RailKonsult

Office of Rail Regulation

Innovation Efficiency Study

Summary Report

Reference BBRT-2573-RP-0001

Version: Issue 2

AMENDMENT CONTROL

This document will be updated with each issue of an amendment.

AMENDMENT RECORD

Issue	Date	Reason for Change	Checked	Approved
0	Dec '12	Initial draft		
1	Feb 13	Updated and comments incorporated		
2	Mar 13	Minor amendments		

DISTRIBUTION LIST

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1 (Master)	Project file
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The authors of this report are employed by Balfour Beatty Rail Technologies. The work reported herein was carried out under a Contract placed in September 2012 by the Office of Rail Regulation. Any views expressed are not necessarily those of that Office.

Executive Summary

The purpose of this study is to review Network Rail's opportunities to make efficiency improvements from innovations in engineering specifications and the introduction of new products and technologies. The study consisted of three stages:

- Review of the Innovation Process;
- An Innovation Scan; and
- Assessment of Potential Value during CP5.

Innovation Process

The existing process for innovation in the railway industry was reviewed against an example from the aerospace industry. A number of key elements were identified following the review. These were:

- Clear understanding of how to measure success;
- A stable long-term programme that has clear objectives;
- Adoption of a systems engineering approach to predict impact of changes;
- Focused technology centres solving specific issues;
- Competitive advantage provided from innovation.

In discussions with a number of stakeholders, it was noted that there have been significant developments in the rail industry over the last few years. These include:

- Developing a strategy that flows through from a long-term industry level vision;
- Improving focus on the problems that require solutions;
- Improving links with both academia and industry to leverage benefits;
- Development of research funding options and support networks to facilitate realisation of innovative ideas.

Further work is planned in the lead-in to the next control period by Network Rail, such as linking their technical strategy to the business and product strategies. There is also an objective to increase research investment to the levels generally accepted as good practice.

This on-going development of innovatory capability in the industry should be encouraged and continued.

Innovation Scan

A scan of the potential areas of innovation was undertaken based on a number of sources, including discussions with various stakeholders and literature reviews.

The scan was undertaken without constraints and without any explicit consideration of the issues facing the industry, i.e. a list of potential solutions were collected. Over 170 potential innovations were identified from this process.

This list of innovations was filtered into the following:

- Innovations already within the industry's plans;
- "Blue Sky" innovations that require significant further development before benefits will be realised;
- Innovations that will have a limited impact on industry costs;
- Innovations that will not be available for implementation during the early stages of the next control period; and
- Short-list of 14 innovations that have the potential to have a positive impact on CP5, representing a typical portfolio of innovations.

Assessment of Potential Value

An initial high-level assessment of the typical portfolio of 14 innovations was undertaken. This was based on consideration of the major items of investment and resultant savings during CP5. This assessment of a typical innovation portfolio indicates the potential opportunity to provide savings of £93.5m over the control period.

The impact of innovation in other industries is generally reviewed in terms of increased turnover from new products and services, rather than a reduction in costs to sustain existing output levels. However, an indicative assessment indicates that the potential range of savings that could be expected during CP5 is between £57m and £113m.

The study team wishes to acknowledge the input provided by members of academia and industry who provided input to this study.

Contents

1.0 INTRODUCTION

1.1 Background

The Office of Rail Regulation's (ORR) Periodic Review 2013 (PR13) will establish access charges, outputs and the associated regulatory framework for Network Rail for Control Period 5 (CP5) that will run from April 2014 to March 2019. The assessment of Network Rail's planned Maintenance and Renewal (M&R) expenditure and its efficiency in delivering outputs in a sustainable manner is an important input in assessing these access charges.

Sir Roy McNulty's 'Rail Value for Money Study' (R-VfM) conducted a review of potential efficiencies available to the rail industry, and drew on a wide range of previous work. The purpose of this study is to review Network Rail's opportunities to make efficiency from innovations in engineering specifications and the introduction of new products and technologies.

1.2 Scope

The study has reviewed three main areas of innovation:

- Innovation Process;
- Innovation Scan; and
- Assessment of potential value of innovation during CP5.

1.2.1 *Innovation*

The following definitions are from the Online Oxford Dictionary:

Innovate:	*Make changes in something established, especially by introducing new methods, ideas, or products.*
Invent	*Create or design something that has not existed before.*
Improve	*Make or become better.*

From this, it is evident that the key element of innovating is making a change. For the purposes of this report, innovation has been considered to be the implementation of changes through new plant, materials, products, technologies or processes.

1.2.2 *Innovation Process*

Sir Roy McNulty's "Rail Value for Money Study" identified the potential efficiencies available to the rail industry, including those that could be expected from a better performing innovation process. This study identified potential industry savings of £190m from improved safety, standards and innovation.

Both A.D. Little and Atkins produced reports that consider these areas in more depth to support of the main "Rail Value for Money Study". A.D. Little also produced a report for the Technical Strategy Leadership Group (TSLG) that reviewed the barriers to innovation in the rail industry.

Both Network Rail and the wider industry have undertaken much work in this area since the publication of the "Rail Value for Money Study" in May 2011. Further developments are planned in the period leading into CP5.

The initial stage of this study undertook a review of these documents. Interviews were also held with a number of industry stakeholders to obtain a view of the improvements made over the last eighteen months.

From this input a view was formed of the improved innovation process in use within the industry. This was compared with good practice identified from elsewhere. This review took cognisance of identified plans for further changes in the rail industry.

1.2.3 *Innovation Scan*

The second stage of the study was to undertake an innovation scan. The initial survey captured all identified innovations from a number of different sources, regardless of their maturity or likely potential to realise a benefit during CP5. No cognisance was taken of the particular issues being faced by the industry, i.e. the list forms a set of solutions, some of which maybe looking for a problem to solve.

This list was then filtered to select those that were most likely to produce a potential saving during the control period. Innovations that it is understood are already being pursued by the industry were not included within this assessment.

1.2.4 *Innovation Assessment*

The final stage of the study was to undertake a high-level assessment of the potential benefits from the filtered list of innovations.

The list forms a typical portfolio of large scale innovations. It only includes those that will have a noticeable impact on the industry's cost-base during CP5 and is intended to provide an indication of the potential benefits available during CP5 from innovation. The assessments provide an indication of the major investment costs and potential benefits.

2.0 INNOVATION PROCESS

2.1 Introduction

It has been identified by a number of previous studies that the process used by GB Rail for identification, development and realisation of innovation offers significant opportunities for improvement. Several previously published reports were reviewed as part of this study. These included the following documents:

- Achieving Value for Money in Safety, Standards and Innovation (A.D. Little for the R-VfM Study);
- Achieving Value for Money from Improving the Management and Delivery of Innovation in the GB Rail Industry (Atkins for the R-VfM Study); and
- Enabling Technical Innovation in the GB Rail Industry – Barriers and Solutions (A.D. Little for RSSB/TSLG).

In addition, discussions were held with a number of stakeholders and a number of conferences were attended.

It should be noted that an initial conclusion drawn from collection of this information was that the issue requires consideration of innovation in the context of "GB Rail" rather than "Network Rail". Although Network Rail's role is a key component, all sections of the rail industry have to play their part in the innovation process. A successful outcome, or otherwise, is dependent on this integrated approach.

2.2 Analysis

2.2.1 *Literature Review*

AD Little's report for TSLG identified three categories of barriers from interviews with a wide range of industry stakeholders: systems view; organisational; and implementation. The identified barriers are summarised below:

- Holistic "systems view":
    - Lack of alignment of incentives;
    - Lack of cross system clarity;
    - Incomplete understanding of customers' priorities;
    - Constraints to available payback time;
    - Disincentives from contract conditions;
    - Small GB-specific market;
- Organisational processes, competence and culture:
    - Unable to identify business model for particular innovation;
    - Reputational risks perceived as too high;
    - Cultural barriers to change;
    - No realisation of own weaknesses;
- Implementation risk management:
    - Lack of testing facilities;
    - Acceptance processes not understood or flexible;
    - Inequitable risk share;
    - Poor IP protection;

- Maintenance approach based on time-served experience;
- Perception that Standards stop changes;
- Perception that current approach is already best.

An updated list of barriers was part of a presentation associated with the launch of the 2012 Railway Technical Strategy given by David Clark (Enabling Innovation Team):

- *"Lack of cross-system thinking;*
- *Difficulty of working across organisational boundaries;*
- *Costs and benefits often with different parties;*
- *Risk aversion and lack of risk capital;*
- *Misalignment of time horizons;*
- *No structure or leadership to encourage innovation."*

From a wider perspective, the Treasury's Infrastructure Cost Review (December 2010), which investigated the cost of major UK infrastructure projects, identified the following in terms of investment in innovation:

> *"Compared to Europe, the UK Tier 1 supply chain has typically invested tactically for the next project, rather than responding to the market as a whole.*
>
> *…*
>
> *The current levels of fragmentation of the industry, compounded by infrastructure pipeline uncertainty and overly complex procurement approaches, militate against a more strategic investment or integrated approach to innovation."*

2.2.2 *Comparator Selection*

The view of good practice has been developed from consideration of the approach adopted by Rolls Royce, particularly with respect to power plants for civilian aircraft.

The Atkins report, that formed part of the Rail Value for Money programme, identified that the two high-performing industry sectors are defence and aerospace. Similar to rail infrastructure, the aerospace sector has long development cycles and long-life assets. The "assets" include a high technology element.

Rolls Royce is:

- An engineering organisation operating within the aerospace industry;
- Acknowledged as a leading innovator and is regularly included in lists of top innovators across all sectors;
- An organisation that has successfully implemented innovation in a British environment;
- An organisation with a business model based on:
    - Service life management of assets ("power by the hour");
    - Performance achieved through monitoring, prediction and excellent logistics management;
    - Earning margin from achieving high reliability and availability targets.

2.2.3 *Comparison Diagram*

Figure 1 below is based on the above input and the comments received from the discussions held with the various stakeholders.

The diagram is intended to summarise both good practice and some of the issues faced by GB Rail. It is primarily focussed on the provision of an environment to encourage innovation, rather than the mechanics of successfully innovating. As such, some issues noted in previous studies do not appear in the diagram.

The diagram consists of four sections:

- Representation of some of the characteristics seen in the rail industry (pink background);
- Identified key criteria that support a successful innovation process (blue boxes);
- Identified good practice, primarily based on the approach reported as being adopted by Rolls Royce (green background);
- Other factors that have been identified during the study (yellow background).

The details of each part of the diagram are explained in the following section.

Although the diagram portrays a “black and white” view inferring that the rail industry is poor throughout the end-to-end process, this is recognised as not being true. Government and a number of industry bodies have worked together to improve the approach. In particular, focus has been applied to improve:

- Visibility of long-term planning;
- Opportunities to gain increased research and development funding, thus leveraging the industry’s own investment;
- Support to enable the members of the supply chain to identify suitable partners to complete development of their innovations; and
- Publication of testing and trial facilities available for use by the industry.

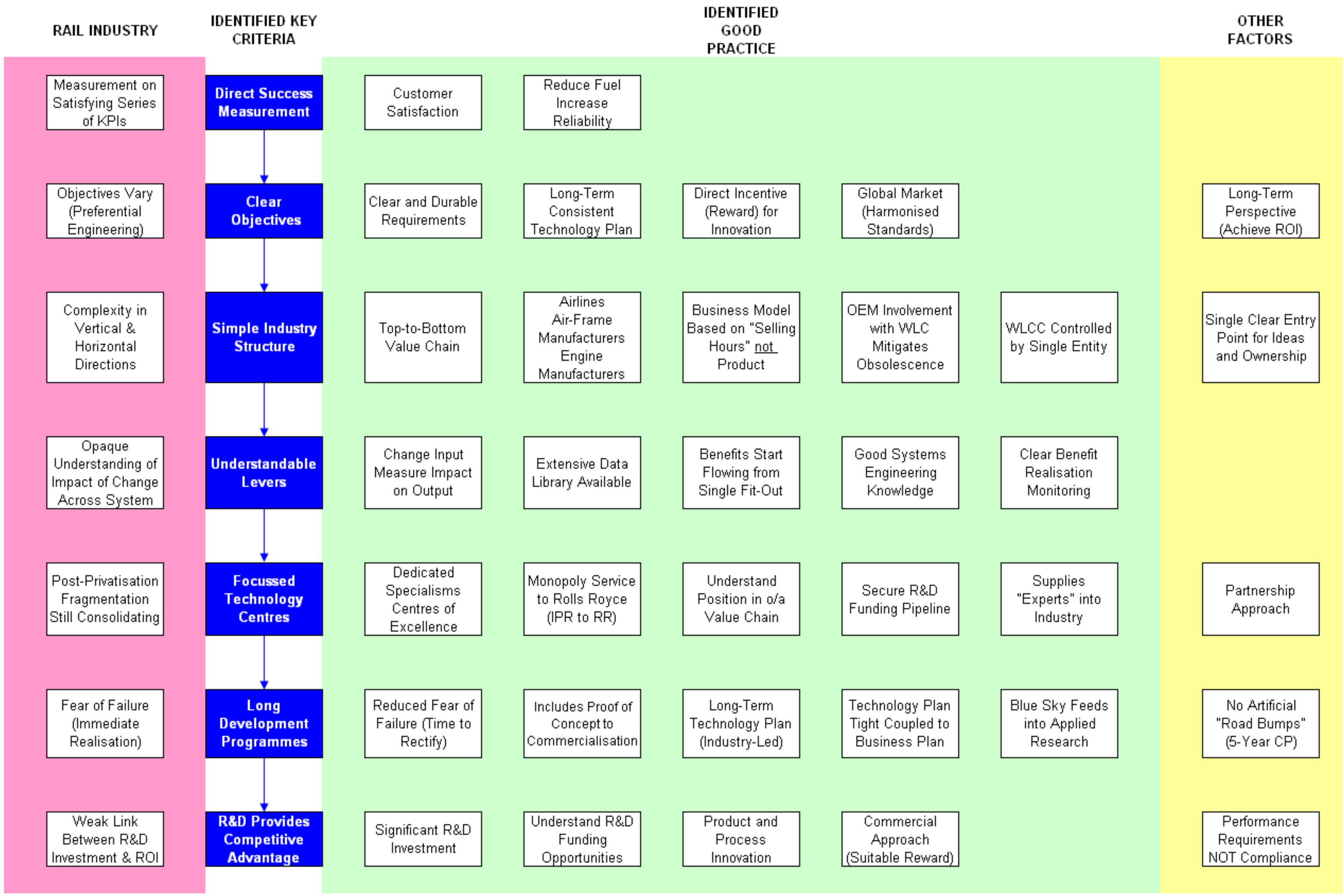
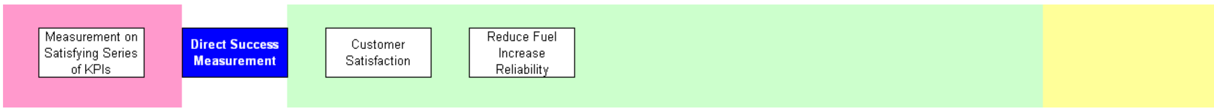


Figure 1: Innovation Process

2.3 Specific Issues

The following sub-sections consider each of the identified criteria (or "rows" in the above diagram). They also identify some of the key improvements already being made to the rail industry's approach.

2.3.1 *Direct Success Measurement*

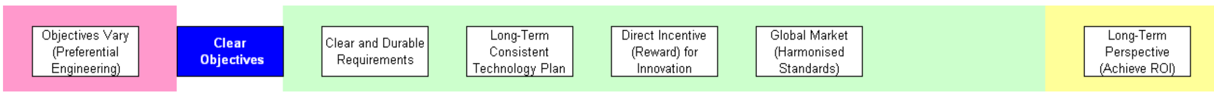


The airline industry has a clear feedback on ***customer satisfaction***: passengers arriving safely and on-time at their destination having paid a price that they perceive as reasonable. If the airlines are considered as the customer, then the primary measurement of success is achieving a reduction in weight as this has a direct correlation with cost by reducing fuel consumption.

In comparison, success in the rail industry is measured through ***satisfying a series of key performance indicators***. It is more difficult to understand success from these indirect measures. Some of these indicators can potentially provide perverse incentives rather than encouraging the required behaviours.

The use of performance indicators is partly as a result of the regulatory nature of the industry. It is also perceived as being a result of the lack of clarity in the purpose of the industry as it serves both direct customers and government.

2.3.2 *Clear Objectives*



Good practice is seen as having ***clear and durable requirements*** that provide a long-term vision on the industry's requirements. This provides the confidence that returns will be made from investing in research. This facilitates the development of a ***long term technology plan*** that remains relatively stable. It is understood that Rolls Royce's Technology Plan covers a twenty year period, based on an understanding of what needs to be delivered to meet the industry's aspirations. The aerospace industry has been noted as having a "relentless appetite" for innovation.

This long term stability enables the supply industry to assess the ***reward for innovation***, providing an incentive to invest in innovation. The business case for investing is strengthened through the global nature of the industry. ***Harmonised standards*** mean that solutions have a large potential market. The confidence to take a ***long term perspective*** increases the likelihood that suitable returns on investment will be achieved.

In contrast, the railway industry in Britain operates as a separate market niche with its own standards, mainly driven by historical factors.

Commercial timeframes have been relatively short and this has led to a dynamic environment with regularly changing priorities. Several stakeholders noted that ***objectives***

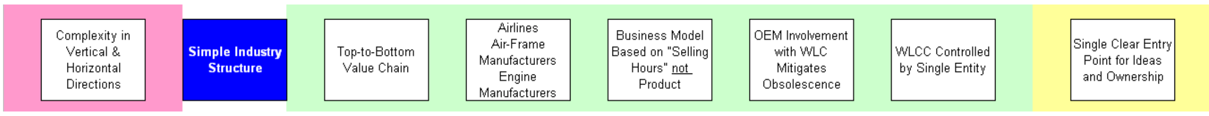
vary as people change positions regularly. A high degree of preferential input has been seen with many local "enthusiasts" driving their own issues, which disappear when that person moves onto a new post.

Network Rail is addressing these concerns by providing improved visibility of the selected areas for innovations. The selected problems are now published on their website. The adopted approach is becoming more formalised to limit the investment spent on local "hot issues".

There has also been a perceived lack of leadership. This is an area where the rail industry has begun improving, with further improvements anticipated over the next year:

- Rail Technology Strategy (RTS) provides a long-term vision for the industry;
- 2012 RTS has greater industry ownership than the previous document;
- Understood that there will be supporting tactical Technology plans developed by Network Rail; and
- Risk of wasted development effort from uncoordinated "sponsorship" of innovation projects by local engineers (that fall by the wayside as the particular engineer moves) are understood and controls are being developed.

2.3.3 *Simple Industry Structure*



The aerospace has developed a simple industry structure, with all the participants clearly understanding the ***top-to-bottom value chain.*** This structure is based on a high-level flow down through ***airlines, air frame manufacturers to engine manufacturers***. This structure is logical, visible and easily understood.

This structure is complemented by a move by engine manufacturers to base their ***business model on "selling hours", not products***. This means that benefit realisation paths can be clearly identified. Competitive pressures result in the demands for low cost high reliability. The provision of a service rather than a product, with consequential involvement of the Original Equipment Manufacturer ***(OEM) throughout the whole life cycle (WLC)***, mitigates the risk to the airlines of having an obsolescent product. The OEM is best placed to develop technology plans that eliminate this risk. This approach of management of the ***WLC by a single entity*** also means that payback is available throughout rather than just at the initial point of sale.

By its nature, the rail industry is complex. It has been described as a series of interlocked systems that are dependent on each other in order to produce good performance level. The systems include traction power, trains, train control and tracks.

