastructure of the business; sometimes, they are financial, such as fixed targets for return on investment or capital, or management accounting rules about how expenses should be treated in a business unit's P&L. A business that is prevented from reacting to new market realities by its organisational structure is put at a competitive disadvantage by its self-imposed constraints, or those demanded by its investors. Either way, measurability brings identifiability – and identifiability makes it attractive to the type of organisation that only thinks in terms of quarterly financial results. Obviously, businesses that pay attention only to a small subset of metrics and results become vulnerable if the assumptions on which this operating model relies cease to remain valid, for example profitability being dependent upon a certain range of supply costs for raw materials. Furthermore, it is likely that the first signs of danger will not affect these 'important' metrics – by the time that they do, it will be too late.

The key to a successful balance of convergent and divergent modes is the mediating function of integration. Integrative modes rely upon the synthesis of a viable and valid way to produce dynamic equilibrium between the quantitative and qualitative, tangible and intangible, extrinsic and intrinsic qualities that have been through both divergent and convergent filters. Only through the operation of integrative modes can a well-formed, rounded and balanced innovation be delivered. Effective innovation delivery is innovation that is able to cope with both the quantitative demands of growth targets and profitability and the qualitative demands of consumer behaviour and demand stimulation. Innovation must be able to speak the language of both customers and technicians, of budget-holders and advertising account managers, of creativity and standards, integrating the requirements of strategy and operational reality.

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Appendix G: Full Version of Benefits Quantification Methodology

The methodology behind quantification of benefits with innovation enablers in place is based on establishing the extent to which innovation projects can deliver better returns to their initiators. There are two approaches to assist in assessment and selection of innovation solutions managed by the proposed RIGT.

- What would be the level of improved returns that could be generated by GB rail, with innovation enablers in place, based on the past performance of the GB rail industry?
- What would be the potential level of return to the industry if the innovation enablers are in place and help to channel in investment for a range of projects, performing to a similar level as comparable organisations (with some projects which would not have been pursued to the same extent or at all without the innovation enablers)?

The level of benefits derived in above scenarios will be compared against the costs associated with setting up and operating innovation enablers.

Approach 1: Based on "Historic Performance"

The historic performance data received from GB rail organisations with regards to their innovation projects implemented in the past contains forecast costs and returns indicators and, hence, net surplus and return ratio is calculated from the available data.

For each individual innovation programme and project, the above parameters are then compared to the actual costs and returns values that have been achieved; this may also include updated and realistic forecasts if the projects have not been fully completed.

Subsequently, each programme or project are analysed to identify the top three problems that would have blocked or influenced the project delivery success rate. Based on this analysis, the problems identified would be mapped against the ISS model dimensions (see section 5.1.1). It is then analysed to explore whether existence of innovation enablers could overcome some of these problems and to what extent, given a likelihood of success is assigned to each ISS dimension. For example, if the innovation enablers are highly likely to address the need for a strategic, system-wide view, but their ability to improve the supply chain is less certain, which would directly affect the probability of achieving favourable results under given circumstances. It is also aimed at gathering information from stakeholders, which highlight the extent to which innovation enablers would have been successful in addressing real problems in the past. This generates a probability of the various innovation enablers being able to successfully implement innovation drivers to deliver the desired results, for example by keeping costs and returns more in line with the forecasts.

The difference between the actual costs and return, with and without innovation enablers, indicate its contribution to the GB rail industry. The above analysis helps to identify, if innovation enablers are effective in overcoming real-life problems in the past and provide costs and returns that are more in-line with the estimated forecasts. On the whole, compared to the past actual, the future net surpluses and return ratios with innovation enablers in place will be higher on similar projects.

An example of the above calculation process is shown in Table 42, using imaginary numbers. The project is assumed to provide a forecasted return of 3:1 but only managed to deliver 1.5:1 at the completion. It is then assumed that with innovation enablers in place the return ratio could have improved to 2.46:1, which eventually resulted in an additional surplus of £1.93m as the added value to GB rail industry.

Variable	Description	Example Value (in millions)
a	Forecast cost	£2
b	Forecast return	£6
c =–b - a	Forecast net surplus	£4
d = b / a	Forecast return ratio	3 : 1
	Result	Fully implemented but could not sell to as widely as envisaged
e	Actual cost	£2
f	Actual return	£3
g =–f - e	Actual net surplus	£3 - £2 = £1
h = f / e	Actual return ratio	£3 / £2 = 1.5 : 1
	Problem 1	Strategic view
	Problem 2	Stakeholder acceptability
	Problem 3	Other – completely unrelated to any of the areas IEs could help to resolve
i = combination of assigned probabilities	Overall degree to which IEs could be able to resolve the problems	64%
j	"With IEs" cost	£2
k = b + –f - b) * (100% – i)	"With IEs" return	£6 + (£3 - £6) * (100% - 64%) = £6 + (-£3) * 36% = £6 - £1.08 = £4.93
l =–k - j	"With IEs" net surplus	£4.93 - £2 = £2.93
m = k / j	"With IEs" return ratio	£4.93 / £2 = 2.46 : 1
n =–j - e	IEs impact on cost	£2 - £2 = £0
o =–k - f	IEs impact on return	£4.93 - £3 = £1.93
P = l- g	IEs impact on net surplus	£2.93 - £1 = £1.93

Table 43: Cost benefit analysis approach based on 'Historic Performance'

It must be noted that the key to the calculation process and realisation of actual benefits depends on the probability of success to resolve issues through 'Innovation Enabler' capability. Therefore, as shown in Table 43 below, the project-level problem solving capability is categorised along the ISS model dimensions and a success factor assigned along each ISS dimension. Please note that the probabilities shown in the table below are purely illustrative. The actual probabilities used are explained in Section 6.2.

