Technical Strategy
June 2013

A future driven by innovation

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"We see a future that challenges the limits of our current technical approaches. A future where we must increasingly rely on our ability to exploit a rich stream of innovation."

Richard Parry-Jones
Chairman

Foreword

Richard Parry-Jones
Chairman

"I am delighted to be able to introduce the Network Rail Technical Strategy (NRTS)."

In compiling the NRTS, we have been driven by the desire to offer customers & passengers a better rail journey experience and by the need to deliver our business outcomes.

Network Rail's success relies on highly technical and complex systems engineering. Our capability today enables us to operate and maintain one of the most intensively used railway networks in the world whilst delivering major upgrades to the infrastructure. Of course we don't do this alone. Our network carries trains as part of a railway system which in turn carry passengers and freight as part of a multi-modal transport system. So we work closely with our partners, suppliers, academics and other stakeholders from across the rail industry to achieve this capability.

However, we see a future that challenges the limits of our current technical approaches. A future where we must increasingly rely on our ability to exploit a rich stream of innovation.

We set out our plans to make progress on our strategic themes and corporate objectives in our Strategic Business Plan. The NRTS takes forward our technology and innovation theme, identifying opportunities in the Research and Development (R&D) arena that can unlock significant benefits for Network Rail and the wider rail industry. In our recent past, we have been under-investing in R&D by any benchmarked standard. These plans, as part of a wider cross-industry and European drive to innovate more through R&D, seek to bring the GB rail industry closer to global norms for R&D investment.

The challenge of the future railway requires dramatic and sustained change to the way we operate, manage and improve the railway system. That future must be driven by innovation, identifying and bringing into use technical solutions that improve the railway across all our key outcomes: safety, performance, customer experience, capacity, cost-efficiency and sustainability.

The industry's Rail Technical Strategy (RTS) was launched by the Technical Strategy Leadership Group in December 2012 which presented a vision of the future railway. In so doing, it called for the industry to step forward and convert the vision of the RTS into reality. This is exactly what we have done in preparing the NRTS, identifying specific R&D projects for implementation with indications of cost, duration, benefits and confidence level to aid prioritisation. The NRTS goes beyond the projects themselves to consider the way we need to work and the skills we need to achieve a future driven by innovation. Skills development as part of the people agenda is critical to our success.

To meet the challenge we need ambition and dedication. Being more ambitious means innovating for better outcomes from the railway as a system; showing dedication means our being prepared to work differently in response to the new challenges.

Our devolved organisation gives us new opportunities to work differently and the NRTS creates a framework that enables us to exploit those opportunities. The NRTS provides a framework within which our routes, working closely with train operators and other stakeholders, can continuously improve. So we pilot new solutions in a route, prove that the solutions work and then apply elsewhere. We need to spend less time displacing trains to carry out maintenance and we need to target the elimination of time our people spend in hazardous working environments. And we therefore see a clear priority to use technology to spend less time on the track and to better target maintenance and renewals.

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Being more ambitious means taking more risks. We need to be prepared for some of our ideas to fail during development. And for those ideas that do progress to prototype, we need to take R&D risks away from the live service environment. We are therefore placing a substantial emphasis on developing modelling and testing capability and working with the industry to make the facilities accessible to the industry as a whole.

Being more ambitious means we must pursue game changing innovations as well as an increase in the pace of incremental change and better components. Game changing innovations must optimise the outcome for the system, not merely shift problems around the system. They must also recognise that there will continue to be a balance between the benefits from universally applied solutions and the benefits from local configuration. Taking capacity increase, for example, innovation to signalling, redesigning pinch points, regulating trains, influencing passenger decisions and designing rolling stock to carry more people all potentially have a part to play. But the role of each must be considered by route and our routes must have the tools to be able to optimise the configuration locally.

Our ability to be more ambitious critically relies on strengthening collaboration at all levels: across disciplines, within Network Rail, between Network Rail and across the rail industry, with European and world railways and beyond the rail industry to other technology sectors.

There must be a strong connection between long term planning and long term technical capability. The Long Term Planning Process and the forthcoming Route Studies need ambitious technical solutions to be deliverable; and, in some cases, technical solutions themselves will drive new thinking about what is possible. We will support this by building on our close working with the technical strategy leadership community across the industry including Europe and including our academic partners and suppliers.

There is much to do. We have a good foundation with the R&D led directly by Network Rail, the R&D already in place through the TSLG community and we now have the NRTS as a key milestone. But it is important to recognise we are at the early stages of a long and challenging journey.