Although Network Rail's revised organisation provides some clarity, the industry structure remains complex and not easily understood by organisations from other industry sectors. Complexity exists in both ***vertical and horizontal directions***, i.e. end-to-end process responsibility and geographical scope. This is one of the outcomes of the privatisation path chosen for the industry. There is rarely just a single organisation involved in any activity. As a result:

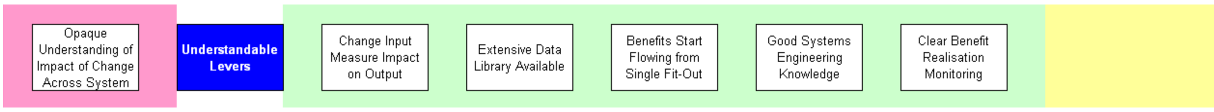
- Potential suppliers find it difficult to identify the correct entry point into the industry for a particular innovation;

- Complexity of structure makes it more difficult to understand how a potential innovation would be implemented;
- Costs and benefits of an innovation are seen by different organisations;
- Whole life cycle costs are met from different budgets making it more difficult to identify a positive business case.

The long life cycle of railway assets introduces several issues as a consequence of the predominant business model being one of purchasing a product rather than a specific output for a defined time period. The first is that the purchaser needs to develop a strategy to mitigate the risk of technology obsolescence rather than the supplier. The second is the length of legacy life locked into the assets that need to be considered as part of any business case for innovation.

The rail industry has also developed its own language and this contributes to the barrier that has been built, impeding the transfer of good innovations from other industry sectors. Progress is being made in translating the industry's requirements so that they are more readily understood by those who operate in other sectors. This will provide the opportunity to leverage benefit from development funding invested in other sectors.

2.3.4 *Understandable Levers*

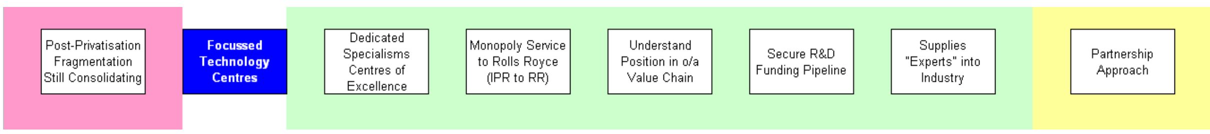


It is difficult to understand the impact of introducing an innovative ***change to the input on the output*** at a rail system level. This can make it difficult to evaluate the potential benefit of any suggested innovation. This is exacerbated as it has been noted that there is a scarcity of this expertise within the rail industry. The integrated nature of the aerospace industry facilitates ***good systems engineering***. It is understood that work has been undertaken to map out the interfaces within the rail system with further work planned for early 2013.

Evaluating the potential impact of changes is more easily identifiable in aerospace as there is an ***extensive data library*** available on historic performance. Rolls Royce routinely monitors and assesses performance data. This monitoring also enables ***clear benefit realisation monitoring***.

A structural advantage that the airline industry has is that the benefits of any innovation are immediately ***realisable following a single fit-out***. The efficiency benefits are seen as soon as any new power plant is fitted to a plane. Within the rail sector, benefit realisation generally occurs following complete rollout across a route and may also require the life cycle of the asset as well.

2.3.5 *Focused Technology Centres*



Rolls Royce has well developed relationships with academic centres. These act as ***centres for excellence***, each having a specific specialism. Amongst the prerequisites that Rolls

Royce require are that the academic organisations provide a ***monopoly service to Rolls Royce***. Rolls Royce also takes ownership of the intellectual property, but they have stated that they have no interest in any spin-off developments. The long-term nature of the relationships provides a relatively ***secure funding pipeline***. This facilitates keeping good quality staff involved and development of longer programmes.

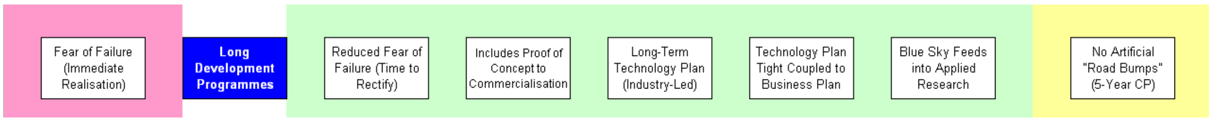
As already noted the supply chain members, including academic centres, fully understand their ***position in the value chain***. This ensures that innovation development is suitably focused.

The relationships have enabled experts to be identified and developed through careers that span both academia and industry. This ***supply of experts into industry*** helps meet the demand for suitably competent people with "state of the art" knowledge.

Prior to privatisation, the rail industry in Britain placed little reliance on academia, with most innovatory development undertaken in-house. This capability was fragmented at privatisation.

The capability within a number of academic organisations has been built. The Rail Research UK Association facilitates a partnership between academic centres and industry. Network Rail has recently identified four academic centres that it is now working with on specific topics. It is understood that the topics will be reviewed to ensure alignment with the RTS and Network Rail's Technology Strategy.

2.3.6 *Long Development Programmes*



The airline industry has a clear understanding that development of new products is a long term activity that is intended to meet the industry's future requirements. This is achieved by having ***long-term Technology Plans***. Each of the main players will have their own technology roadmaps, which are ***tight-coupled to their business plans***.

The rail industry is improving the linkage between business and technology plans. Network Rail have indicated that they will produce their own technology plan, which will link with their Strategic Business Plan and support the industry's Railway Technical Strategy.

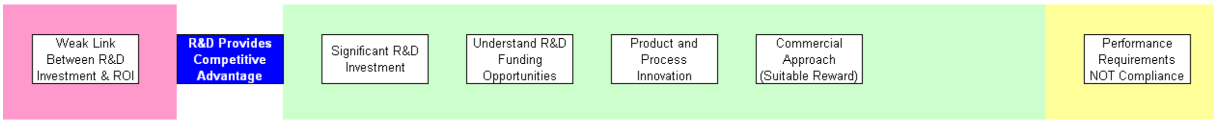
The integration of long-range business and technology planning provides visibility of ***blue sky research feeding through into applied research***. A portfolio of innovations is required as the nature of research activity is that nothing is certain and there will be failures. This acceptance means that there is ***reduced fear of failure***. This appreciation of the long-term nature of the industry spreads beyond the organisations themselves. There is an acceptance that development programmes will require time to rectify issues as they arise. The latest products (Boeing 787 and Airbus 380) have suffered delays, but without great publicity.

There is greater impact and visibility of new rail systems not being commissioned when planned. The failure of a newly installed railway signalling system results in significant media pressure. This fear of failure, particularly at a personal level, is widespread within GB Rail and is seen as an inhibitor to innovation.

Another factor is the potential constraint introduced as a consequence of the industry working to five-year control periods. This may produce an ***artificial "road bump"*** as the industry changes objectives and reassesses its investment priorities. Many innovative ideas require investment in one control period in order to produce a return several control periods later. It is not entirely clear that the current processes are able to include easy consideration of this issue.

Another issue that might be related to the fear of failure is the difficulties seen in trying to develop an innovation through ***proof of concept to commercialisation*** in the intended operating environment. This represents the progression through the middle technology readiness levels and is known as the "Valley of Death". Again, this issue is the focus of attention from Network Rail and other industry bodies with a number of initiatives being deployed to remove the blockage.

2.3.7 *R&D Providing Competitive Advantage*



The airline industry appears to have a much greater appreciation of the competitive advantage provided by research and development than the rail industry. This has resulted in the industry making ***significant R&D investment***. The value of this investment is leveraged by a good ***understanding of R&D funding*** mechanisms, enabling the industry to obtain a significant proportion of the available funds. Some of this difference in attitude can be explained by the clarity provided by the previous criteria discussed above. It has also been noted that organisations with shareholders face greater pressure to invest in new products and services in order to provide opportunities to retain their share value.

One reason may be the strong association with the construction industry. Implementation of innovation is not one of the strengths of this industry either, as identified by the Treasury's recent Infrastructure Cost Review. The review noted that innovation was focused at a tactical level, i.e. project by project basis.

However, these issues are being addressed. Structures and schemes are being put in place by Network Rail, RSSB, RIA and other industry groups that will encourage innovation and provide a number of funding paths. Guidance is being developed that will enable organisations to identify the most appropriate scheme for their circumstances. The target is to significantly close the gap between the rail industry's level of investment in research and the levels accepted as good practice, i.e. improve from the current levels of0.5% to 1% of turnover up to 3% to 5% of turnover.

Rolls Royce undertakes both ***product and process innovation***. In general, improvements to the manufacturing process are easier to implement and provide better returns on investment.

Several of the input sources used by this study noted that there is a perception that the ***commercial approach*** seen in the rail industry is an inhibitor to innovation. This is due to a belief that there is an inequitable sharing of risk.

Another aspect of the rail industry commented on is the low use made of ***performance requirements***. Most specifications are prescriptive and require absolute compliance. This does not encourage investment in the development of innovative solutions to problems.

2.4 Industry Changes

The industry is in the midst of a number of significant changes that may impact on its approach to innovation. One is the devolution of Network Rail's organisation into ten Routes.

This has introduced competition, with each of the Routes being encouraged to perform better than its peers. This is seen as encouraging the adoption of innovation and encouraging the organisations to be more open to potentially good ideas.

Each Route will also be looking for a way of performing better than their peers, so there will be an incentive not to share good ideas and practices. This tendency may also lead to the same idea being developed independently by several Routes at the same time. The intended governance is not yet clear, as this may mitigate these risks.

2.5 Summary

From the above analysis, good practice can be summarised as:

- Direct measurement of success is easily obtainable;
- Long-term objectives available that target innovation based on future requirements;
- Simple industry structure so that benefit sources are easily identifiable and potential solutions can be selected from other industries as applicable;
- Adopt a systems engineering approach so that the impact on outputs from changes to inputs can be reliably predicted;
- Focused technology centres harness specialists to work on programmes to solve specific issues based on latest thinking;
- Major improvements require long-term innovation programmes, that will encounter failures en route;
- Investment in innovation to be encouraged if it provides competitive advantage.

There are plans in place that will improve the rail industry's innovation performance as noted in the sections above. These are intended to provide the right environment to encourage innovation and provide the long-term stability that enables these plans to be implemented and deliver the required results.

In assessing the current rail industry's capability to innovate it was noted that there have been significant developments over the last few years. In addition to those already mentioned, work is on-going in a number of areas including:

- Developing a strategy that flows through from a long-term industry level vision;
- Linking business, technology and product strategies;
- Improving visibility of the problems that require solutions and ensuring that these form the focus for innovations;
- Improving links between academia and industry to leverage benefits;
- Maximising the research funding options available to the industry;
- Developing and support networks to facilitate realisation of innovative ideas.

This on-going development of innovatory capability in the industry should be encouraged and continued.

3.0 INNOVATION SCAN

3.1 Basis of Scan

3.1.1 *Approach*

The second part of this review was to undertake a scan of the potential areas of innovation. This was undertaken with input from:

- Review of products and services exhibited at Innotrans;
- Review of 2007 RTS and the emerging views of 2012 RTS;
- Themes being developed by other industries that appear transferable;
- Discussions with various stakeholders;
- Attendance at Conferences; and
- Literature reviews

The scan was undertaken without constraints and without any explicit consideration of the issues facing the industry, i.e. a list of potential solutions were collected. This meant that ideas were collected regardless of potential issues such as:

- Technology readiness and likelihood of success;
- Potential overlap with other ideas; and
- Potential overlap with existing initiatives.

3.1.2 *What is Innovation?*

As indicated previously, the dictionary definition of innovate from the online Oxford Dictionaries is:

> *"Make changes in something established, especially by introducing new methods, ideas, or products".*

Other definitions include the requirement to add value through the changes. The approach used in this study has been to identify ideas or changes to the existing approach within the GB Rail industry. This includes:

- Plant;
- Technology;
- Products
- Materials; and
- Processes.

This means that the compiled list includes ideas that are well known and proven, but not yet deployed. Some of the identified processes are also potentially described as "good asset management practice" rather than innovation.

3.2 Filtering Process

The second stage of the process was to filter the list of potential innovations to identify a list of items likely to provide a positive contribution during CP5.

A set of criteria were initially applied as the first filter that identified those that were outside the study remit. This was due to one of two reasons:

- Initiative already seen to be included within the current portfolio (particularly those already under development and implementation by Network Rail);
- Initiative classified as "Blue Sky" requiring either significant further development or a payback period that significantly exceeded the length of the control period.

This filtering process produced a list of potential CP5 innovation projects that could meet the criteria of making a positive contribution before 2019.

A further set of potential constraints were then considered in the filtering process in order to produce a short-list of innovations. This filtering process considered criteria such as:

- Ease of transferability (idea already trialled in rail industry, either in Britain or elsewhere);
- Level of investment required (equipment, training, approvals); and
- Potential barriers (due to significant changes required to culture or standards).

However, in practice, the primary criterion used was the assessed size of the potential benefits. This identified a small number of potential innovations that were subject to an initial financial assessment as described in Section 4.

A full listing of the innovation ideas is included as Appendix A of this document.

3.3 Initial Observations

The diagram below depicts the process and some of the issues that were identified as a consequence of this analysis.

The purpose of the filtering process was to identify the potential innovations that fitted into the green area. These were innovations that were likely to provide a significant return on investment during CP5. In addition, a filter was applied that identified innovations that were evaluated as having few constraints. The constraints considered are as noted above.

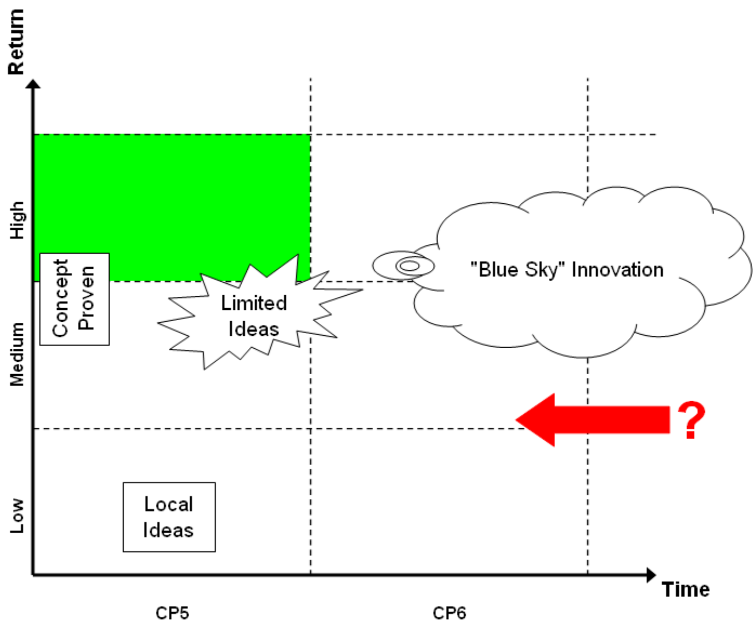


Figure 2: Innovation Scan Framework

The diagram identifies the following issues:

- "Red arrow" indicating that time until innovatory benefits are realised could be an artificial constraint as there are methods of accelerating development programmes if required;
- "Concept proven" indicates that many of the identifiable innovations likely to provide a positive contribution during CP5 are already well known;
- "Limited ideas" indicates a low number of new potentially high-value innovations were identified for CP5;
- "Local ideas" identifies a group of innovations that are likely to improve performance, but only have a localised impact, i.e. low returns;
- "Blue Sky Innovation" was defined as innovations that were unlikely to impact on Network Rail's performance until CP6 at least.

Each of these areas is considered further below.

3.3.1 *Time Period*

This issue is indicated in Figure 2 by the red arrow and question mark.

A number of the innovation ideas were seen as "blue sky". This was mainly due to the low level of technology readiness, particularly when viewed from a railway industry perspective if the development is occurring in another sector. However, during discussions, it has been noted that innovations that appear to provide good benefits may be brought to maturity earlier by increasing the resources available to the development team.

This can achieve earlier deployment in some cases. However, the items included as "Blue Sky" innovations are those that remain assessed as unlikely to achieve a positive benefit during CP5. In several cases, these innovations are further developments to those that are currently being finalised and implemented. Others require an extended time period before the benefits exceed the initial investment costs.

3.3.2 *Concept Proven*

A number of the identified innovations relate to improvements that have already been identified by the industry, but not yet introduced into the "business-as-usual" environment. Some of these concepts have been proven on other railways or in other industry sectors. This group forms a high proportion of the prioritised list of innovations as a consequence of the limited ideas issue described below.

3.3.3 *Novel CP5 Innovations*

This issue is indicated in figure 2 by the "limited ideas" graphic.

The innovation scan identified few new ideas that could be deployed to positive effect during CP5. Many of the items included within the green area are in fact "well known but not deployed" ideas.

It is believed this is because many new ideas will be reaching full development. As such, the developers will be protecting their investment and intellectual property in order to achieve a return on their investment. This means that they will not be publicising their concepts at this stage.

3.3.4 *Local Ideas*

A number of the identified innovations have been categorised as “local ideas”. Although potentially good innovations, the impact of their introduction is unlikely to result in a significant impact at a national level because of their limited scope of application.

3.3.5 *Process Innovation*

There are also a limited number of innovative processes that have been identified within the scanning process. This is seen as a consequence of good process being specific to the environment and organisational characteristics within which they are used. As such, few are generic and deployable as good practice across the industry.

Notwithstanding this observation, realising the full benefits from an innovation may require changes to existing processes. Several of the prioritised innovations relate to the improvement of processes in order to leverage more benefit from the implemented change.

3.3.6 *Initiatives Already Under Consideration*

The study team have taken a view on those identified innovations that are already part of the industry’s existing portfolio of implemented initiatives that are being rolled-out, or those planned for implementation and rollout during CP5. In the main, this category consists of innovations already believed to be being developed by Network Rail. Further details of each are included within Appendix A1. They are summarised below using three generic headings:

- Plant:
    - Automated Complete Drain Maintenance Process;
    - Robotic Welding;
    - Road/Rail Materials Handling;
    - Utilise Full Machine Capacity;
    - Automated S&C Inspection Vehicle;
    - Automated Inspection;
    - Ballast Under-Cutter (Gopher);
    - RailVac;
- Materials and Equipment:
    - “Plug and Play” Signalling Equipment;
    - Anti-Theft Cables;
    - Improved Traction Power System;
    - Improved Pad Design;
    - Off-Site Manufacture;
    - Concrete Canvas;
    - Improved POE Design;
    - Improved OHLE Equipment Design;
- Systems and Process Improvements:
    - Consolidated Train Control Centres;
    - Integrated System Level Planning Software;
    - Risk-Based Maintenance;
    - Data Mining;
    - Data Consolidation.

There is not full visibility of this area and items might have been excluded that should have been included, or vice versa.

3.4 Blue Sky Themes

A number of "blue sky themes" were identified within the set of potential innovations. These are innovations where the technology is still developing. In most cases, this technology is being developed in other industry sectors, or requires further validation and development before performance improvements can be obtained within Britain's railway environment.

These innovations have been grouped into five main areas in the diagram below. Further details of each potential innovation are included as Appendix A2 of this document.