Sr.#	ISS Model Dimension	Likelihood to Resolve Problem with an IE	Justification of likelihood
0	(don't know)	0%	Don't know, can't judge
1	Strategic / policy fit	90%	The purpose of innovation enablers is to provide a strategic system-view
2	Compatibility – sector, environment, regulations	70%	Innovation enablers can influence this, but not totally, as there are important organisations outside the innovation enablers' influence, or rather innovation enablers will need to take views from them.
3	Stakeholder viability & achievability	70%	(as 2)
4	Technical viability & achievability	50%	Innovation enablers can help to bring together technical input but their capability may be limited by the virtual nature of any organisation (arm-length)
5	Value for money & cashflow	50%	(as 4)
6	Compatibility – industry culture, skill-set,	70%	(as 2)

Sr.#	ISS Model Dimension	Likelihood to Resolve Problem with an IE	Justification of likelihood
	structure		
7	Supply & delivery capability riskiness	70%	(as 2)
8	Industry competitiveness	70%	(as 2)
9	Impact on industry relationships & channels	70%	(as 2)
10	User & customer appetite	50%	(as 4)
99	Other problems that are completely unrelated to the above and factors that could be influenced by the SA	0%	Cannot be influenced by innovation enablers

Table 44: Cost benefit analysis approach based on 'Comparator Study'

Caveats

It must be noted that the proposed likelihood and justifications should be validated with the RVfM and the GB rail industry partners.

It is understood that the individual organisation's own judgement on the likelihood of 'innovation enablers' being able to resolve the problems is based on the probabilities listed below:

- Certainty: 100%
- Likely: 75%
- Maybe: 50%
- Unlikely: 25%
- Not at all: 0%
- Don't know: 0%

The above methodology relies on the availability and quality of project-level data received from GB rail industry partners. If such data is not made available on a project-by-project level, then programme level can also be used to draw high level conclusions, but it would be difficult to identify areas where improvements could be made, if at all. Where neither project nor programme level data is made available the organisational-level data could be used but this would not construct a robust argument to realise the benefits of innovation enablers in achieving project or programme efficiencies. Overall, at all levels it is absolutely necessary to have GB rail industry spending and returns for forecasts forecast and actual i.e. the data in the model needs to represent the industry as a whole, or at least the vast proportion of the industry's activities. If only a sub-set of the overall data can be obtained, then a multiplier factor will need to be used for the data to be representative of the industry as a whole.

The strength of the "Historic Performance" approach is that it is based on real-life projects that faced actual problems, which could be analysed under with or without the 'Innovation Enablers' scenario. However, the weakness of this approach is that it cannot predict future generation of ideas and projects as the result of having innovation enablers in place. In addition, this approach relies on a large amount of quality data being made available. This weakness is to be countered by using the "comparator" approach discussed below.

Approach 2: Based on Other Rail and Non Rail "Comparator Study"

As discussed above that the 'Historic performance' approach provides a basis for forecasting the future improvements. However, the types of projects that are introduced under the existing industry set-up may not be reflective of future projects under a different industry set-up. The extent to which the industry as a whole could perform with the innovation enablers in place cannot be judged based on past project data alone. Instead, comparator organisations and industries should be reviewed to establish their performance, and therefore the potential contribution to GB rail from the innovation enablers, if they perform as well as these comparators..

For example, we may find that typically £5 is generated for every £1 invested in projects from a comparator, then this 5 : 1 ratio will be used on the project investment managed by the innovation enablers.

The level of project investment that can be managed by the innovation enablers depends on their level of resourcing. A benchmark ratio of 'project funding managed' : 'resource spend' will be established. This ratio will be applied to the level of resourcing that is judged to be appropriate.

For example, if it is found that a benchmark organisation has £1m of resource spending (based on staffing levels) and manages of £100m of project work, then this 100 : 1 ratio will be applied to the innovation enablers' resourcing level. If the innovation enablers' resourcing level is £100k, then the manageable project worth would be £10m.

The return ratio established (the example being 5 : 1) will be applied to the project investment level (with the example being £10m) to derive the return that is likely to be generated (in this case £50m of returns, against £10m of project costs, with a net of £40m).

The strength of this "comparator" approach is that it establishes the level of performance that could be attained with innovation enablers capability in place. The weakness is that this approach is not based on real-life projects within the GB rail industry, which is already addressed by the 'historic performance' approach discussed above.

'Innovation Enabler' Added Value

The "Historic performance" approach would generate one level of the Innovation Enablers' contributions towards the overall net surplus and return ration of innovation projects in the GB rail industry. On the other hand, the "Comparator" approach would generate another level, based on examples and best practises in other rail and non-rail industries.

The two bands of benefits from innovation enablers would be annualised based on a view of the turn-over of projects considered in the "Historic Performance" approach i.e. projects frequency over certain period of years. The annualised benefits will be compared to the initial set-up and operations costs of the innovation enablers.

The set-up cost will be informed by the ADL report. The operating cost will be calculated based on the appropriate staffing level for the innovation enablers, with consideration for non-staff operating costs.

The benefit estimated through the "historic" and "comparator" (benchmarked) approaches will be compared to the costs.

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Certain information was provided by the following third parties:

Network Rail, the Technology Strategy Board (TSB), Rail Research UK, RIA, ATOC, Bechtel, Freightliner, Eversholt Trains, East Midlands Trains, Pandrol, Invensys Rail, Knorr-Bremse, Interfleet, Screwfast, Omnicom Engineering, Kilfrost, the RSSB, Rail Research UK, ERRAC, Loughborough University, the Aerospace Knowledge Transfer Network (KTN) and the Energy Generation and Supply KTN.

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