The consultation process for the NRTS has been extensive, reaching out to every part of the business with a draft prepared in December 2012. There has been overwhelming support for the NRTS from the business and now comments and feedback from the industry's technical leadership community have been incorporated into this first published version.

We will be keeping the strategy under review but our priority now is to move forward with the process of implementation.

I look forward to continuing to work with all of you to deliver the huge benefits available to us.

Richard Parry-Jones
Chairman

Network Rail Technical Strategy at a glance

Contents

Strategic business outcomes, themes and enablers.

Strategic business outcomes are achieved through technical innovation using a whole system approach. The whole system approach is underpinned with information which connects the function of physical assets to form the railway system. Our objectives are enabled by people collaborating to progress the innovation process.

How the R&D investment programmes are organised

R&D portfolios

The programmes of R&D investment are grouped under eight portfolios that reflect our major areas of opportunity. These are:

- Monitoring, assessment and optimised maintenance
- Modelling and decision support
- Traffic management
- Seamless end-to-end journeys
- Increased data and information flow
- Better energy use
- Enhanced design
- Transformation

Strategic business outcomes

The R&D investment programmes are linked to six strategic business outcomes where we mainly expect to realise benefit. These are:

- Safety
- Performance
- Improving the customer experience
- Capacity
- Cost-efficiency
- Sustainability

Themes

The Network Rail Technical Strategy (NRTS) is structured under the eight themes used in the 2012 Rail Technical Strategy (RTS) produced by the Technical Strategy Leadership Group (TSLG) for the rail industry in Great Britain. The first two themes relate to the way that customers use the railway and how all our assets work together with other railway assets as an integrated and interdependent system to meet their needs. The remaining six deal with our groups of assets. The list of themes comprises:

- Customer experience
- Whole system approach

- Information
- Telecommunications
- Command and control
- Energy
- Infrastructure
- Rolling stock

Asset themes

Enablers

The enablers to achieve our objectives through R&D investment are:

- Innovation process
- People
- Collaboration

A guide to this document

The R&D summary table on pages 14 to 16 groups programmes of R&D investment under their respective portfolios. It also indicates the theme and strategic outcome that each programme addresses.

Pages 18 to 74 describe the eight themes in greater detail. In each case we outline:

- What we aim to achieve before, during and after the end of Control Period 5 (CP5) in 2019
- The scope and scale of the work – giving an indication of 'the size of the prize'
- The challenges and opportunities we face and our approach to technology. For example, are we reaching the limits of current technology? If new technologies are needed, where and how might these be sourced?
- R&D work currently under way
- Requirements and expectations for the future.

After each description is an indicative investment table showing the contribution we expect individual projects to make to strategic business outcomes along with the relative impact of the benefits and the likely magnitude of investment.

The eight themes are followed by a description of our 'enablers' – how we will develop and use our innovation processes, people and collaborations to achieve our objectives.

Summary

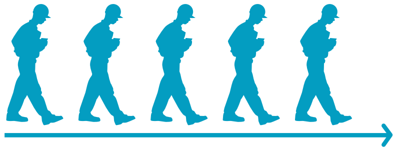
The Network Rail Technical Strategy (NRTS) sets the framework for R&D investment, progressing the technology and innovation strategic theme in our Strategic Business Plan (SBP). The NRTS identifies technical barriers to achieving our corporate objectives and the opportunities to overcome these through research and development (R&D). Investing in technology and applying off-the-shelf technology will transform our ability to reduce and design out failures, optimising the way the railway functions. This will make us better at targeting where, when and how we improve the railway, and will lead to a future driven by innovation.

The NRTS supplements the SBP to support the substantial planned increase in R&D investment during CP5. It sets out gaps and priority investment areas for R&D using the framework of themes and opportunities set out in the industry Rail Technical Strategy. While Network Rail expects to make a substantial investment in R&D during CP5, we also expect suppliers to innovate, invest and share risks from the development and commercialisation of products where appropriate. We recognise that many elements of the NRTS will require extensive collaboration across the industry including Europe, with design and delivery of some activities being performed externally to Network Rail. Having published this strategy, we will now go on to develop a market engagement strategy to target investment and identify opportunities to collaborate both across the industry and beyond to other sectors and global markets.

Our strategy for R&D investment takes a holistic view of the railway and pursues both near-term needs and long-term opportunities. However, within that holistic framework, our approach will be targeted. We will put particular emphasis on investing in R&D for near-term benefit that reduces risk to workers and the public, improves the cost-effective maintenance and renewal of assets and leads to better customer information and passenger experience. Alongside this, we will invest in R&D for the longer term to increase capacity while achieving combined levels of reliability, availability, maintainability and safety simply not achievable with today's technologies and system design.