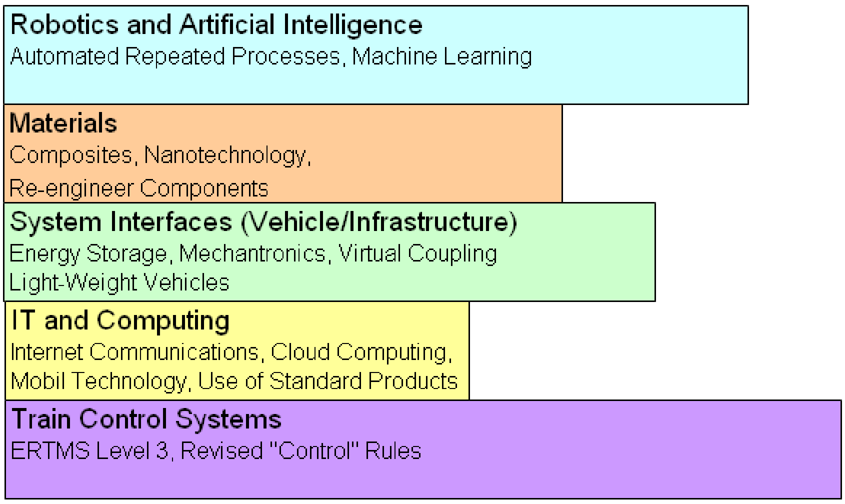


Figure 3: "Blue Sky" Themes

The following sections provide an overview of each of these areas.

3.4.1 *Robotics and Artificial Intelligence*

This is an approach that has been adopted in other industry sectors. It is particularly useful with repeatable activities, with Network Rail already developing the concept for activities such as robotic repair of rail surface defects. The next phase of development identified from the innovation scan is providing artificial intelligence to the machines.

The initiatives included within this generic area are:

- Machine learning;
- Generic robotic technology;
- Unmanned aerial vehicle (UAV) for surveys.

3.4.2 *Materials*

Materials technology is advancing rapidly. Several drivers have been identified, including the increased demand and scarcity of natural resources. The availability of high-strength light weight materials is already being explored by the rail industry, with notable examples being their use for bridge and signalling structures.

In addition to these general developments, research is also being undertaken within the rail industry to better understand the requirements of various infrastructure components. There is currently a particular focus on ballast.

The initiatives included within this generic area are:

- Advanced composite materials;
- Nanotechnology for anti-graffiti glass;
- Nanotechnology for rail friction management;
- Maintenance free rail;
- Optimum sleeper shape and material;
- Increased ballast stiffness;
- Improved ballast grading;
- Under ballast pads.

3.4.3 *System Interfaces*

A group of innovations have been identified that are focussed on improvements to rolling stock. Ultimately, these improvements will facilitate achievement of enhanced operational performance at lower levels of infrastructure investment. Some of these innovations are already well developed. However, their impact has yet to flow through and be realised in enhancement designs.

The initiatives included within this generic area are:

- Regenerative braking;
- Hybrid vehicles;
- Energy storage;
- Mechatronic bogies;
- Active pantograph;
- Driver advisory systems;
- Virtual coupling.

3.4.4 *IT and Computing*

This has been an area of significant recent technological development. The innovations listed below represent potential transfers of commercial developments into the rail industry. The next step is either to ensure that the equipment is sufficiently robust and secure to be used for safety critical applications, or separate out the safety critical aspects of the potential applications.

The initiatives included within this generic area are:

- COTS IT for SCADA;
- COTS IT for signalling;
- COTS IT for control of level crossings;
- Radio-based level crossing controls;
- Cloud-based IT;
- IT developments in other industry sectors.

3.4.5 *Train Control Systems*

The industry already has plans in place to adopt the latest technologies to control the movement of trains. However, there are a number of organisations who are already looking at the capability that might be offered by the next generation of systems.

The initiatives included within this generic area are:

- Virtual lineside signalling;
- ERTMS level 3 control systems;
- Signalling beyond ETCS/traffic control;
- Wi-Fi based communications for train control;
- Re-engineer operating rules.

3.4.6 *Other Innovations*

The group of "blue sky" innovations also includes several proven concepts that have been classified within this category as implementation and/or realisation of benefits that are likely to be beyond CP5. This is a consequence of either the time required to generate a return within CP5, the current maturity of the innovation or recent investment in current technology.

The initiatives included within this generic area are:

- Formation rehabilitation train;
- Automated drainage cleaner;
- Monitoring bridge deflections;
- Adoption of fault tolerance philosophy;
- Use of Chinese supply chain.

3.5 Filtered Innovations

The list of potential innovations was filtered to select a short-list of innovations for which an outline financial assessment was undertaken. The short list is considered in the following section of the report. The following sub-sections provide an indication of those innovations that were filtered out at this stage. Further details of these are provided in Appendix A3.

Although as previously described a number of criteria were applied to the list of innovations, it was found that in practice the impact of two predominated in this filtering process:

- Size of potential return during CP5; and
- Implementation period until start of benefit realisation.

The size of the potential return was assessed as being from high to low. It was found that there was a natural break with a clear group of innovations in the high category. The time until realisation of benefits was affected by two main factors:

- Innovation immediately available for transfer and implementation; and
- Further development, approval and production required.

The output from this filtering process was tabulated using the framework indicated below and items that appeared in each of these quadrants are listed in the following sections. Appendix C contains a tabulated set of details for each of the innovations.

It should be noted that items that were assessed to provide a relatively low return may have a high cost-benefit ratio as they require lower levels of investment.

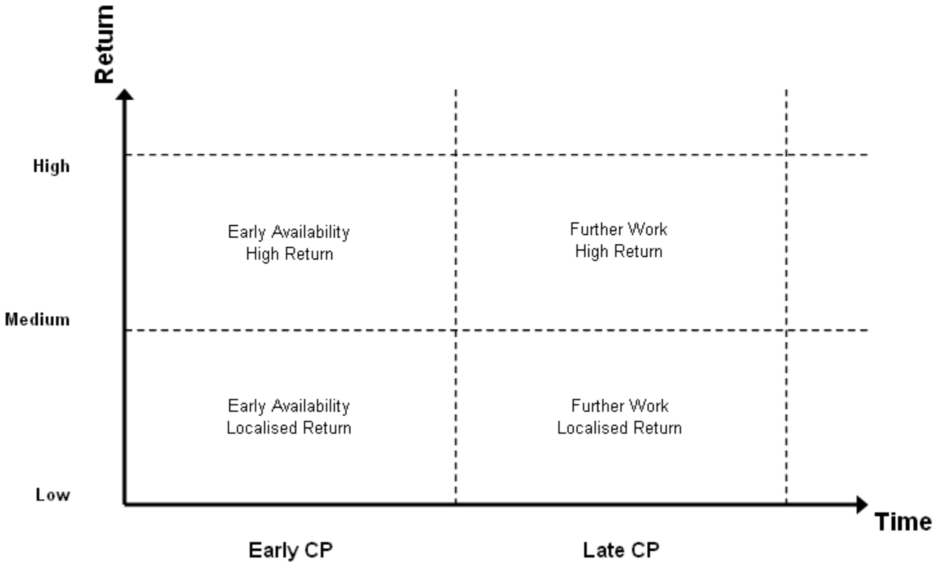


Figure 4: Innovation Filtering Framework

3.5.1 *Early Availability, Potentially High Return Innovations*

The innovations within this quadrant are generally already developed and available for widespread rollout. The following were filtered into this quadrant:

- "GRIP-Lite" process for simpler projects;
- Reduced design costs from standardised designs;
- Composite structures;
- Renewable energy;
- Decision support to optimise wheel-set maintenance;
- Variable stiffness suspension bushes;
- Integrated monitoring systems;
- Trolley-based measurement systems;
- Dataloggers and transducers;
- Thermal imaging cameras;
- Reliability monitoring at "hotspots";
- On-train monitoring data;
- Extended use of UTGMS;
- BIM models;
- Camera controlled switch-heaters;
- Intelligent switch heaters;
- Energy-saving switch-heaters.

3.5.2 *Early Availability, Potentially Localised Return Innovations*

As with the first quadrant, the innovations within this quadrant are generally already developed and available for widespread rollout. However, these innovations are likely to have a lower impact on overall costs. The following innovations were filtered into this quadrant:

- Aluminium conductor rail;
- Fixed cameras;
- “Spider” mechanical climber;
- 4-D modelling to assess interfaces;
- Radiographic NDT rail testing;
- Eddy-current NDT rail testing
- Motion sensors for electrical equipment;
- Remote radio controlled plant;
- Standardised level crossing surfaces;
- Monitoring wheel/rail interface;
- Weigh-in-motion sensors;
- 3-D model interface to tamper;
- Heater stressing;
- Track geometry measurement trolleys;
- “Deploy and forget” sensors;
- Rail stress monitoring;
- Luge trollies;
- Surface lubrication policy;
- Electronic lubrication systems;
- Top-of-rail lubrication systems;
- Intelligent lubrication systems;
- Frozen fastener remover;
- In-pipe lining systems;
- Ballast shoulder consolidation;
- LED lights on stations;
- On-site vehicle maintenance;
- Rail web-tuners.

3.5.3 *Further Work, Potentially High Return Innovations*

The third quadrant contains those innovations that are unlikely to be available in the early part of the control period. This is generally either because further development or approvals are required or significant changes to processes in order to realise the benefits. The following innovations were filtered into this quadrant:

- High-speed grinding;
- Output-based standards;
- Tram/train standards;
- “Skako” train;
- Clay embankment slope decision support;
- “Hertzog Plus” train.

3.5.4 *Further Work, Potentially Localised Return Innovations*

As with the third quadrant, the fourth quadrant contains innovations that are unlikely to be available until later in the control period. These innovations were assessed to have a lower impact on overall costs, either due to the localised nature of the innovation or the extended timescale before benefits will be realised. The following innovations were filtered into this quadrant:

- 3-D geo-structural modelling of rock walls;
- Pipe-nails incorporating drainage;
- Low adhesion monitoring;
- Track-lifting device;
- High-efficiency weed-killer train;
- Reliable switch-toe bearers;
- Strengthened rails;
- Rail steel composition;
- Next generation multi-purpose vehicles;
- Rail milling;
- Shoulder ballast cleaner;
- Ditch cleaner;
- Slab-track;
- Modular slab-track.

4.0 ASSESSMENT

4.1 Basis of Assessments

An initial assessment of the filtered innovations has been undertaken. These are not intended to be full business cases. They are intended to provide an indication of the potential value available.

The assessments have been undertaken primarily using data from the public domain, in particular Network Rail's Regulatory Accounts for 2011/12. This information has been supplemented by information from suppliers for particular innovations as appropriate.

The approach taken is very high-level. The assessment includes consideration of the major items of investment required and the sources of potential benefits. No potential benefits that will be realised after CP5 have been included within the figures, although the existence of such benefits has been indicated in a number of cases. A simple approach has been taken with all the investment costs included in the assessment taken during CP5.

An illustration of the nature of the assessment undertaken is provided by considering the mobile maintenance units. No costs have been included for the operation of the units. However, neither have any savings been included for the reduction in road fleet operating costs due to the revised delivery of staff, materials and plant to site using these units.

4.2 Output from Assessments

Further detail for each of the selected innovations is included within Appendix B. This includes an indication of the basis used to calculate the financial assessments. The following sections provide a summary of each of these innovations.

There are no signalling related innovations included within the list. The reasons for this are seen as being as a result of:

- Major innovations of ERTMS and traffic control systems that have already been incorporated within the industry's plans;
- Short-term innovations such as the adoption of a modular approach and introduction of "plug and play" concepts are part of CP4; and
- Complexity of train command and control, plus the safety critical nature of these systems, means that the next generation of solutions are unlikely to arrive in time to influence CP5 costs.

4.2.1 *Use of GPR to Optimise Ballast Renewal and Formation Rehabilitation*

With continual technology progress, the use of Ground Penetrating Radar to drive ballast renewal and formation rehabilitation work has been developed further by other Infrastructure Managers. It can also identify potentially collapsing culverts.

Minimal development is required, with the main requirement being the development of a suitable end-to-end processes and full implementation. The LADS (Linear Asset Decision Support tool) development as part of the ORBIS project will support realisation of the benefits.

The primary benefits are:

- Shorter lengths of renewal specified to correct limits;
- Reduction in maintenance through better quality specification;
- Additional track asset life cycle; and

- Reduced risk of track collapse.

4.2.2 *Non-Intrusive Crossovers (NICS)*

The non-intrusive crossover (NICS) is a proprietary system that has been developed. It provides a temporary crossover facility that can be used during engineering works. It does not form part of the infrastructure controlled by signallers.

The equipment is already available and has been recently used on another British Infrastructure Manager's network. Further safety approvals will be required, which are estimated to delay implementation until 18 months into CP5.

The primary benefits from the use of NICS are:

- Increased possession availability leading to higher productivity;
- Increased train capacity on possession work using single line working approach;
- Connection of virtual sidings allowing engineers' equipment to be stabled closer to the site of work;
- Reduction of run round times in possessions; and
- Enables single line working on possessions.

4.2.3 *Timber Bearer Refurbishment*

This innovation involves a process to rehabilitate timber bearers in switch and crossing layouts, restoring alignment and extending the asset life. A suitable system has already been developed and initial trials undertaken in Britain. Application of the system could also be extended to plain line track on timber sleepers. This will reduce the premature replacement of timber bearers being replaced. It will also reduce the wear of other S&C components by providing a solid foundation, removing the relative movements.

The necessary investment in training and equipment has been made by the supplier. Benefits are assumed to be available from the start of CP5.

The benefits are:

- Life extension of wooden sleepers / bearers on both S&C and plain line track;
- Returns track to original gauge and alignment; and
- Prevents excessive wear on the ironwork thus eliminating premature renewal.

Additionally, there will be renewals savings from life extension of S&C units, but these savings will be seen in later Control Periods.

4.2.4 *Modular Level Crossing*

Modular one-piece systems exist and are in use by other European Infrastructure Managers. It is understood that at least one system has been trialled in Britain.

The following benefits are obtained:

- Reduced maintenance (particularly tamping);
- Reduced inspection;
- Reduction in road closure requirements;
- No replacement of individual components required; and
- Longer life cycle.

Other intangible savings include improved safety for both rail and road traffic by eliminating the risk of individual units moving free. The service life is in excess of 30 years, compared to

12 years for a traditional crossing system. It is designed to be virtually maintenance free for the life of the system.

4.2.5 *On-Train Measurement Systems*

Improved use of train mounted equipment that regularly monitors the condition of the overhead line system will provide engineers with a better indication of impending failures. This will improve maintenance efficiency, particularly as better visualisation systems are provided to local engineers.

Although the technology is available, there will need to be an approval and installation programme. It is estimated that a period of 18 months will be required before the equipment can be deployed into full service.

The primary benefits are:

- Eliminate early and late maintenance intervention;
- Improved understanding of system interfaces e.g. impact of a track fault on the traction power system; and
- Reduced need for manual inspection.

The assessment is based on the performance of the existing electrified railway. No consideration has been included of the increased efficiency available by extrapolating the reduced unit costs across the planned extension of the electrified network.

4.2.6 *Staff Protection Systems*

The Dutch use an advanced T-COD system to provide quick and simple protection for staff working on track. These can be permanently installed and also provide the ability to undertake more detailed assessments. The system reviewed has been approved for use in Britain and is under further consideration from a safety perspective. However, it is not yet being extensively used on Network Rail infrastructure. Benefits are assumed to be available from the start of CP5.

The financial benefit is obtained through increased productivity from the capability to safely mobilise sites in a shorter time.

These savings may duplicate those assumed within the possession improvement programme. On the basis of this, the calculated benefits have been halved to provide a conservative view.

4.2.7 *Undersleeper Pads*

Adding pads to the underside of sleepers extends track component life and reduced ballast degradation. The product is already available and in use elsewhere in Europe. It is assumed that specific approval for use on Network Rail's infrastructure will be required.

The assessment is based on achieving a reduction in the tamping required as a result of lower rates of ballast degradation. The benefit will be realisable towards the end of the Control Period, as the pad-fitted sleeper population increases. Further savings will be made in future control periods as the benefits from extended asset life are realised.

4.2.8 *Application of Overhead Line Technical Developments*

A number of technical innovations have been identified that improve the performance of the overhead line system. These include on site cold wire welding of contact wires and automatic tensioning devices.

All the identified innovations already exist, but they will need approval and installation into the existing system. It is forecast that it will take two years to develop and approve, plus a period for initial rollout. It is anticipated that there will be a progressive campaign rollout to target existing hot-spots.

Re-engineering the existing system with this type of innovation will reduce both the likelihood and impact of component/system failures, i.e. the annual costs associated with dewirements.

4.2.9 *Refurbish and Cascade Materials*

The major elements of this development are the creation of processes that maximises the potential opportunities provided by refurbishment technology. It is envisaged that investment costs would be minimal as there are already various depots set up to accommodate serviceable material

The main benefits are seen as a reduction in the amount of premature scrapping of reusable components (particularly ironwork) and the potential to reuse serviceable S&C units following refurbishment. From observations across the network, the opportunity exists to extend the rail cascade programme. The assessment assumes that Network Rail already has processes in place that fully utilise the available opportunities to recycle ballast and cascade serviceable sleepers.

POST DRAFT INPUT

Review of Network Rail's SBP document summarising their proposed efficiency savings for CP5 notes a further saving of £8.3m has been included within their plans. This has been discounted from the assessment.

4.2.10 *Improved Monitoring of Bridge Condition*

Several innovations have been identified that will improve the capability to manage condition and degradation of bridges. These are based around better modelling to provide improved decision support to asset managers and the use of camera-based systems that are capable of monitoring bridge scour issues.

The software and hardware components of this initiative are under development. It has been assumed that initial production versions will be available for use within the first year of CP5.

The potential benefits from improved monitoring include:

- Undertake heavy maintenance/refurbishment instead of renewal;
- Avoid repairs following scour damage; and
- Avoid track closure waiting for water to drop and allow divers to inspect.

The risks associated with bridge scour are seen to be increasing as a consequence of changes in the climate.

4.2.11 *Mobile Maintenance Units (MMU)*

These units provide the capability for staff to travel directly to site with all the necessary materials, plant and safety facilities to enable maintenance repairs to be undertaken. Designs already exist for these vehicles. It has been assumed that it will take at least 18 months to procure and gain safety approval for use on Network Rail's infrastructure.

Productivity improvements are obtained from:

- "Adjacent Line Open" operations without need for additional protection;

- Immediate mobilisation on site;
- Ability to work in an environment that provides protection from the weather; and
- All tools, lighting and materials to hand

POST DRAFT INPUT

It is understood that the review of Network Rail's activities on the West Coast Main Line led by Chris Gibb included a recommendation to adopt this technology. However, this innovation has not identified in the SBP document summarising Network Rail's proposed efficiency savings for CP5. As such, it has been retained within this portfolio of potential innovations.

4.2.12 *Plastic Sleepers*

Plastic sleepers made from recycled materials are being installed by a number of infrastructure managers in a variety of circumstances, from transit systems through to heavy haul freight. It is believed that they would be available for use from the start of the Control period.

The main benefit obtained from using plastic sleepers is that they provide the same characteristics as a timber sleeper, but they do not rot. This increases there useful life and provides a virtually maintenance free product. They are also sustainable through use of recycled materials.

Note that a conservative view has been taken in assessing the benefits of this innovation: It has been assumed that the savings would only be realised in control periods beyond CP5, as renewal rates decrease due to the increased asset life. This innovation has been retained within the portfolio to illustrate that some innovations will only produce a positive benefit over an extended period due to the average life of the assets.

4.2.13 *Repadding Machine*

The concept of a machine able to repad track is well advanced. It is estimated that a further year is required to complete the design and necessary approvals. It is understood that there is forecast to be a significant increase in changing pads during CP5 as a result of the changes in asset policy.

The benefits are achieved through a reduction in manpower and higher productivity from mechanisation of the repadding process.

4.2.14 *Specialist Gantries*

Specialist gantries have been developed that travel on a rail vehicle with replacement switches or crossings. They self-unload and are able to install the new component with minimal manual intervention required. It is estimated that a further 18 months is required to complete the design and necessary approvals.

The benefits are:

- Removes all road transport of S&C units;
- Removes requirement for road rail machine hire;
- Reduces number of possessions required; and
- Reduction in manpower.

4.2.15 *Benefits Summary*

The assessments for these innovations are summarised in the table below. From the information available to the study team, it is not believed that these innovations are included within the CP5 plans, other than as commented in the sections above.

	Title	Develop Period	CP5 Benefits
1	Use of GPR	Nil	£11m
2	Non-Intrusive Crossover	18 months	£4m
3	Refurbish Timber Bearers	Nil	£12.5m
4	Modular Level Crossings	Nil*	£0.5m
5	On-Train Measurements	18 months	£3m
6	Protection Systems	Nil	£5m
7	Undersleeper Pads	Nil*	£1.5m
8	OHLE Components	2 years	£1m
9	Cascade Materials	Nil	£15m
10	Model of Bridge Behaviour	1 year	£9.5m
11	Mobile Maintenance Units	18 months	£15.5m
12	Plastic Sleepers	Nil	Negligible
13	Pad Replacement Machine	1 year	£3m
14	Specialist Gantries	18 months	£12m
		TOTAL	£93.5m

Although it has been assessed that no delay due to further development work is required for modular level crossings and under-sleeper pads, a reduced benefit period has been included in the calculations. These are indicated by an asterisk in the table above.

The list above should be viewed as a generic portfolio as any of the indentified initiatives may not progress through to full implementation. However, this portfolio is seen as typical of the opportunities available at any particular time. It is assumed that this is a portfolio that will deliver improvements during CP5 and any innovations that emerge during the latter half of the control period will deliver benefits in CP6.

4.3 Initial Considerations

4.3.1 *Novelty and Readiness*

The development period for these items is generally short and the degree of novelty is generally low. This is as a result of the filter criteria that were applied, which required the benefits within the control period to exceed the investment requirements.

4.3.2 *Other Initiatives*

As indicated in Appendix A, a number of other innovations that were identified have been assessed as already being included within the industry's plans for CP5. The assessment process has also identified potential overlaps with other areas already considered as part of the periodic review process, particularly possession utilisation.

4.3.3 *Risk of Realisation*

As already indicated, most of the assessed innovations are already well advanced in their development. As a consequence there is a reduced risk that they might fail to deliver as anticipated, but the risk remains. The list is seen as indicative though and other innovations will appear to replace those that fail. Realisation of the benefits from any innovation is the key aspect.

4.4 Value from Innovation

4.4.1 *Innovation in Rail Industry*

The recently published "Industry Rail Technical Strategy 2012 – The Future Railway" includes a section on innovation. This notes that the industry needs to innovate in order to meet the future demands of customers and investors. The document identifies a number of initiatives that have been put in place to improve the industry's innovative performance:

- Establishing the Enabling Innovation Team;
- Inclusion of funding for CP5 within the HLOS statement;
- Development of several programmes in collaboration with the Technical Strategy Board, such as the Accelerating Innovation programme;
- Industry-led initiatives such as RIA's Unlocking Innovation programme; and
- Involvement in European programmes such as Shift2Rail.

The document also notes that the rail industry's levels of investment in innovation have been around 0.5% of turnover, whereas best practice is seen as 3.5%. No indications are given of the expected rates of return from this investment.

The Rail Value-for-Money study identified potential industry savings of £190m from improvements in the areas of safety, standards and innovation.

4.4.2 *Lessons from General UK Industry Experience of Innovation*

Innovation is widely recognised as one of the main drivers of economic growth. As such, it is seen as a strategically important area of investment for the government. However, the impact of innovation is generally reviewed in terms of increased turnover from new products and services, rather than a reduction in costs to sustain existing output levels.

The "Innovation and Research Strategy for Growth" (December 2011), published by the Department for Business Innovation and Skills (BIS), reports that innovative businesses grow twice as fast as businesses that fail to innovate, both in employment and sales. This was based on research undertaken by National Endowment for Science, Technology and the Arts (NESTA) and published in their document "The Vital 6 per cent" (2009). Their econometric analysis indicated that innovative organisations had a 4.4% average employment growth rate (2004-07) against an average of 2% for other organisations.

The 2011 Annual Innovation Report, issued jointly by BIS and NESTA, reports similar details. It also concludes that:

- UK businesses' expenditure on R&D as a share of GDP has remained at 1.1% of GDP and slightly down on the share of 1.2% of GDP in 2000; and
- Labour productivity grew by 2.24% per year between 2000 and 2008, with innovation contributing 63% of that productivity growth, adding an average of 1.41% percentage points to productivity growth per year over the period.

The average changes in staff levels have been considered in order to provide an initial indication of the potential opportunity. The figures indicate changes in staff levels of between

2.2% and 1.4%. As rail's average investment levels are only 0.5% rather than UK's general industry levels of 1.1%, the equivalent figures have been reduced to between 1% and 0.5%. If these changes were achieved within rail as a result of innovation, then the calculated range in savings is £7.6m and £3.8m year-on-year for maintenance. This equates to savings of between £57m and £113m during the control period.

4.4.3 *POST DRAFT INPUT: SBP Technical Strategy*

Included within the documentation published by Network Rail in 2013 was an introduction to their Technical Strategy that will be published in June 2013. Network Rail also state that they:

> *"… expect a major part of R&D investment to be in understanding the opportunities to apply existing technologies and preparing those to function at a system level to make them Implementation Ready (IR)."*

This fits well with the initiatives reviewed within this study, most of which are based on available technology.

The document also indicates that Network Rail intends to increase it's investment in innovation to 4% of turnover by the end of CP5, from their current level of 1%. Network Rail anticipates that an average benefit to cost ratio of 5:1 is anticipated. Depending on the rate at which the benefits are realised and the investment rate increases, this broadly equates to a savings in the range £48m to £145m.

5.0 SUMMARY

5.1 Conclusions

The conclusions are as follows:

- Good practice has identified a number of items that need developing in the rail industry to improve the innovation process;
- Much work has been undertaken over the last 18 -24 months within the industry to improve the process;
- An innovation scan has identified many potential areas, from blue sky through to available for deployment;
- A significant number are already perceived as being included in the industry's plans for CP5;
- A shortlist of 14 have been assessed as providing positive benefits in CP5;
- Initial assessment of the potential benefits is £93.5m.

5.1.1 *Innovation Process*

A number of key elements were identified following review of an innovation process that is generally acknowledged to be successful. These were:

- Clear understanding of how to measure success;
- A stable long-term programme that has clear objectives;
- Adoption of a systems engineering approach to predict impact of changes;
- Focused technology centres solving specific issues;
- Competitive advantage provided from innovation.

5.1.2 *Progress in the Rail Industry*

In assessing the current rail industry's capability to innovate it was noted that there have been significant developments over the last few years. These include:

- Developing a strategy that flows through from a long-term industry level vision;
- Improving visibility of problems that require solutions;
- Improving links with both academia and industry to leverage benefits;
- Development of research funding options and support networks to facilitate realisation of innovative ideas.

Further work is planned in the lead-in to the next control period by Network Rail, such as linking their technical strategy to the business and product strategies. There is also an objective to increase research investment to the levels generally accepted as good practice.

5.1.3 *Innovation Scan*

A scan of the potential areas of innovation was undertaken based on the following sources:

- Review of products and services exhibited at Innotrans;
- Review of 2007 Rail Technical Strategy and the 2012 version;
- Discussions with various stakeholders; and
- Literature reviews

The scan was undertaken without constraints and without any explicit consideration of the issues facing the industry, i.e. a list of potential solutions were collected. This meant that ideas were collected regardless of potential issues such as:

- Technology readiness and likelihood of success;
- Potential overlap with other ideas; and
- Potential overlap with existing initiatives.

Over 170 potential innovations were identified from this process.

5.1.4 *Filtering of Innovations*

This list of innovations was filtered to produce a short-list of those that were assessed to have the potential to provide a positive benefit during CP5.

The filtering process resulted in the following groups of innovations:

- Innovations already within the industry's plans;
- "Blue Sky" innovations that require significant further development before benefits will be realised;
- Innovations that will have a limited impact on industry costs;
- Innovations that will not be available for implementation during the early stages of the next control period; and
- Short-list of 14 innovations that have the potential to have a positive impact on CP5, representing a typical portfolio of innovations.

5.1.5 *Assessment of Benefits from Innovation*

An initial high-level assessment of the typical portfolio of 14 innovations was undertaken. This was based on consideration of the major items of investment and resultant savings during CP5. This assessment of a typical innovation portfolio indicates the potential opportunity to provide savings of £93.5m over the control period.

The impact of innovation in other industries is generally reviewed in terms of increased turnover from new products and services, rather than a reduction in costs to sustain existing output levels. However, an indicative assessment indicates that the potential range of savings that could be expected during CP5 is between £57m and £113m.

APPENDIX A: INNOVATION SCAN

The following lists include all potential ideas that were identified during the review.

The code numbers within the titles cross-reference back to the original list of innovations that is included within this document as Appendix C.

A1: Existing Portfolio

1. Automated Complete Drain Maintenance Process (A89)

Mechanised approach to inspection and maintenance (cleaning-out) trackside catchpits and drains.

2. Robotic Welding (A19, C6)

Includes both weld repair and rail joining activities. Pilot/rollout of similar equipment included within CP4.

3. Road/Rail Materials Handling (T23)

Make use of a side-tipping rail-rail dump-cart.

4. Utilise Full Machine Capacity (A56)

Issues include use full facilities on tamper machines such as shoulder consolidator and/or third arms. This requires detailed planning, competent operators and suitable on-site preparation.

5. Improved Traction Power System (A72)

Methodology and proof of concept for the conversion of 3rd rail system to OHLE. Pilot scheme included within HLOS.

6. Integrated System Level Planning Software (M7)

Implement a single system that will provide an overall view of all the planned work activities. This is believed to be within the scope of Project ORBIS.

7. "Plug and Play" Signalling Equipment (A24)

This has been under development for a number of years and is part of both the modular signalling and S&C development programmes.

8. Anti-Theft Cables (T6)

This was the subject of a recent NR press release. A similar approach had been identified in France.

Note that the SNCF press release is about developing a solution, i.e. example of reinvent syndrome outside GB Rail.

9. Data Consolidation (A80)

Consolidate all available data so that it can all be accessed and full value extracted from data mining. This also supports the concept of "a single truth" avoiding issues with conflicting data. This is believed to be within the scope of Project ORBIS.

10. Automated S&C Inspection Vehicle (M6)

This includes development/acquisition of appropriate instrumentation and software analysis tools. A Dutch solution has been identified, but British solution is understood to be well developed.

11. Improved Pad Design (A86)

Better material characteristics will extend both pad life and the life of other components such as sleepers and rails. Pandrol have developed solution that provides integrated "pad & nylon".

12. Ballast Under-Cutter (Gopher) (T5)

Gopher or road rail vehicle attachment that can be used to remove ballast underneath the track whilst the track remains insitu

13. RailVac (C3)

Rail mounted self propelled on track machine that is uses high powered vacuum technology for removing ballast from under the track whilst the track remains insitu (can undertake numerous other maintenance and renewals activities)

14. Off-Site Manufacture (E3)

Improve build quality by manufacturing in factory environment. This reduces site construction and testing requirements. Concept is the basis of existing modular programme (S&C, signalling, platforms, foot-bridges)
This approach also facilitates "product standardisation"

15. Concrete Canvas (E4)

Concept based on rolls of material that are impregnated with cement. When water is applied on site the rolls convert into a stiff material, enabling it to be used to strengthen slopes. Press releases indicate that it has already been used on Network Rail infrastructure.

16. Automated Inspection (E5)

Modern technology enables inspection processes to be automated, increasing repeatability and productivity. There are a number of Network Rail initiatives that are under development (and rollout) including PLPR and Intelligent Infrastructure.

17. Improved POE Design (E6)

Manufacturers continue to improve products in order to achiever higher levels of reliability and lower maintenance costs. Network Rail is understood to be assessing current market.

18. Improved OHLE Equipment Design (E7)

Network Rail is understood to be developing a new basic design of components for the HLOS electrification programme.

19. Consolidated Train Control Centres (E8)

As part of the signalling strategy associated with introduction of ERTMS Level 2 is the introduction of modern traffic management technology that enables a significant reduction in the number of Control Centres. This was included within the IIP document.

20. Data Mining (E9)

This is achieved as a consequence of (9) above. It facilitates better visibility of emerging trends. This is believed to be within the scope of Project ORBIS.

21. Risk-Based Maintenance (E18)

This is incorporated within exiting Network Rail programmes such as Project ORBIS, RoSE and reliability engineering. It is the subject of a separate report.

A2: Blue Sky

1. Machine Learning (A96)

Introduction of artificial intelligence will enable machines to learn process and also learn how to continuously improve.

2. Generic Robotic Technology (A98)

Less sophisticated than AI, this will enable machines to be programmed to undertake repeatable tasks.

3. UAV for Aerial Surveys (A97)

Technology transfer (from defence) to enable regular automated topographical surveys of the infrastructure. Capability could also include thermal imaging. Network Rail already looking at generic concept (ITT issued w/c 03/12/12), but processes need developing to facilitate civilian use of this type of technology in Britain.

4. Regenerative Braking (A29)

This is proven and deployed technology, but systems interface issues mitigate its use throughout the network. It has been partially solved for the existing network and it is anticipated that further benefits will be obtained from proactive incorporation into new electrification.

5. Hybrid Vehicles (A100)

Technology transfer (electric cars). Rapid technology development has been seen in cars over last decade and it could be sufficiently advance soon to enable its economic widespread use in rail. From an infrastructure manager's perspective, it potentially enables short sections of expensive OHLE installations to be eliminated whilst still facilitating end-to-end electrified services.

6. Energy Storage (E12)

This is related to the previous two ideas. It relates to the storage of regenerated power until it is required, either on the vehicle or at the trackside.

7. Mechatronic Bogies (E10, A70)

Technology transfer involving the development of active bogies that are able to reduce forces imposed on rails. This will reduce infrastructure wear and consequently the level of maintenance intervention required.

Potential vision involves being able to "steer" through S&C – eliminating need for moveable infrastructure components

8. Active Pantograph (A73)

Based on the same technology transfer as above, but this time involving a pantograph that is controlled so that it is able to reduce the forces imposed on contact wire (thus again reducing infrastructure wear and maintenance)

9. Virtual Coupling (E13)

Concept is a vision whereby trains operating in a close grouping, so acting as "one track occupation". However, they are able to quickly separate and travel to different destinations. This provides capacity improvement without additional infrastructure to hold trains whilst being coupled and uncoupled.

10. COTS IT for SCADA (A37)

Use of standard IT equipment for SCADA applications, therefore ensuring that there is no "gold-plating" of specification (or inclusion of "we're different" reasons). *May need to separate out any safety critical applications and treat differently.*

11. COTS IT for Signalling (A85)

Use of standard IT equipment for signalling applications, where possible, therefore ensuring that there is no "gold-plating" of specification. This will require a review to separate out any safety critical applications and treat differently. Long-term (ETCS-based) signal strategy may mean that development of this approach is not justified.

12. COTS IT for Control of Level Crossings (E14, A83)

Similar to above, this is the use of standard IT equipment to control operation of level crossings therefore reducing installation and maintenance costs. .Again, there will be a need to separate out any safety critical applications and treat differently. Public perception of risks at level crossings may mean that this is not viable.

13. Radio-Based Level Crossing Controls (A44)

Systems have been developed that operate level crossings using radio-based controls, hence eliminating the need for cables. As with previous item, public perception of risks at level crossings may mean that this is not viable.

14. Virtual Lineside Signalling (T12)

Winner of RIA Innovation of Year award (Frazer Nash and Park Signalling). The concept involves the secure transmission of signal indications to train cabs.

15. ERTMS Level 3 (A2)

The current signalling strategy plans are understood to relate to introduction of ERTMS Level 2. ERTMS Level 3 adds further capacity improvements and reduced fixed infrastructure requiring maintenance.

16. Signalling beyond ETCS/Traffic Control (E15, A74, A75, A76)

Initial thoughts are already turning to next generation of train control systems.

17. Wi-Fi -Based Communications for Train Control (A23)

This maybe a specific subset of previous idea, but involves the use of secure WiFI and GPS to control the movement of trains.

18. Re-engineer Operating "Rules" (E11)

University research is underway that has started with no preconceptions on the existing safety and signalling operating rules. The aim of the research is to maximise capacity of existing network. Initial thoughts include some radical concepts around junctions.

19. Driver Advisory Systems (A25)

Driver Advisory Systems (DAS) are already deployed to support drivers in driving in an efficient manner that ensures the timetable is met with minimum energy consumption. Introduction of traffic management systems enable this to be enhanced to maximise capacity (without further infrastructure change) and also take account of temporary speed restrictions when providing the advice.

20. Internet-Based Communications (A46, A77, A104)

As part of other programmes, an enhanced communications network is being installed across the network. This provides opportunities to introduce more widespread data transmission systems. These could be used for various purposes, including collection of remote automated condition monitoring equipment.

21. Cloud-Based IT (A111)

The "cloud" enables much easier remote access to large amounts of data. This may have a number of applications, such assisting identification of root causes of faults. Main concern to be resolved is whether there any security issues or not with storing data in this way.

22. IT Developments in Other Industry Sectors (A112)

Software is being developed in all sorts of ways, some of which is already being adopted by the rail industry. Network Rail already has a number of IPhone/Ipad rail specific apps. Other obvious transferable concepts include Google Earth/Maps.

23. Nanotechnology for Anti-Graffiti Glass (A95)

Nanotechnology can be used to create specific material characteristics. Glass surfaces are being developed in other sectors that are resistant to graffiti.

24. Nanotechnology for Rail Friction Management (A62)

Nanotechnology can be used to create specific material characteristics. Opportunity exists to develop components such as rail that are resistant to wear.

25. Maintenance-Free Rail (T11)

Voest Alpine have a new rail under trial that has a bainitic structure designed to be wear resistant.

26. Advanced Composite Materials (A105, A106, A107, A109)

Lightweight high strength composites have been developed in a number of industries. These have been used already for bridges, but are not widespread in their use yet. Other options include OLE support structures, providing high strength components with minimal foundation requirements.

Another area is DMLS (Direct Metal Laser Sintering). This enables detailed components to be manufactured with complex cavities. It is also an additive process, so there is no waste created. This will enable more efficient manufacture of small components.

27. Formation Rehabilitation Train (C2)

Although not innovative technology, this item of plant is not available to GB Rail and the number of high-output trains already provided mean it is unlikely to have a positive business case during CP5. Future improvements in understanding formation condition may change this position after CP5.

28. Optimum Sleeper Shape and Material (A69)

Research work is being undertaken to identify the optimum shape, size and material of a sleeper.

29. Increased Ballast Stiffness - Plastic Reinforcement (A61)

Research work is being undertaken to identify whether ballast properties can be improved by the introduction of plastic reinforcement. An objective is to extend the useful life of ballast such that the need for mid-life ballast cleaning is eliminated.

30. Improved Ballast-Grading (A65)

Research work is being undertaken to identify whether ballast properties can be improved by revising the size grading. An objective is to extend the useful life of ballast such that the need for mid-life ballast cleaning is eliminated.

31, Under-Ballast Pads (A4)

As noted elsewhere, under-sleeper pads have already been developed and proven to reduce whole life costs. Work is now underway to investigate whether the introduction of under-ballast pads will improve the performance of the traditional track-form.

32. Automated Drainage Cleaner (T34)

Development of an item of plant that is able to inspect a drainage system and automatically rectify any defects identified.

33. Monitoring Bridge Deflections (A90)

Use a specific rail vehicle that will regular impose standard loads onto a structure. The deflections can be monitored using a standard device, or sensors fitted to the structure. This will enable the structure's health to be monitored.

34. Fault Tolerance (E17)

This is a technology transfer item. Use redundancy or another approach to make the system tolerant of faults at critical areas. As an example, install two point machines so that a lead continues to operate if one becomes faulty. It requires an understanding of cost – risk balance.

35. Chinese Supply Chain (A11)

Chinese manufactured items tend to be cheaper than those from European factories. However, the belief is that they will be focussed on satisfying internal demand during CP5.

A3: Potential Innovation Ideas

1. "GRIP Lite" Process (C14)

A simplified project control process suitable for repeatable, non-complex items such as construction platform walls.

2. Standardised design (M14, A78)

A standardised design approach with a reduction in bespoke designs and preferential engineering that will lead to reduced requirements for checks and bespoke calculations, lower design costs. Significant work has already been undertaken to adopt standardised design of details and components.

3. Plastic platforms and bridges (A5, A67)

This innovation involves the use of composite materials and plastic for constructing items such as footbridges, station platforms and electrification structures. A number of pilot projects have already been undertaken.

4. Renewable energy (C12, A91, A28, A101, A102)

The use of renewable energy sources such as wind, heat pumps and solar panels to power line-side equipment which will reduce the need for external energy supplies, particularly in remote locations where it is difficult to connect external power supplies. This approach has already been adopted for discrete items of lineside equipment, but further opportunities exist.

5. Using GRP to reinforce bridges (A66)

This involves using the properties of GRP materials to reinforce existing structures in order to extend their useful life. It is a technique that has been used previously but is not apparently widespread.

6. Utilise W-SPA (A58)

Optimisation of wheel-set maintenance will reduce track damage, thus prolonging the useful life of the infrastructure and reducing maintenance costs. W-SPA is a recently developed software tool that enables wheel-set maintenance to be optimised.

7. Variable stiffness suspension bushes (A30, A84)

Track damage has been reduced through the introduction of variable suspension characteristics as a successful pilot on SouthWest Trains.

8. Aluminium conductor rail (C7)

Aluminium conductor rail provides improved conductivity and reduced maintenance costs as a result of its lighter weight. It can also reduce maintenance costs as it can be manufactured to lower tolerances.

9. Fixed cameras to monitor asset performance (A88)

The concept of using fixed camera to monitor asset performance has been proven. These can be installed to monitor specific assets, either at remote locations or locations which are performance critical but difficult to gain safe access.

10. "Spider" (T33)

A remotely operated device that is able to climb vertical walls and undertake detailed inspections or/and maintenance tasks such as shot blasting structures.

11. 4-D modelling (A108)

Using CAD models to "fly-through" new designs for verification purposes, particularly in order to check cross-functional interfaces such as undertaking signal sighting. The concept has already been used on several projects, but is not routinely deployed.

12. Radiographic Rail NDT testing (A47)

Non-Destructive Testing of rail welds can be undertaken using radiographic techniques such as X-Ray or Gamma radiography. This has been previously used (e.g. the SafeRad system), but an effective commercial deployable solution has yet to be developed.

13. Motion sensors on lights & escalators (A92)

Motion sensors are used in many buildings to switch electrically operated equipment on and off when not in use, saving of electricity. This concept can be spread to other non-safety critical applications, such as escalators.

14. Remote radio controlled plant (A1)

The use of remote control technology for operating plant such as cranes and piling mechanisms removes the direct human interface. It improves accuracy and safety by relocating the operator to a better location.

15. Standardised level crossing surfaces (M2)

Adoption of standardised level crossing units will provide cost savings through the reduction in training and equipment needed to install and remove the variety of different types currently used.

16. GOTCHA (C13)

"GOTCHA" is a trackside monitoring system that is used to measure train and wheel performance. The most common modules used are wheel defect detection and weighing in motion to determine train loadings

17. Weigh-in-motion sensors (A7/A8)

Load detectors using fibre optics to monitor train / wagon loadings. Different systems are available, some requiring a bolted connection to the rail, whilst others use alternative fixing arrangements.

18. Direct Trimble/Tamper interface (A54)

An automatic interface is available that enables the 3-D alignment design model to be transferred directly to the tamper as a front-offset file. This is a proprietary system that uses Trimble equipment.

19. Eddy current rail NDT technology (A26)

Eddy current technology can be used to identify surface cracks and defects in rails

20. Heater stressing (T25)

Stressing of rails using heaters has been shown to provide productivity improvements in Europe. This approach is also understood to provide a more linear and even extension throughout the length of the rails being stressed.

21. Geismar Amber trolley (M12)

It is understood that the Geismar Amber Trolley (track geometry measuring device) is being used in localised hot-spots to identify root causes of track quality problems.

More widespread use offers the opportunity to avoid abortive work by identifying the correct solution.

22. Deploy & forget sensors in buildings (A79, A99)

The cost of sensors has significantly reduced. Other parts of the construction industry are starting to adopt a "fit and forget" strategy. This involves installing sensors into the fabric of structures during construction, reducing the need for periodic inspection and providing better data capture for maintenance activities.

23. Rail stress monitoring at vulnerable sites (M11)

Remote condition monitoring equipment for monitoring stress in rails at vulnerable locations will remove the need for track patrollers and better management of speed restrictions.

24. NDT equipment to measure/monitor rail stress (T13)

Simple system to measure rail stress without the need for cutting or unclipping of the rail.

25. Luge Trolleys (T29)

Luge trolleys are small customised motorised devices that can increase productivity on renewal and maintenance items, particularly for re-padding and stressing activities.

26. Standardised surface lubrication policy (M4)

Standardised national policy on the optimum approach for surface lubrication of rails, including location and type of equipment used, plus best lubricant.

27. Electronic rail lubrication system (T14)

A rail lubrication system that extrudes lubricant through holes drilled in the rail. It can be remotely monitored to reduce maintenance requirements.

28. Top of rail lubrication system (T20)

Track lubrication system for the top of the rail that reduces wheel rail friction and results in fuel / energy savings.

29. On-train lubrication system (C4)

Rail lubrication system fitted to train wheels rather than installed as part of the infrastructure.

30. Intelligent lubrication (A27)

Improved wheel rail interface management from correct lubrication using a train mounted intelligent device that applies lubricant as and where it is needed

31. Automatic switch lubrication (T19)

An automatic railroad switch lubrication system that lubricates all critical surfaces: switch plates, switch points, mating surfaces, top of switch rails, and stock rails.

32. LED lights on stations (A38)

The use of LED lighting in stations to reduce energy and maintenance costs by up to 30%.

33. Maintaining rail vehicles on site (A9)

Deploying maintenance and servicing vehicles to site, rather than transiting vehicles to depots reduces downtime and increases availability.

34. Integrated line-side remote monitoring systems (A45)

Integrated remote monitoring systems are available that measure and monitor multiple outputs from a single installation. Potential functionality of these devices include monitoring hot axle-boxes, locked brakes, wheel impact loads, dragging objects, gauge excess check, pantograph check, wheel rolling parameters.

35. Rail measurement condition (M1)

An on-train measurement system is available that has integrated systems that measure rail condition and shape plus the contact wire with a non-contact system. This enables real-time understanding of the infrastructure wear rates at both wheel/rail and pantograph/contact wire interfaces.

36. Trolley based system for taking rail profiles (A13)

System exist that use laser technology to accurately measure and record the cross sections of rail profiles, including the complex sections of switch and crossing units.

37. Data Acquisition (A14)

Data can be regularly captured from data-loggers, transducers and their associated software. Extensive development has been made of these sensors to measure forces such as those between rails and wheels.

38. Enhanced utilisation of thermal imaging cameras (A31)

Thermal imaging cameras are already in use to identify hot spots on overhead line equipment. This technology can be used to monitor other types of electrical equipment where increased temperatures provide an early indication of a potential defect.

39. Focus RCM kit on reliability hotspots (A52)

Condition monitoring equipment can be fitted at locations where reliability is a key issue in order to provide early indication of a potential fault and better understanding of the root causes of failures. These locations will be identified through detailed analysis.

40. Use of on train monitoring data (A94)

Monitoring of the voltage applied to electric traction power systems together with pictures from pantograph cameras to identify potential defects

41. Widespread use of UTGMS (A110)

Extended rollout of monitoring equipment onto service trains provides the capability to gain a better understanding of dynamic real time asset condition.

42. Frozen E-Clip remover (T30)

A safe mechanised method to remove corroded or frozen-in track fastenings without damaging the clip housing or sleeper.

43. BIM Models (A103)

Building Information Modelling is being used in other parts of the construction industry to manage issues such as whole life cycle costs and facility management of buildings and structures.

44. In-pipe lining systems for culverts (T24)

An efficient culvert lining system is available that can be used to reinforce or repair a culvert rather than undertaking expensive renewal work.

45. Rail web tuners (N&V) (A10)

In-web rubber tuners can be used to reduce noise and vibration emissions at sensitive locations.

46. Switch heaters controlled by cameras (T1)

Switch heaters can be automatically operated when cameras identify that preset conditions exist that require the heaters to be switched on. This saves energy cost by removing the need to have the heaters on regardless of conditions at a particular site.

47. Energy saving switch heaters (A42)

Switch heaters that are controlled by electrical resistors, which monitor rail temperature, provide improved efficiency.

48. Ballast shoulder consolidation (M10)

Consolidation of ballast shoulders following ballast renewal increases the lateral resistance and avoids the need to impose emergency speed restrictions during hot weather.

49. High-speed grinding (A20)

Maintenance grinding of rails at speeds of between 80 and 100 kilometres per hour enables grinding to be done in-traffic without the need for possessions.

50. Output based standards (C9)

A move to standards that prescribe outputs, rather than defining the required inputs, will support a more flexible maintenance strategy appropriate to local conditions.

51. Tram/Train standards (A22)

Adoption of appropriate standards for the type of traffic operating on a particular route can reduce inspection and maintenance requirements. Work is currently being undertaken to determine the potential efficiencies where the traffic is restricted to tram-style trains.

52. 3-D geostructural modelling of rock walls (T4)

A remote condition monitoring system that is used to monitor areas that are susceptible to rock falls or land slides

53. Pipe nails c/w drainage (T9)

A bank stabilising method is available that provides the dual-functions of bank slope reinforcement and drainage.

54. Low adhesion monitoring (E1)

A model is being developed that is based on a condition monitoring system to identify low adhesion conditions in real time, enabling focussed mitigating actions to be applied rather than global treatment of all risk sites.

55. Self-Discharge Ballast Train (T27)

The Skako train allows ballast to be placed quickly, accurately and safely by means of wagons that have a built in a conveyor belt system. This system enables track renewals to be undertaken a lot quicker and safer than conventional methods.

56. Modelling behaviour of clay embankment slopes (E2, A64)

Models are being developed that provide a better understanding of earthworks and enable engineers to better predict the behaviour of clay slopes under specific loading conditions.

57. Track-lifter (A50)

The introduction of a mechanised track lifting device on bottom-up renewals, or conventional ballast cleaning sites, will reduce the tamping time required. It also enables the tamper to concentrate on achieving the design lifts rather than ensuring the ballast is adequately consolidated for safe passage of trains.

58. Hertzog Plus Train (T26)

Intelligent top-ballast distribution system that is computer controlled, therefore requiring no manpower to operate the doors and increasing the accuracy of supplying stone to the required locations. It can operate in-traffic, avoiding the need for possessions.

59. High efficiency weed-killer train (T2)

A weed killing train that has an on board image analysis system so that the appropriate treatment is only applied where it is required.

60. Standardised reliable switch toe bearers (M9)

The use of a standard reliable switch toe bearer will make maintenance easier and reduce delays through point failure faults

61. MHT Rail/UIC60 Rail (C8)

The use of harder and larger sections of rail will increase the life of rail therefore requiring less rail replacement

62. Grade of rail steel (A6)

Making engineering decisions to select the correct grade of rail steel required to meet the local conditions.

63. Super MPM Train (A49)

A Multi Purpose Machine (MPM) Train that consists of 2 power units (one at each end) and six low wagons which are configured so that a back-actor can traverse along the length of the train and can load / unload the wagons.

64. Rail milling (C15, A34)

The use of milling techniques to re-profile rail rather than grinding gives a better quality finish and can remove more material in one pass. Milling is especially beneficial in environments that require spark free operations.

65. Shoulder ballast cleaner (incl. under rail seat) (T18)

Purpose built machine for cleaning ballast shoulders. This improves drainage of the track and can avoid the need for a complete reballast of the track.

66. Loram badger ditch cleaner (T17)

Purpose built machine for clearing out ditches to improve drainage, rather than using conventional RRV’s.

67. Bogl modular slab (T15)

Modular units of slab track that are prefabricated in a factory environment and then transported to site and installed end to end to form a continuous slab track.

68. Slab-track (C10, A33)

The installation of slab track reduces life cycle costs through the reduction in deterioration of components as a consequence of its fixed geometry. This reduces inspection and maintenance costs. A number of different proprietary slab-track systems are available.

A4: Prioritised Ideas

1. Use of GPR Technology (M13, C1, T3)

Involves the use of GPR to detect cavities, thus providing the ability to find potential areas of collapse in suspect locations, and improve the scoping of track renewals. Use is already made of GPR to support track renewal scoping, but it is believed that further opportunities exist based on the opportunities seen elsewhere.

2. Non-Intrusive Crossovers (T21)

This is a temporary installation that can be installed at an engineering site. It requires no permanent alteration to the infrastructure, but provides the capabilities of a standard crossover or an ability to install a temporary siding.

3. Timber Bearer Refurbishment (T28)

Processes exist to extend the life of timber bearers within S&C layouts, thus avoiding the need to install new bearers.

4. Modular One-Piece Level Crossings (T35)

Modular level crossing systems exist that are one-piece from a civil engineering perspective. The rails are cast into the “product” to effectively form a short section of slab-track. This reduces the need for maintenance of both the level crossing and associated track. They also have a longer life than traditional level crossing systems.

5. On-Train Measuring Systems (C5, A51, T16, A41, A93, A63)

Although a number of train-mounted infrastructure monitoring systems are already within Network Rail’s fleet, technology continues to advance and the scope of reliable monitoring continues to increase. In particular, a number of recent developments have been noted that improve an infrastructure manager’s capability to monitor the traction power system. The scope of these monitoring systems includes non-contact measurement of both overhead and conductor rail infrastructure.

6. Staff Protection Systems (M3, C11)

Staff protection systems have the capability to not only improve safety, but also increase efficiency. A system is available on the market that can be permanently installed and provides a quick method of applying possession protection.

7. Undersleeper Pads (A3)

Significant improvements in track performance are being achieved by the use of pads fixed to the underside of sleepers. Reduced maintenance intervention and extended component life are being achieved.

8. Advanced OHLE Components (T8, T7, T10, A32)

The innovation scan identified a number of technical improvements related to the overhead line traction power system. These included cold pressure welding of the contact wire, automatic tensioners and motorised isolation switches.

9. Cascade/Refurbish Materials (M8, A12, A81)

Refurbishment and cascading of materials is an accepted process, both in Britain elsewhere. Technology developments are increasing the applicability of cascading, but suitable processes need to be implemented to enable this to occur. One particular development that has been identified is the modification of the tilting wagon fleet to enable serviceable switches and crossings to be cascaded.

10. Improved Monitoring of Bridges (A60, A68)

The monitoring of bridges can be improved by better assessment and modelling of the behaviour of the structures under the specific loading conditions that they experience. A further enhancement is the installation of fixed cameras and associated software to provide early warning of scour risk.

11. Mobile Maintenance Units (T22, M5)

Mobile maintenance units are rail vehicles that provide transport to site for staff, materials and plant. Once at site they provide power and lighting plus an enclosed working area. This protects staff from both the climate and trains operating on the adjacent lines.

12. Plastic Sleepers (A16)

Plastic sleepers are being installed by a number of infrastructure managers. Extended testing has been undertaken at the TTCI facilities in the United States. They are seen as a method of attaining the benefits of timber sleepers without the associated problems.

13. Pad Replacement Machine (T32)

The proposed track asset management policy for CP5 is understood to include significant quantities of repadding. A mechanised method of undertaking this work in a safe manner will provide considerable benefits.

14. Specialist Gantries (T31)

Specialist gantries have been developed that facilitate the quick and easy transportation of replacement S&C components (cast manganese crossings and half sets of switches) to site without the need for additional machinery or possessions.

APPENDIX B: DETAILS OF BENEFIT ASSESSMENTS

B1 Use of GPR

Development

Minimal development required, with main requirement being development of a suitable end-to-end process. As such, benefits are assumed to be available from the start of CP5.

Investment

GPR systems available already and it is understood that an investment has been made to upgrade to high-definition instruments.

Assessment of the cost of data collection and analysis is £0.9m per annum for 1,000km. This is based on service provision to other infrastructure managers. With 573km track reballasted during 2011/12, assume that 3,000km monitored per year.

Benefits

Primary benefits are:

- Shorter lengths of renewal specified to correct limits;
- Reduction in maintenance through better quality specification;
- Additional track asset life cycle; and
- Reduced risk of track collapse.

Assessment

2011/2012 plain line renewal (composite rate measures)	£480m
1% saving through better specification	£4.8m per annum
Total saving for CP5	£24 million
Assume 1 culvert reconstruction avoided in CP	£0.5m (estimate)
Overall assessed benefit for CP5	£11m

Note: Further savings will be made in subsequent control periods from improved whole life cycle cost, but these have not been included

B2 Non-Intrusive Crossovers

Development

Equipment is already available. Some safety approvals will be required, which are estimated to delay implementation until 18 months into CP5.

Investment

Estimated cost per site is £10k for hire of equipment and £10k to install and a further £10k to remove.

Benefits

Installation of a temporary non-intrusive crossover can be used to:

- Enable single line working on possessions
- Increase possession availability leading to higher productivity
- Increase train capacity on possession work using single line working approach
- Connection of virtual sidings allowing engineers trains / tampers to be closer to the site of work
- Reduction of run round times in possessions

Benefits have been assumed on the basis that the system would save on access costs. This is based on information supplied by the developers of the system.

Assessment

Schedule 4 costs for 2011/12	£80m
Assumed 20 major possessions for 50 weekends accounting for 80% of Schedule 4	
Average Schedule 4 costs per site	£64k
Assume 1 possession suitable for NICs per fortnight, i.e. 25 per annum	
Savings in CP5	£5.6m
Costs in CP5	£1.8m
Overall assessed benefit for CP5	£4m

B3 Timber Bearer Refurbishment

Development

A suitable system has already been developed and initial trials undertaken in Britain. The necessary investment in training and equipment has been made by the supplier. Benefits are assumed to be available from the start of CP5.

Investment

As a service provision, the cost per bearer treated is approximately £100.

Benefits

The benefits are:

- Life extension of wooden sleepers / bearers on both S&C and plain line track;
- Returns track to original gauge and alignment;
- Prevents excessive wear on the ironwork thus eliminating premature renewal.

This will reduce the premature replacement of timber bearers being replaced. It will also reduce the wear of other S&C components by providing a solid foundation, removing the relative movements.

Assessment

Maintenance savings achieved through reduction in cost of replacing bearers.

Bearer replacement costs	£17.5m (7,200 no)
Assumed reduction achieved	15%

Costs of treatment	£0.5 for CP5
Overall assessed benefit for CP5	£13m

Additionally, there will be renewals savings from life extension of S&C units.

Unit renewal cost for S&C	£444k
Number of units renewed per annum	333
Assumed reduction in renewal rate	10%
Annual savings	£15m

However, these savings will be seen in later Control Periods.

B4 Modular Level Crossing

Development

Modular one-piece systems exist and are in use by other European Infrastructure Managers. It is believed that at least one system has been trialled in Britain.

Investment

The cost of installation is approximately £42k, compared to a typical cost of £16k for a traditionally constructed level crossing (e.g. precast interlocking concrete units).

Benefits

Following benefits are obtained:

- Reduced maintenance (particularly tamping);
- Reduced inspection;
- Reduction in road closure requirements;
- No replacement of individual component (sleepers, ballast, crossing surface units);
- Longer life cycle;

Other intangible savings include improved safety for both rail and road traffic.

The service life is in excess of 30 years, compared to 12 years for a traditional crossing system. It is virtually maintenance free for the life of the system.

Assessment

From a maintenance perspective, traditional ballasted level crossings are inspected and tamped at least once every 4 years.

Number of units installed during first 2 years of CP5	50
Cost to remove, inspect and tamp	£30k (2-tracks)
Assumed average civil engineering maintenance costs	£1k per unit p.a.
Extra/over cost of installing 50 units	£1.3m
Overall assessed benefit for CP5	£0.4m

Note: Considerably more savings will be made in future control period as life expectancy is 30 years, eliminating maintenance costs and renewal after 12 years without further investment.

B5 On-Train Measurement Systems

Development

It is estimated that a period of 18 months will be required before the equipment can be deployed into full service. Although the technology is available, there will need to be an approval and installation programme.

Investment

It is estimated that each system will cost about £0.3m to install. It is assumed that two systems will be fitted to two trains.

Benefits

The primary benefits are:

- Eliminate either early or late maintenance intervention;
- Understand system interfaces e.g. impact of a track fault on the traction power system; and
- Reduce need for manual inspection

Assessment

This assessment is based on the performance of the existing electrified railway. No consideration has been included of the planned extension of the electrified network.

The savings available from this particular potential initiative may be duplicated within other initiatives, such as the ORBIS and asset management projects. As such, a conservative approach has been taken in calculating the benefits, with this initiative being viewed as an enabler.

Major incidents (dewirements) have been included in the assessment of B8 below.

Other delays due to traction power faults	75,000mins
Average Schedule 8 value (see B8)	£9.50/min
Assumed avoided delays	33%
Electrification maintenance costs	£47m p.a.
Assumed reduction in maintenance	2%
Investment costs	£1.2m
Overall assessed benefit for CP5	£3m

B6 Staff Protection Systems

Development

The system being considered exists (Dual Inventive) and has been approved for use in Britain. It is not yet being extensively used on Network Rail infrastructure. Benefits are assumed to be available from the start of CP5.

Investment

The system will not be appropriate or suitable for use across the network. It requires track-circuited track and is not likely to provide significant financial benefits when used on rural low traffic routes. The investment requirements are estimated as £0.25m.

Benefits

The financial benefit is through increased productivity due to quicker site set up.

Assessment

Assumed length of midweek possession	6 hours
Working time increase	4 to 4.5 hours (12.5%)
Number of applicable Delivery Units	50%
Annual possessions affected	8 per week, 50 weeks p.a.
Number of staff on average per possession	10
Cost per shift	£225
Overall assessed benefit for CP5	£10m (see note below)

However, these savings may duplicate those assumed within the possession improvement programme. It might also not be possible to realise all these savings as the staff maybe required elsewhere. However, as a minimum, it is believed that savings on overtime can be realised. On the basis of this, the calculated benefits have been reduced by 50% to £5m.

B7 Undersleeper Pads

Development

Designs are available and in use elsewhere in Europe. Specific approval for use on Network Rail's infrastructure will be required.

Investment

Sleepers fitted with pads will be more expensive than standard sleepers. Austrian experience indicates a 3% increase in construction costs.

Benefits

The benefits are extended track component life and reduced ballast degradation. The majority of the benefits are seen over the full life of the asset. Based on Austrian experience, a 23% reduction in whole life costs has been achieved.

Assessment

Based on a 5% reduction in tamping from a reduction in ballast degradation, an annual saving of £1.5m is obtainable. This benefit will be realisable towards the end of the Control Period as the population of sleepers with pads increases.

Note: Further savings will be made in future control period as the benefits of extended asset life is realised.

B8 Application of Overhead Line Technical Developments

Development

All the identified innovations already exist, but they will need approval and installation into the existing system. It is forecast that it will two years to develop and approve, plus a period for initial rollout. It is anticipated that there will be a progressive campaign rollout to target existing hot-spots.

Investment

It is estimated that there will an extra/over spend of £2m will be required during the Control Period.

Benefits

Re-engineering the existing system with this type of innovation will reduce both the likelihood and impact of component/system failures, i.e. the annual costs associated with dewirements.

Use of motorised switches will reduce time required to take an isolation and hence increase possession utilisation. However, it has been assumed that these benefits have been taken elsewhere. As such, the installation costs have also been excluded from the assessment.

Assessment

As with the previous electrification-related initiative, this assessment is based on the performance of the existing electrified railway and no consideration has been included of the planned extension of the electrified network.

Number of AC Power incidents causing >500mins delay	50
Time lost due to traction power incidents	199,197 mins
Assumed reduction in incidents	10%
Assumed reduction in "time-to-fix" of remainder	50%
Assume average incident length	2500 mins
Average cost of Schedule 8 minute (8.4m mins, £80m)	£9.50/min
Assume average incident requires (20 men for 12 hour shift)	£15k
Average cost per incident	£38.75k
Overall assessed benefit for CP5	£1m

B9 Refurbish and Cascade Materials

Development

The major elements of development are the creation of a process that maximises the potential opportunities provided by refurbishment technology. Although Network Rail's tilting wagon fleet is unable to recover removed panels, it has been assumed that additional standard wagons can be included in the train consist (at no significant extra cost) to enable switch and crossings to be recovered.

Investment

It is envisaged that investment costs would be minimal as there are already various depots set up to accommodate serviceable material

Benefits

The benefits are seen as a reduction in the amount of premature scrapping of reusable components (particularly ironwork) and the potential to reuse serviceable S&C units following refurbishment.

Assessment

Savings in the region of £4 million per annum could be made by cascading of serviceable rail. Facilities have been provided, but observations across the network indicate that significant quantities of rail remain at the lineside following track renewals.

In addition, it has been assumed that 10% of crossings and switches can be recovered from renewal sites and cascaded for use elsewhere, providing £3.5m savings.

The assessment assumes that Network Rail already has processes in place that fully utilise the available opportunities to recycle ballast and cascade serviceable sleepers.

POST DRAFT INPUT

Review of Network Rail's SBP document summarising their proposed efficiency savings for CP5 notes a further saving of £8.3m has been included within their plans. This has been discounted from the assessment.

Overall assessed benefit for CP5 is £15m.

B10 Improved Monitoring of Bridge Condition

Development

The software and hardware components of this initiative are under development. It has been assumed that initial production versions will be available for use within the first year of CP5.

Investment

The assumed level of investment required is:

- £0.5m to complete software development and validate;
- £0.5m to populate the decision support tool with required data; and
- £1m hardware costs (for anti-scour cameras).

Benefits

Benefits from improved monitoring are:

- Undertake heavy maintenance/refurbishment instead of renewal

- Avoid repairs following scour damage
- Avoid track closure waiting for water to drop and allow divers to inspect

The risks associated with bridge scour are seen to be increasing as a consequence of changes in the climate.

Assessment

Number of renewals replaced with component repairs	1 site per annum
Reduction in costs per site	£5m to £2.5m
Number of heavy repairs avoided (scour)	1 site (£1m in CP)
Train delays from Schedule 8 (scour)	£0.1m p.a.
Overall assessed benefit for CP5	£9m

B11 Mobile Maintenance Units (MMU)

Development

Designs already exist for these vehicles. It is assumed that it will take at least 18 months to procure and gain safety approval for use on Network Rail's infrastructure.

Investment

It is estimated that each unit will cost £2m, based on economies of scale achieved from procuring the anticipated number of units.

Benefits

Productivity improvements are obtained from:

- "Adjacent Line Open" operations without need for additional protection;
- Immediate mobilisation on site; and
- All tools, lighting and materials to hand

Assessment

Assume average mid-week possession is 6 hours in duration, with 4 hours available for productive work. It is assumed that, on average, of 6 operatives are deployed to a worksite, plus 2 providing protection duties.

Use of an MMU releases the staff undertaking protection duties, removes the lost time mobilising the site and enables the other 6 staff to be fully utilised with increased productivity due to the working environment. Additionally, the need for a preparatory shift is eliminated. An MMU can operate 5 shifts for 50 weeks of the year.

Assuming a fleet of 40 units is deployed, the overall assessed benefit for CP5 is £15.5m.

POST DRAFT INPUT

It is understood from press reports that the review of Network Rail's activities on the West Coast Main Line included a recommendation to adopt this technology. However, this innovation is not identified in the SBP document summarising Network Rail's proposed efficiency savings for CP5.

B12 Plastic Sleepers

Development

Plastic sleepers are being installed by a number of infrastructure managers in a variety of circumstances, from transits through to heavy haul freight. It is believed that they would be available for use from the start of the Control period.

Investment

Plastic sleepers are more expensive than timber currently. However, it is anticipated that economies of scale will reduce the price as they become more widely used.

Benefits

Benefits from using plastic sleepers are that they provide the same characteristics as a timber sleeper but they do not rot. They are also sustainable through use of recycled materials.

Assessment

In 2011/2012, reported number of spot sleeper changing was 34,988, at an average cost of £213 per sleeper, i.e. £7.5m per annum.

Hence a 10% reduction in sleeper replacement through longer-life would save £0.75m per annum, or £3.75m per control period. Note: This saving would only be realised in control periods beyond CP5, as the renewal rates decrease due to the increased asset life.

B13 Repadding Machine

Development

The concept of the machine is well advanced. It is estimated that a further year is required to complete the design and necessary approvals.

Investment

It is estimated that each machine will cost £150k. Delivery using dedicated units will require investment in 4 machines.

Benefits

Benefits are achieved through a reduction in manpower and higher productivity from mechanisation of the repadding process.

Assessment

Activity level in 2011/2012 was recorded as 570,971 yards at £16/ yard, i.e. £9.1m per annum. A conservative assumption indicates the potential saving of 10%, i.e. £0.9m per annum or £3.6m for the control period.

Overall assessed benefit for CP5 is £3m.

B14 Specialist Gantries

Development

It is estimated that a further 18 months is required to complete the design and necessary approvals.

Investment

It is estimated that each set of gantries will cost £600k. It has been assumed that product approval by the manufacturer is included within this cost. Delivery of the predicted workload (1100 units) is estimated to require 5 sets of gantries.

Benefits

The benefits are:

- Removes all road transport of S&C units;
- Removes requirement for road rail machine hire;
- Reduces number of possessions required; and
- Reduction in manpower.

Assessment

Cost of maintenance S&C unit renewal	£17m
Reduction in S&C unit replacement rate	25%
Overall assessed benefit for CP5	£12m

APPENDIX C: LIST OF IDENTIFIED INITIATIVES

Ref No.	Innovation Idea	Description	Supplier(s)	Source	Engineering Discipline(s)	Development Status	In Use			Transferability	CP5 Benefits	Enablers	Barriers					Ease of Implement	Size of NR Prize
							UK Rail	Other Rail	Other Industry			(Investment, training, etc.)	Culture	Standards	Safety	Organisation	Union		(CP5)
	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
A1	Radio Remote Control	Use of remote control technology to operate cranes	www.hetronic.com	Innotrans	Track Civil Engineering	Proven technology	Unaware	Yes	Yes	Yes	Yes	Interface with existing equipment	Yes	Not obviously	EMC?	No	No	Easy	Low
A2	ERTMS Level 3	Master Plan to get to ERTMS level 3	www.infrabel.be	Innotrans	Signal	Developing technology	No	No	N/A	Yes	No								
A3	Under Sleeper Pads	Under sleeper pads to reduce maintenance plus N&V and extend component life	www.cdm.eu	Innotrans	Track	Proven technology	Unaware	Yes	N/A	Yes	Yes	Training and awareness	No	Change to specification	No	No	No	Easy	Medium
A4	Under Ballast Pads	Alternative to geogrids?	www.cdm.eu	Innotrans	Track	Proven technology	Unaware	Yes	N/A	Yes	No	Product approval Training and awareness	No	Change to specification	No	No	No	Difficult	Low
A5	Use of composites	Use of FRP for platforms, crossings, bridges	www.ctscom.de	Innotrans	Civil Engineering	Proven technology	Understood to be some use	Yes	N/A	Yes	Possibly	Product approval	No	Change to specification	To be confirmed	No	No	Medium	Low
A6	Grades of Rail Steel	Choice of steel grade to meet local circumstances	www.tatasteelrail.com	Innotrans	Track	Developing technology	Yes	Yes	N/A	Yes	Possibly (long asset life)	Product approval	No	Change to specification	No	No	No	Medium	Low
A7	Weigh-in-motion	Load detectors using fibre optics able to monitor load - no bolts to rail (accurate reliability data)	www.sst.ag	Innotrans	Track	Proven technology	Similar	Yes	N/A	Yes	Yes	Product approval	No	Not obviously	To be confirmed	Who uses data & alerts?	No	Easy	Low
A8	Weigh-in-motion	Load detectors using bolts to rail (accurate reliability data)	www.meridianengineers.com.au	Innotrans	Track	Proven technology	Similar	Yes	N/A	Yes	Possibly	Product approval	No	Not obviously	No	Who uses data & alerts?	No	Medium	Low
A9	OTP Maintenance	Dedicated maintenance of vehicles on-site	www.gleisbaumechanik.de	Innotrans	Vehicles	Proven technology	Yes	Yes	Yes	Yes	Unlikely	Concept development and rollout	Possibly	No	Probably not	Possibly	Possibly	Medium	Low
A10	Rubber Noise Dampners	Use of in-web tuners to reduce N&V emissions	www.rex.ch	Innotrans	Track	Proven technology	Limited	Yes	N/A	Yes	Unlikely	Proof of concept and policy	No	No	No	No	No	Medium	Low
A11	Chinese Supplies	Use of Chinese manufacturers to produce small tools and associated consumables	www.myqiangli.com	Innotrans	All	Developing capability	Limited	Limited	Yes	Yes	No								
A12	Euroswitch Recovery	Use of tilting wagons to recover scrap switch panels	www.euroswitch.info	Innotrans	Track	Proven technology	No	Yes	N/A	Yes	Yes	Redesign of existing fleet	Yes	Not obviously	Working at Height?	No	No	Medium	Medium
A13	Rail Profiles (P/line and S&C)	Trolley based laser c/w logger	www.measprog.com	Innotrans	Track	Proven technology	Similar	Yes	N/A	Yes	Yes	Product approval Training & investment	Yes	Not obviously	Green Zone	No	No	Medium	Low
A14	Data acquision	Data loggers, transducers and associated software	www.hbm.com	Innotrans	Potentially all	Proven technology	Similar	Yes	Yes	Yes	Yes	Training & process change	Yes	Possibly	No	Possibly	Unlikely	Medium	Low
A16	Recycled plastic sleepers	Use of recycled plastic as effective alternative to wood sleepers (and bearers0	www.axih.com	Urban Transport Agenda	Track (+ civil engineering?)	Proven technology	Pilot site?	Yes	N/A	Yes	Possibly (long asset life)	Product approval (and proof of concept)	Maybe	Change to specification	To be confirmed	No	No	Easy	Medium
A19	Robotic MFBW	Improved (repeatable) quality and strength from automation	www.plassertheurer.com	EURAILmag Business & Technology	Track	Proven technology	Standard MFBW	Yes	N/A	Yes	Minimal	Procurement and training	No	Not obviously	No	No	No	Medium	Low
A20	High Speed Grinding	Maintenance grinding of rails at 80-100kph (in traffic) - reduces N&V also (RTR Magazine - p40)	www.vossloh-rail-services.com	EURAILmag Business & Technology	Track	Proven technology	Not known	Yes	N/A	Yes	Yes	Procurement and training	No	Not obviously	No	No	No	Easy	Medium
A22	Tram-train concept	Use of tram technology to travel via national network	N/A	Industry Press	All	Proven technology	No	Yes	N/A	Yes	Minimal	Proof of concept Safety case approval	Yes	Yes	To be confirmed	To be confirmed	Unlikely	Difficult	Low
A23	WiFi Comms for train control	The use of secure WiFi and GPS to control the movement of trains	N/A	Technical reports	Signalling	Developing technology	No	No	Similar	Possibly	Unlikely								
A24	Plug and play signalling connections	Quick and reliable method of connecting and testing signalling systems following infratsructure renewals	Various	Various European Railway Systems	Signalling	Proven Technology	No	Yes	Yes	Yes	Yes	Investment, training, standards	Yes	Yes	Yes	No	Possibly	Medium	Medium

Ref No.	Innovation Idea	Description	Supplier(s)	Source	Engineering Discipline(s)	Development Status	In Use			Transferability	CP5 Benefits	Enablers	Barriers					Ease of Implement	Size of NR Prize
							UK Rail	Other Rail	Other Industry			(Investment, training, etc.)	Culture	Standards	Safety	Organisation	Union		(CP5)
	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
A1	Radio Remote Control	Use of remote control technology to operate cranes	www.hetronic.com	Innotrans	Track Civil Engineering	Proven technology	Unaware	Yes	Yes	Yes	Yes	Interface with existing equipment	Yes	Not obviously	EMC?	No	No	Easy	Low
A2	ERTMS Level 3	Master Plan to get to ERTMS level 3	www.infrabel.be	Innotrans	Signal	Developing technology	No	No	N/A	Yes	No								
A25	Driver Advisory Systems	Reduction in energy requirements	Various	Technical reports	Traction Systems	Proven Technology	Yes	Yes	Yes	Yes	Minimal	Enhancement schemes	Possibly	Not obviously	No	No	Unlikely	Difficult	Low
A26	NDT for surface cracks	(Commercial) Deployment of eddy current technology	www.rohmann.de	Railway Strategies	Track	Recently proven technology	No	Infrequent	Not known	Yes	Possibly	Product approval (and proof of concept)	No	Maybe	No	No	No	Medium	Low
A27	Intelligent lubrication	Improved wheel/rail interface management from correct lubrication	www.rowehankins.com	Railway Strategies	Track	Proven technology	Yes (Sheffield)	Unknown	N/A	Yes	Minimal	Product approval	No	Not obviously	No	No	No	Easy	Low
A28	Solar panels	The use of solar panels to power lineside equipment particularly in remote locations	Various	Industry Press	All	Proven Technology	Yes	Yes	Yes	Yes	Yes	Product approval	No	Not obviously	No	No	No	Medium	Low
A29	Regenerative braking	A energy recovery mechanism which slows a vehicle or object down by converting its kinetic energy into another form, which can be either used immediately or stored until needed.	Various	Technical reports	Traction Systems	Proven technology	Yes	Yes	Yes	Yes	Minimal	System re-engineering	Yes	Not obviously	No	Possibly (industry level)	No	Difficult	Medium
A30	Variable stiffness suspension bushes	Reduced track damage through variable suspension characteristics	V/T SIC	ORR Start-Up Meeting	Track	Proven technology	Yes	Unknown	Unknown	N/A	Yes	Provision of suitable incentive	Possibly	Not obviously	No	Possibly (industry level)	No	Difficult	Medium
A31	Thermal imaging cameras	For identifying hot spots on OHL equipment	Various	Industry Press	OHL, Signalling	Proven technology	Yes	Yes	Yes	Yes	Yes	Product approval	No	Not obviously	No	No	No	Medium	Low
A32	Modern motorised switches	Use of motorised switches that are simple to install and maintain	www.morrisline.co.uk	Railway Strategies	Traction Systems	Proven technology	Unknown	Yes	N/A	Yes	Possibly	Product approval	No	Maybe	No	No	No	Easy	Low
A33	Slabtrack	Reduced whole life cycle costs	Various	RTR + ORR start up meeting	Track	Proven technology	Yes	Yes	N/A	Yes	Possibly (long asset life)	Policy change	Yes	No	No	No	No	Difficult	Medium
A34	Rail milling	Reprofile rails (rather than grind) especially in environments w/o sparks	www.vossloh-rail-services.com	Railway Track & Structures	Track	Proven technology	Maybe	Yes	N/A	Yes	Possible	Product approval	No	Maybe	No	No	No	Medium	Medium
A37	Multi-purpose SCADA COTS	SCADA system able to work with variety of assets	www.toshiba-railway.com	Innotrans	Signalling Traction Systems	Proven technology	Unknown	Unknown	Yes	Yes	Possible	Product approval	Yes	Yes	Yes	No	No	Difficult	Low
A38	LED illumination of stations	Used in trains and saving 30% energy	www.toshiba-railway.com	Innotrans	Buildings	Proven technology	Unknown	Yes	Yes	Yes	Possible	Policy change	No	No	No	No	No	Easy	Low
A41	Event recording on electric trains	Event monitoring can include contact wire voltage and unit power consumption - AM data	www.avpt.ru	Innotrans	Traction Systems	Proven technology	Unknown	Yes	N/A	Yes	Possible	Product approval (and proof of concept)	Yes	Maybe	No	Yes	No	Low	Low
A42	Energy saving switch heating	Switch heaters using electrical resistors controlled on basis of rail temperatures	www.revenga.com	Innotrans	Plant (Signalling)	Proven technology	Unknown	Yes	N/A	Yes	Possible	Product approval	No	No	No	No	No	Low	Low
A44	Radio-based level crossing system	SIL-4 communications system to periphals	www.revenga.com	Innotrans	Signalling	Proven technology	Unknown	Yes	N/A	Yes	Yes	Product approval	Yes	No	Yes	No	No	Difficult	Low
A45	Integrated remote monitoring systems	Hot-box, brake locking, WILD, dragged object, gauge excess check, pantograph check, wheel rolling parameters	www.revenga.com	Innotrans	All	Proven technology	Unknown	Yes	N/A	Yes	Possible	Product approval	Yes	Yes	Yes	Yes	No	Medium	Low

Ref No.	Innovation Idea	Description	Supplier(s)	Source	Engineering Discipline(s)	Development Status	In Use			Transferability	CP5 Benefits	Enablers	Barriers					Ease of Implement	Size of NR Prize
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	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
A1	Radio Remote Control	Use of remote control technology to operate cranes	www.hetronic.com	Innotrans	Track Civil Engineering	Proven technology	Unaware	Yes	Yes	Yes	Yes	Interface with existing equipment	Yes	Not obviously	EMC?	No	No	Easy	Low
A46	IP internet-based communications	Use of internet networks for voice and software communications	www.revenga.com	Innotrans	All	Proven technology	Unknown	Yes	Yes	Yes	Possible	Product approval (and proof of concept)	Yes	No	No	No	No	Difficult	Low
A47	Radiography testing	NDT of rails using radiography 9X-Ray, Gamma and SafeRad)	www.frazernashndt.co.uk	Innotrans	Track	Proven technology	Historic	Unknown	Yes	Yes	Unknown	Product approval (and proof of concept?)	Yes	Yes	Yes	No	No	Medium	Low
A49	Super-MPM train	MPM of 2 power units, 6 low wagons and back-actor traversing along top	www.herzogcompanies.com	Innotrans	Track Structures	Proven technology	No	Yes	N/A	Yes	Possible	Type approval & procurement plus management	Yes	No	No	Yes	No	Medium	Low
A50	Track lifter	Continuous track lifter (unpowered) to follow reballast	www.harscorail.com	Innotrans	Track	Proven technology	No	Yes	N/A	Yes	Possible	Type approval & procurement plus management	Yes	No	No	No	No	Medium	Low
A51	Cross-industry condition monitoring	Value for infrastructure from train condition monitoring	Concept only (T1011)	RSSB Research Ideas	All	Proven technology, but new use	Development	Unknown	N/A	Yes	Possible	Product approval (and proof of concept)	Yes	No	No	No	No	Medium	Medium
A52	RCM mapped onto reliability framework	Focus condition monitoring on reliability hot-spots	Concept only (T844)	RSSB Research Ideas	All	Proven technology, but new use	Development	Unknown	N/A	Yes	Possible	Product approval (and proof of concept)	Yes	No	No	No	No	Medium	Low
A54	Interface between Trimble & tampers	Automatic interface between 3-D design model (as usedby Trimble) & tamper front offset	Geoff Brown	Innotrans	Track	Proven technology	Unknown	Yes	N/A	Yes	Possible	Procuement & training	No	No	No	No	No	Low	Low
A56	Staff training	Train staff to be able to use full capacity of available plant	N/A	Innotrans	Track	Proven technology	No	Yes	N/A	Yes	Possible	Procuement & training	Yes	No	No	No	Maybe	Low	Low
A58	Optimised wheelset maintenance	Reduced track damage and systemlevel WLCC minimised from modelling	University of Huddersfield	RRUKA Annual Conference	Track Signalling	Developing technology	Yes	Unknown	N/A	Yes	Possible	Development and analysis	Yes	No	No	No	No	Medium	Medium
A60	Asset management modelling	Minimise WLCC of bridges by modelling different inspection and maintenance strategies	University of Notingham	RRUKA Annual Conference	Structures	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium
A61	Ballast reinforced with plastic	Increased stiffness achieved by introducing recycled plastic into ballast	Track21 / University of Southampton	RRUKA Annual Conference	Track	Developing technology	Unknown	Unknown	Unknown	Yes	No								
A62	Alternatives to lubrication	Utilisation of nanotechnology to remove requirement for railhead friction management	Blue Sky (Niall Fagan, HS2)	RRUKA Annual Conference	Track	Developing technology	Unknown	Unknown	Unknown	Yes	No								
A63	Instrumented conductor shoe	Identification of third-rail infrastructure to identify defects train/rail interface	Southern University of Birmingham	RRUKA Annual Conference	Track Traction Power	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium
A64	Improved understanding of earthworks	Develop models that predict behaviour of clay slopes under rail loading	University of Southampton	Interview	Civil Engineering	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium
A65	Improved ballast performance	Use of different grading profiles of ballast to improve asset life/performance	University of Southampton	Interview	Track	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	Possibly	Unlikely	No	No	Difficult	Low
A66	GRP reinforcement of bridges	Use properties of new material to reinforce existing structure	University of Southampton	Interview	Structures	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium

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							UK Rail	Other Rail	Other Industry			(Investment, training, etc.)	Culture	Standards	Safety	Organisation	Union		(CP5)
	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
A67	Plastic bridges	Use of new material to construct structures	University of Southampton	Interview	Structures	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium
A68	Monitor bridge scour	Use of cameras to monitor bridge scour degradation	University of Southampton	Interview	Structures	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Low
A69	Improved sleeper material and shape	Optimum shape and material of sleepers to optimise WLCC	University of Southampton	Interview	Track	Developing technology	Unknown	Unknown	Unknown	Yes	No								
A70	Active suspension	Utilisation of mechatronics to produce an active vehicle suspension that minimises infrastructure damage	University of Loughborough	Interview	Track Structures	Developing technology	Unknown	Unknown	Unknown	Yes	No								
A72	Convert 3rd-rail DC to OHLE AC	OHLE 25kV AC system more efficient infrastructure than 3rd rail 750v DC systems	University of Loughborough	Interview	Traction Systems	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium
A73	Active Pantograph	Utilisation of mechatronics to produce an active pantograph that minimises infrastructure damage	University of Loughborough	Interview	Traction Systems	Developing technology	Unknown	Unknown	Unknown	Yes	No								
A74	Traffic Management Systems	Train control coupled with Driver Advisory Systems	N/A	Technical reports	Operations	Developing technology	No	Possibly	N/A	Yes	No								
A75	Intelligent traffic management	Optimise capacity and efficient movement of trains	IRSE RTS Paper	IRSE RTS Paper	Signalling	Developing technology	No	Possibly	N/A	Yes	No								
A76	ATO	Closer headways and remova of lineside signalling	IRSE RTS Paper	IRSE RTS Paper	Signalling	Developing technology	No	Possibly	N/A	Yes	No								
A77	High-speed internet protocol communications	High-speed internet protocol communications	IRSE RTS Paper	IRSE RTS Paper	Signalling	Developing technology	No	Possibly	N/A	Yes	No	Product approval (and proof of concept)	Yes	No	No	No	No	Difficult	Low
A78	Standardisation of designs	*Reduction in bespoke designs and preferential engineering*	IRSE RTS Paper	IRSE RTS Paper	All	Proven technology	Yes	Yes	Yes	Yes	Yes	Development of principles	Yes	No	No	No	No	High	Medium
A79	Automation of inspection and maintenance	Greater use of sensors, exploitation of data and maintenance optimisation	IRSE RTS Paper	IRSE RTS Paper	All	Developing technology	Yes	Yes	Yes	Yes	Yes	Further research development	Yes	Possibly	No	No	Unlikely	Medium	Low
A80	Consolidation of information	Federation of databases using common architectures, languages and data directories	IRSE RTS Paper	IRSE RTS Paper	All	Proven technology	No	Possibly	Yes	Yes	Unlikely	Policy and development of principles	Possibly	No	No	No	No	Medium	Low
A81	Cascade serviceable material	Evaluation, transportation, reconditioning, planning	N/A	NR Paper	All	Proven technology	Yes	Yes	Yes	Yes	Yes	Process development	No	Possibly	No	No	No	Medium	High
A83	Local (COTS) controllers for level crossings	Use of industry standard PCs to control level crossings on a local basis (reduced systems integration = simpler safety assurance?)	N/A	ORR Start-Up Meeting	Signalling	Developing technology	No	Unknown	N/A	Yes	No								
A84	Variable train stiffness (SWT)	Reduced track damage through variable suspension characteristics	V/T SIC	ORR Start-Up Meeting	Track	Proven technology	Yes	Unknown	Unknown	N/A	Yes	Provision of suitable incentive	Possibly	Not obviously	No	Possibly (industry level)	No	Difficult	Medium
A85	No gold-plating of signalling systems	Identification of signalling safety specific functionality and transfer remaining functionality to COTS (cheaper) products	N/A	ORR Start-Up Meeting	Signalling	Developing technology	No	No	N/A	N/A	No								

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	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
A67	Plastic bridges	Use of new material to construct structures	University of Southampton	Interview	Structures	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium
A68	Monitor bridge scour	Use of cameras to monitor bridge scour degradation	University of Southampton	Interview	Structures	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Low
A69	Improved sleeper material and shape	Optimum shape and material of sleepers to optimise WLCC	University of Southampton	Interview	Track	Developing technology	Unknown	Unknown	Unknown	Yes	No								
A86	Improved pad design	Reduced maintenance requirements through optimising material properties	Pandrol	ORR Start-Up Meeting	Track	Proven technology	Yes	Yes	N/A	Yes	Minimal	Product approval	No	No	No	No	No	Easy	Low
A88	Fixed cameras	Monitoring asset performance remotely	Various	ORR Start-Up Meeting	Structures Signalling Track	Proven technology	Possibly	Unknown	Yes	Yes	Yes	Process development & approval	Possibly	Possibly	No	No	Unlikely	Difficult	Low
A89	Maintain drains	Minimise deterioration of track and signalling assets	N/A	ORR Start-Up Meeting	Signalling Track	Proven technology	Yes	Yes	Yes	Yes	Yes	Resources	Possibly	No	No	No	No	Easy	Low
A90	Monitor changes in bridge deflections	Use WILD and standard vehicle to regularly monitor bridge deflections	N/A	ORR Start-Up Meeting	Structures	Developing technology	No	No	No	N/A	No								
A91	Renewable energy sources	Wind and solar power sources to eliminate need for cable networks	Various	ORR Start-Up Meeting	All	Proven Technology	Yes	Yes	Yes	Yes	Yes	Product approval	No	Not obviously	No	No	No	Medium	Low
A92	Motion sensors on lights and escalators	Reduce energy requirements in buildings and depots	Various	ORR Start-Up Meeting	Buildings	Proven technology	Yes	Yes	Yes	Yes	Yes	Installation (investment)	No	No	No	No	No	Easy	Low
A93	Active monitoring of defects	Utilise SMRT approach where fault condition provided to depot so ready to repair	SMRT	ORR Start-Up Meeting	All	Proven technology	No	Yes	Yes	Yes	Unlikely	Product approval (and proof of concept)	Yes	Probably	No	No	No	Difficult	Medium
A94	Use of on-train monitoring data	Monitor voltage supplied to trains to identify potential defects & pictures from pantograph cameras	N/A	ORR Start-Up Meeting	Traction Power	Proven technology, but new use	Development	Unknown	N/A	Yes	Possible	Product approval (and proof of concept)	Yes	No	No	No	No	Medium	Medium
A95	Nanotechnology on glass	Reduce damage costs associated with graffitti	N/A	ORR Start-Up Meeting	Buildings	Developing technology	No	Unknown	Yes	Yes	No								
A96	Artificial intelligence	Use of AI techniques to enable machine learning	N/A	EsPRC Research areas	All	Developing technology	No	No	Yes	Yes	No								
A97	Unmanned Air Vehicles (UAV)	Regular aerial surveys of network	N/A	EsPRC Research areas	All	Proven technology, but new use	No	Possibly	Yes	Yes	No								
A98	Robotics	Undertake repetitive tasks using robotic technology	N/A	EsPRC Research areas	All	Developing technology	No	No	Yes	Yes	No								
A99	Sensors	Fit "deploy & forget" sensors into structures	BB Innovation	Interview	Buildings Structures	Proven technology	No	Unknown	Yes	Yes	Possible	Product approval (and proof of concept)	Possibly	No	No	No	No	Medium	Low
A100	Hybrid vehicles	Use of hybrid technology in OTMs (or avoiding OHLE infrastructure)	BB Innovation	Interview	Fleet Traction Power	Developing technology	No	Yes	Yes	Yes	No								
A101	Heat Pumps	Reduced need for external energy supplies	BB Innovation	Interview	Buildings	Proven Technology	Yes	Yes	Yes	Yes	Yes	Product approval	No	Not obviously	No	No	No	Medium	Low
A102	Solar panels at trackside	Reduced need for external energy supplies	BB Innovation	Interview	All	Proven Technology	Yes	Yes	Yes	Yes	Yes	Product approval	No	Not obviously	No	No	No	Medium	Low
A103	BIM modelling	Use BIM models for WLCC and handover (CDM)	BB Innovation	Interview	Primarily buildings & structures	Proven technology	Yes	Unknown	Yes	Yes	Possible	Development of process	Possibly	Not obviously	No	No	No	Easy	Low
A104	Use 4G and WiFi networks	Eliminate need for installing cable-based communications network	BB Innovation	Interview	All	Developing technology	No	No	Unknown	N/A	No								
A105	Materials: Ceramics	Use in low friction, low weight environments	BB Innovation	Interview	All	On-going development	Unknown	Unknown	Yes	Possibly	No								

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	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
A107	Materials: Additive Manufacturing	Complex components with minimal waste material (includes techniques such DMLS)	BB Innovation	Interview	All	On-going development	Unknown	Unknown	Yes	Possibly	No								
A108	4-D modelling	Virtual signal sighting (already in limited use)	Various	PB Innovation Book	All	Proven technology	Limited	Unknown	Yes	Yes	Possibly	Investment, rollout and training	No	Not obviously	No	No	No	Medium	Easy
A109	Mobile buildings built from Bonded Structural Panels (SIPS)	Flexible temporary buildings with integrated services and low energy solutions (including solar panels)	N/A	PB Innovation Book	All	On-going development	No	No	Yes	Possibly	No								
A110	Widespread use of UTGMS	Dynamic real-time understanding of track condition	Various	BBRT	Track	Proven technology	Yes	Yes	N/A	N/A	Yes	Investment and rollout	Yes	Possibly	Possibly	Possibly	Possibly	Medium	Medium
A111	Cloud Based IT	Enables access to large amounts of data to be stored	Various	Technical reports	All	On-going development	Limited	Unknown	Yes	Yes	Possibly	Development, rollout and training	No	Not obviously	No	No	No	Difficult	Low
A112	IT Developments in other sectors	Software development that will allow assist in communicating of information (Iphone/Ipad apps)	Various	Internet	All	Proven technology	Yes	Yes	Yes	Yes	Possibly	Development, rollout and training	Yes	Not obviously	No	No	Unlikely	Easy	Low
T1	Switch Heaters	Individual heating plates that can be controlled by cameras	www.indheater.com	Innotrans	Signalling	Proven technology	Unaware	Yes (Sweden)	N/A	Yes	Possibly	Product approval and training	No	Not obviously	No	No	No	Easy	Low
T2	High efficiency weedkiller train	On board image analysis system that applies treatment only where required	SNCF-Infra	Innotrans	Track	Proven technology	Unaware	Yes (France)	N/A	Yes	Possibly	Investment	No	Not obviously	No	No	No	Easy	Low
T3	Detection of cavity under seating structures	GPR type equipment that can detect underground cavities in high risk subsidence locations	SNCF-Infra	Innotrans	Track	Proven technology	Unaware	Yes (France)	Unaware	Yes	Possibly	Investment, product approval and training	No	Not obviously	No	No	No	Easy	Low
T4	3D Geostructural Model of rock walls	For monitoring of areas that may be susceptible to land slides or rock falls	SNCF-Infra	Innotrans	Civils	Proven technology	Unaware	Yes (France)	Unaware	Yes	Possibly	Investment, product approval and training	No	Not obviously	No	No	No	Easy	Low
T5	Ballast Undercutter	Road rail ballast undercutter excavator with discharge conveyor	Mitsui & Co. Plant Systems	Innotrans	Track	Proven technology	No	Yes (Japan)	N/A	Yes	Possibly	Investment, product approval and training	Possibly	Not obviously	Possibly	No	No	Easy	Medium
T6	Anti theft solution for cables	Making cables harder to cut and harder to separate the pure copper from other metals. Also identificatiion tags that cannot be destroyed	www.nexans.com/railways	Innotrans, railway gazette international sept 2012	Signalling	Proven technology	Unaware	Yes (Europe)	Unaware	Yes	Yes	Product approval	No	Not obviously	No	No	No	Easy	High
T7	Accumulator Tension Balancer	Automatic tensioner for OHL	www.tekki.co.jp/english/index.html	Innotrans	OHL	Proven technology	Unaware	Yes (Japan)	Unaware	Yes	Possibly	Investment, product approval and training	No	Not obviously	No	No	No	Easy	Low
T8	Contact wire cold presssure welding device	Allows contact wire to be butt welded together rather than spliced together	www.tekki.co.jp/english/index.html	Innotrans	OHL	Proven technology	Unaware	Yes (Japan)	Unaware	Yes	Possibly	Investment, product approval and training	Possibly	Possibly	No	No	No	Easy	Medium
T9	Pipe - Nail Method	System provides two functions of drainage and slope reinforcement	www.chiyoda-kizai.co.jp	Innotrans	Civils	Proven technology	Unaware	Yes (Japan)	Yes	Yes	Possibly	Investment	No	Possibly	No	No	No	Easy	Low
T10	Catenary Safety Condition Monitoring System	System that monitors the self tensioning euipment of OHL contact wires	www.impulseenc.com	Innotrans, railway gazette international sept 2012	OHL	Proven technology	Unaware	Yes (USA)	Unaware	Yes	Possibly	Investment	No	Not obviously	No	No	No	Easy	Low

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							UK Rail	Other Rail	Other Industry			(Investment, training, etc.)	Culture	Standards	Safety	Organisation	Union		(CP5)
	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
T11	Miantenance free rail (Dobain)	Changing the micro structure of the steel for a heat treated bainitic structure will prevent the development of RCF throughout the life of the rail	www.voestalpine.com/schienen/en/technology_and_competence/research_development/projects/bainitic_rail.html	Innotrans, railway gazette international sept 2012	Track	Under development and being trialled in Germany	No	Under trial in Germany	N/A	If proven, yes	Possibly	Product approval	No	Possibly	Possibly	No	No	Medium	Low
T12	Virtual lineside signalling	Utilises off the shelf hardware (mobile phones, ipads) to transmit encrypted messages between control centre and the train	www.park-signalling.co.uk	Innotrans, railway gazette international August 2012	Signalling	Under development and being trialled in UK	Under Trial	Unaware	Unaware	If proven, yes	Possibly	Investment, product approval and training	Yes	Yes	Yes	Yes	Possibly	Difficult	Low
T13	Rail Stress Test	A none destructive piece of equipment for measuring stress in rails	www.railstresstester.com	Innotrans	Track	Proven technology	Unaware	Yes (Holland)	N/A	Yes	Possibly	Investment, product approval and training	No	Possibly	No	No	No	Easy	Low
T14	Electronic rail lubrication system	Lubrication system that extrudes lubricant through holes drilled in the rail. Can be remote monitored	www.moklansa.de	Innotrans	Track	Proven technology	Unaware	Yes (Switzerland and Canada)	N/A	Yes	Possibly	Investment, product approval and training	No	Possibly	Possibly (drilling of rails)	No	No	Easy	Low
T15	Bogl Slab Track	Modular units of slab track that are prefabricated in a factory environment	www.max-boegl.com	Innotrans	Track	Proven technology	Unaware	Yes (Germany, Italy, Austria, China)	N/A	Yes	Possibly	Investment, product approval and training	No	Possibly	No	No	No	Easy	Low
T16	Railway Box	State of the art electricity metering and data management (for electric trains)	OBB-Infra	Innotrans	OHL	Proven technology	Unaware	Yes (Various European countries)	Unaware	Yes	Possibly	Investment	No	No	No	No	No	Easy	Low
T17	Loram Badger Ditch Cleaner	Purpose built machine for clearing out ditches	www.loram.com	Innotrans	Track	Proven technology	No	Yes (Nth America)	N/A	Yes to smaller gauge	Possibly	Investment, product approval and training	Possibly	No	Possibly	Possibly	No	Medium	Low
T18	Shoulder Ballast Cleaner	Purpose built machine for cleaning ballast shoulders	www.loram.com	Innotrans	Track	Proven technology	No	Yes (Nth America)	N/A	Yes to smaller gauge	Possibly	Investment, product approval and training	Possibly	No	Possibly	Possibly	No	Medium	Medium
T19	SWITCHENHANCER	Automatic switch lubricator	www.loram.com	Innotrans	Track	Proven technology	Unaware	Yes (Nth America)	N/A	Yes	Possibly	Investment, product approval and training	No	No	No	No	No	Easy	Medium
T20	TracShield	Track lubrication system for the top of the rail	www.loram.com	Innotrans	Track	Proven technology	Unaware	Yes (Nth America)	N/A	Yes	Possibly	Investment, product approval and training	No	No	No	No	No	Easy	Low
T21	None Intrusive Crossover System	Temporary crossover that does not affect the signalling system	nics.com	RailKonsult PR08 report	Track	Proven technology	No	Yes (Nexus)	N/A	Yes	Possibly	Product Approval	Yes	Possibly	Yes	No	No	Easy	Medium
T22	Mobile Maintenance Unit	Enclosed vehicle for undertaking safe maitenance activities with ALO	www.robel.info	Innotrans and RailKonsult PR08 report	Track	Proven technology	No	Yes (Europe)	N/A	Yes	Yes	Investment, product approval and training	No	No	No	No	No	Easy	High
T23	Side Dump Cart	Side tipping small trailer for use with RRV's	www.rcequip.com	Internet	Track	Proven technology	No	Yes (Nth America)	N/A	Yes	Possibly	Investement, product approval	No	No	Possibly	No	No	Easy	Low
T24	Inpipe	Culvert liming system	en.railcare.se/railcare	Meetings with the company Railcare	Civils	Proven technology	Unaware	Yes (Scandinavia)	Unaware	Yes	Possibly	Product approval	No	Possibly	No	No	No	Easy	Low
T25	Heater Stressing	High productivity stressing method when done in conjunction with MFBW	Methodology used in Europe	Site visits arranged by Sersa	Track	Proven technology	Trialled	Yes (Europe)	Unaware	Yes	Possibly	Training	Yes	No	Possibly	No	No	Easy	Low
T26	Herzog Plus Train	Accurate ballast distribution using Herzog's Programmable Lininear Distribution System	www.hrsi.com/railroad_services_plus_train.php	Internet and RailKonsult PR08 report	Track	Proven technology	No	Yes (Nth America)	N/A	Yes	Possibly	Investment, training	No	No	Possibly	No	Possibly	Easy	Medium

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	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
T27	Skako Train	Accurate distribution of granular material via a conveyor system	DB Schenker	DB Schenker	Track	Proven technology	Yes but only limited supply	Yes (Europe)	N/A	Already IN uk but more vehicles needed	Yes	Investment	No	No	No	No	No	Easy	Medium
T28	Second Life System	Resignification of screw holes on wooden sleepers and bearers	www.sersa-group.com	Sersa Group	Track	Proven technology	Yes but not utilised enough	Yes (Europe)	N/A	Already in UK but not used as much as it should be	Yes	Spread best practice and knowledge of the system	Yes	No	No	Possibly	No	Easy	Medium
T29	Luge Trolleys	Small mechanised trolleys used for high productivity and safer placing of clips and nylons	www.bsmekaniska.se	Visit to Sweden	Track	Proven technology	No	Yes (Scandinavia)	Unaware	Yes	Possibly	Investment, product approval	Yes	No	No	No	No	Easy	Low
T30	Frozen e-clip remover	Removes rusted in e-clips without damaging the sleeper housings	www.melvelle.com.au	Neil Andrew	Track	Proven technology	Unaware	Yes (Australasia)	Unaware	Yes	Possibly	Product approval	No	No	No	No	No	Easy	Low
T31	PMC Gantries	Switch handling gantries for renewing 1/2 sets of switches and individual crossings with dedicated teams	Geismar	Geismar	Track	Proven technology	No	Yes (France)	N/A	Yes	Yes	Product approval	No	No	No	No	No	Easy	Medium
T32	Rapid Automated Padding Machine (RAPM)	Mechanised repadding system	Not available yet	Blue Sky	Track	Concept	No	No	N/A	Design needed	Possibly	Design, Build and Product approval	No	No	No	No	No	Easy	Low
T33	The spider	bridge inspection or sand blasting with remote controlled vacumm clamping device	Company in Aberdeen	Company in Aberdeen	Civils	Proven technology	No	Unaware	Yes, ship cleaning and renovation	Yes	Possibly	Adaptability and product approval	No	No	No	No	No	Medium	Low
T34	New Automated Drainage cleaner	Remote control method of cleaning catchpits and drainage runs	Concept Only	Blue Sky	Track	Concept	No	No	Possibly	Possibly	No	Design, Build and Product approval	No	No	No	No	No	Difficult	Low
T35	Harmelen Level Crossing	Modular concrete slab units with embedded rail fitted	http://www.volkerrail.co.uk/en/about-us/volkerrail-products/harmelen-level-crossings	Volker Rail	Track	Proven technology	Trialled	Yes (Netherlands)	N/A	Yes	Possibly	Product Approval	No	No	No	No	No	Easy	Medium
M1	Inspection and Measurement System	Rail measurement condition & shape plus non-contact OHLE measure	www.bvSys.de	Innotrans	Track and OHL	Proven technology	Not this system	Yes	N/A	Yes	Possibly	Product Approval	Possibly	No	No	No	No	Easy	Low
M2	Standardised level crossing surfaces	Reduces costs through the reduction of skills ansd equipment needed to install and removedifferent level crossing surface units	Many, UK and Europe	Innotrans, Trade Publications	Track	Proven technology	Many different types, little standardisation	Yes, all Administrations	N/A	Yes	Possibly	Product Approval	No	No	No	No	No	Medium	Medium
M3	Dualinventive possession management	Innovative TCOD system (that can be remote controlled)	www.dualinventive.com	Innotrans	Track	Proven Technology	Product approved	Yes (Netherlands)	N/A	Yes	Yes	Investment and training, further product approval	No	No	No	Some previous history	No	Medium for whole network roll-out	Med to High
M4	Standardised surface lubrication policy	Policy required for standardised surface lubrication	Many, UK and Europe	Innotrans	Track	Policy	System and procedure	Yes, all Administrations	N/A	Yes	Yes	Unified policy	Possibly	No	No	Possibly	No	Easy	Low
M5	Mobile Maintenance Unit	Enclosed vehicle for undertaking safe maitenance activities with ALO	www.robel.info	Innotrans and RailKonsult PR08 report	Track	Proven technology	No	Yes (Europe)	N/A	Yes	Yes	Investment, product approval and training	No	No	No	No	No	Easy	High
M6	S&C inspection vehicle with instrumentation & software	Output compatible with existing systems	Geismar UK Ltd	Supplier	Track, Signalling, O&3rdRail Elec.	Proven technology	Prototype	HS1,	N/A	Yes	Yes	Principle approved, data transfer being developed	Possibly	No	No	Possibly	No	Easy	Medium

Ref No.	Innovation Idea	Description	Supplier(s)	Source	Engineering Discipline(s)	Development Status	In Use: UK Rail	In Use: Other Rail	In Use: Other Industry	Transferability	CP5 Benefits	Enablers (Investment, training, etc.)	Barriers: Culture	Barriers: Standards	Barriers: Safety	Barriers: Organisation	Barriers: Union	Ease of Implement	Size of NR Prize (CP5)
	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
M7	Integrated maintenance planning system (disciplines/OTP)	Unified interpretation and use of data produced	Many, UK and Europe	Innotrans, Trade Publications	All	Proven technology	Disparate systems, incoherent policy	Yes, all Administrations	N/A	Yes	Yes	Unified policy	Possibly	Possibly	No	Yes	Possibly	Difficult	High
M8	Materials recycling policy (ballast washing, sleeper/rail cascade)	Efficient use of NDS purpose-built facilities.	Network Rail's own organisation	Observation	All	Facilities in place	Yes	Yes, all Administrations	N/A	Yes	Yes	Implement policy	Yes	No	No	Yes	No	Difficult	High
M9	Standardised reliable switch toe bearers	Industry standard	Many, UK and Europe	Innotrans	Track and Signalling	Proven technology	Yes, but not standardised	Yes, all Administrations	N/A	Yes	Yes	Standardisation policy	No	Possibly	Yes	Yes	No	Easy	Low
M10	Ballast shoulder consolidation	Consolidation of ballast shoulder to increase lateral resistance after renewal and maintenance work	Plasser, Matisa, Harsco	Innotrans, observation	Track	Proven technology	In past, not currently	Yes, all Administrations	N/A	Yes	Yes	Policy	Yes	No	No	Yes	No	Easy	Medium
M11	Rail stress monitoring at vulnerable sites	Remote condition monitoring equipment for Rail stress monitoring at vulnerable sites	Many, UK and Europe	Innotrans, Trade Publications	Track	Proven technology	Minimal	Yes	N/A	Yes	Yes	Policy	No	No	No	Yes	No	Easy	Medium
M12	Geismar Amber Trolley	National policy required to encourage the use of the Geismar Amber trolley	Geismar UK Ltd	Supplier	Track	Proven technology	Yes	Similar	N/A	N/A	Yes	Policy	Yes	No	No	Yes	No	Easy	High
M13	GPR	The use of GPR and the correct interpretation of the results for specifications	Various	Technical reports	Track	Proven technology	Limited	Yes, particularly USA	Yes	Yes	Yes	Policy	No	No	No	Yes	No	Easy	High
M14	Standardisation of designs	Standardised design to reduce design costs	Design Consultancies	Observation	All	Some progress	Limited	Yes, particularly some European administrations	N/A	Yes	Yes	Policy	Yes	Yes	No	Yes	No	Difficult unless NR exercise design control on consultants	High
C1	GPR Renewal Specification	Renewal based on GPR results	Zetica	Known System	Track	Proven technology	Yes	Yes	Yes	Already available	Yes	Policy	No	Possibly	No	No	No	Easy	Medium
C2	Formation rehabilitation train	Purpose built high out put train for formation renewals	Plasser	Previous studies	Track	Proven technology	No	Yes	No	Yes with UK design	No								
C3	RailVac	Vacuum technology on rail mounted vehicle	Railcare	Previous studies	Track	Proven technology	Yes	Yes	Yes	Yes	Yes	Policy	Yes	Possibly	No	No	No	Easy	High
C4	On-train lubrication system	Lubricators on trains instead of on the track	Various	Previous studies	Track	Proven technology	Yes	Yes	N/A	Yes	Yes	Investment, Policy	No	Not obviously	No	No	No	Medium	Low
C5	On-train measuring systems	Train bourne measuring systems for various infrastructure components	Various	Previous studies	Track	Proven technology	Yes	Yes	No	Already available	Yes	Investment, Policy	No	Yes	No	Possibly	Possibly	Easy	High
C6	MFBW	Mobile flash butt welding on track renewals and defect renewal sites	Various	Previous studies	Track	Proven technology	Yes	Yes	No	Already available	Yes	Policy	No	Yes	No	No	No	Easy	Medium
C7	Aluminimum conductor rail	Better conductivity and power transfer than tradityional metals	Various	Previous studies	Track	Proven technology	Limited	Yes	Yes	Already available	No	None	No	No	No	No	No	Easy	Low
C8	MHT Rail/UIC60 Rail	Harder and larger sections of rail that will last longer	Tata	Previous studies	Track	Proven technology	Yes	Yes	No	Already available	No	Policy	No	Yes	No	No	No	Easy	Low
C9	Output based standards	Standards that are written based on actual outputs rather than instructions	Various	Previous studies	Track	On-going development	Yes	Yes	Yes	Yes	Yes	Process development and rollout (training)	Yes	Possibly	No	No	Possibly	Medium	Medium
C10	Slab-track	Concrete based track form	Various	Previous studies	Track	Proven technology	Yes	Yes	No	Already available	No	Investment / Policy	No	Possibly	No	No	No	Medium	Low

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	Title	Brief outline of innovation idea	Developer / supplier	Where idea found	Track, signal, etc	How well developed (technology readiness)	Details of existing deployment			Can it be used by NR	Benefits in CP5?	What required to implement	Any barriers to implementation					Easy/Difficult	High or Low
C11	Automated track protection systems	Various track protection systems in use arround the world	Various	Previous studies	Track	Proven technology	Yes	Yes	No	Already available	No	Policy	No	No	Yes	No	No	Medium	Low
C12	Renewable energy (solar panels, wind, heat pumps)	Powering line side equipment etc with reneable energy such as solar or wind power	Various	Various documentation	All	Proven technology	Maybe some equipment	Yes	Yes	Yes	Yes	Investment	No	Possibly	No	No	No	Easy	Low
C13	GOTCHA	Intellegent wheel impact and monitoring system	Strukton Systems	Previous studies	Track	Proven technology	Not aware	Yes	No	Yes	Yes	Investment / Training	No	Possibly	No	No	No	Easy	Medium
C14	GRIP lite process for platform walls	Simplified project control process for non-complex items	N/A	Previous studies	Civils	On-going development	Not aware	N/A	N/A	N/A	Possibly	Process development and rollout (training)	No	Yes	No	No	No	Medium	Medium
C15	Rail milling	Rail milling versus rail grinding	Various	Previous studies	Track	Proven technology	No	Yes	Yes	Yes	Possibly	Policy	No	Yes	No	No	No	Easy	Low
E1	Low Adhesion Monitoring	The use of a model based condition monitoring system to identify low adhesion conditions in real time	Loghborough University	RSSB Research Ideas	Track	Developing technology	No	Unknown	N/A	N/A	Unlikely	Continuous development of concept and policy change	No	Yes	Possibly	No	No	Difficult	Low
E2	Modelling behavior of clay embankment slopes	Develop models that predict behaviour of clay slopes under rail loading	University of Southampton	Interview	Civil Engineering	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium
E3	Off Site Manufacture	Improve build quality by manufacturing in a factory environment	Various	Modular S&C concept	All	On-going development	Yes	Yes	Yes	Yes	Yes	Continuous development of concept	No	No	No	No	No	Medium	Medium
E4	Concrete Canvas	Rolls of material impregnated with cement. Water is applied to make the rolls into a stiff material	concretecanvas.co.uk	Internet	Civils	Proven technology	Yes	Yes	Yes	Already been used	Possibly	Standards	No	Yes	No	No	No	Easy	Low
E5	Automated Inspection PLPR	Modern Technology that will enable inspection to be undertaken by vehicles	Omnicom	Various papers	Track	Developing technology	Being trialled	Similar systems	No	Being trialled	Yes	Investment, training, standards	Yes	Yes	Yes	Yes	Yes	Medium	Medium
E6	Improved POE Design	Improved products to achieve higher levels of reliability	Various	Literature review	Track	On-going development	Yes	Yes	N/A	N/A	Yes	Proof of concept and rollout	No	Possibly	No	No	No	Medium	Medium
E7	Improved OHLE components	New design of improved OHL components for new electrification systems	Various	Literature review	OHL	On-going development	Yes	Yes	N/A	N/A	Yes	Proof of concept and rollout	No	Possibly	No	No	No	Medium	Medium
E8	Consolidated Train Control Centres	Modern traffic management systems that enable a significant reduction in the number of control centres	N/A	Literature review	Operations	Developing technology	No	Possibly	N/A	Yes	No								
E9	Data Mining	A system that facilitates better visibility of emerging trends from data capture	N/A	Literature review	All	On-going development	Limited	Unknown	Yes	Yes	No								
E10	Mechatronic Bogies	Development of active bogies that are able to reduce forces imposed on rails thus reducing damage to the infrastructure	University of Loughborough	Interview	Track Structures	Developing technology	Unknown	Unknown	Unknown	Yes	Possible	Proof of concept	No	No	No	No	No	Medium	Medium
E11	Re-engineer junction rules	Research being undertaken to maximise capacity of the existing network	University of Loughborough	Interview	Track	Developing technology	No	No	No	N/A	No								
E12	Energy Storage	The storage of regenerated energy until it is required	University of Loughborough	Interview	All	Developing technology	No	Unknown	Yes	Yes	No								
E13	Virtual Coupling	Concept whereby trains travel to gether in close proximity but have the ability to quickly separate and go on different routes	University of Loughborough	Interview	Rolling Stock	Developing technology	No	No	No	N/A	No								
E14	COTS level crossing controllers	The use of IT equipment to control operations of level crossings	University of Loughborough	Interview	Signalling	Developing technology	No	Unknown	Yes	Possibly	No								
E15	Signalling beyond ETCS/Traffic control	Next generation of train control systems	University of Loughborough	Interview	Signalling	Developing technology	No	No	N/A	N/A	No								
E17	Fault Tolerance	Research into using redundant duplicate equipment to make critical areas tolerant of faults	University of Loughborough	Interview	All	Developing technology	No	Unknown	Yes	Possibly	No								
E18	Risk Based Maintenance	This is incorporated within existing Network rail programmes	University of Loughborough	Interview	All	On-going development	Yes	Yes	Yes	Yes	Yes	Continuous development of concept	Yes	Possibly	No	Possibly	Possibly	Medium	Medium

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