The R&D investment will be influenced by Network Rail's Long Term Planning Process (LTPP), which exists to plan the long-term capability of the network, up to 30 years into the future, to promote the efficient use of network capability and capacity. Network Rail's Network Route Utilisation Strategy (NRUS) has already considered the future of rolling stock, electrification and the operation of independently powered Electric Multiple Units (IPEMU) on the rail network.

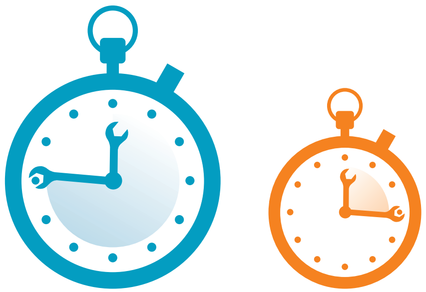
Reducing the risk to trackside workers



At present

Our ambition

Reducing the duration and impact of maintenance

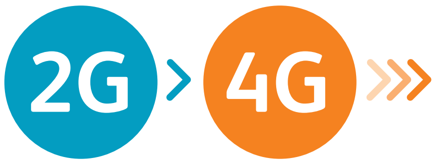


At present

Our ambition

Increasing modelling and testing

Upgradeable industry standard technology



Working towards our strategic business outcomes

Our ambition for R&D investment is summarised below against our six strategic business outcomes.

Safety

We will work with our industry partners to operate the network with an expectation that casualties will reduce towards the elimination of fatalities, serious injuries and repeat-cause incidents, embedding a "Safety by Design" philosophy to everything that we do.

Our work on safety will be addressed through three of the R&D portfolios.

Monitoring, assessment and optimised maintenance

The safety of track workers, including power and communications workers, will be improved through automated monitoring and assessment and better targeted maintenance and repair, with automated self-adjustment of assets in the longer term. This will separate trains and people, reducing the need for workers trackside. The application of new command and control systems will enable embedded automated systems to rapidly impose and remove safety zones for track workers.

Public safety will be improved as level crossings are made safer and more intelligent, with efficient systems to detect obstacles on or near the track and more direct interaction with road vehicles utilising automotive GSM capability.

Passenger safety will be improved through high frequency automated monitoring of infrastructure for safety-critical failures.

Seamless end-to-end journeys

Passenger safety will be improved through design improvements at stations – anti-social behaviour detection through CCTV and intelligent image processing, for example – and a reduction in slips, trips and falls through developments such as an intelligent interface between platform and train.

Enhanced design

Passenger safety will be improved through the European Train Control System (ETCS) with Automatic Train Protection (ATP).

Performance

An early focus is to reduce the variability in train service reliability. We will work with Train Operating Companies (TOCs) to ensure increasingly resilient timetables are put in place and evolve our approach to asset management with automated monitoring, less emergency maintenance and design for less maintenance overall.

Our work on performance will be addressed through five of the R&D portfolios.

Monitoring, assessment and optimised maintenance

The condition of assets will be measured using automated monitoring and assessment. Non-disruptive inspection and targeted timely maintenance interventions will maximise track availability with automated self-adjustment of assets in the longer term. We will use our telecommunications assets to support vehicle identification for increased monitoring of the infrastructure by trains.

We will work with industry partners to increasingly improve the train specification and railway system compatibility relationship to minimise damage to all assets and to ensure that the capability from the infrastructure is fully exploited.

Modelling and decision support
Decision-making will be improved through better modelling techniques that will integrate information by considering the whole railway system. Trade-offs such as those between capacity and performance will be optimised through modelling and decision-support tools. Modelling will be closely linked to the design and outputs that can be routinely achieved from enhanced testing facilities that represent the railway network.

Traffic management
We will support industry partners to develop better performing rolling stock, with more predictable acceleration and braking and faster freight, and will enable quicker recovery from disruption by improving traffic management. Telecommunications assets will be used to support traffic management through train positioning.

Where access for maintenance and renewals is required, the impact will be reduced using new capabilities from the ETCS including bi-directional running.

Increased data and information flow
The increase in data generated from automated monitoring and assessment to improve the performance of assets will be enabled through enhancements to telecommunications capacity.

Enhanced design
The resilience of assets will increase through the development and use of new materials. New switch and crossing designs will increase reliability for the current railway and the design of asset components will be developed to provide improved weather resilience. For the longer term, we will invest in more radical solutions using integrated mechanical, electronic and computer technologies (mechatronics) to transform performance.

Improving the customer experience
We will generate outstanding value for taxpayers and customers by continually improving the railway with more train paths delivered reliably, safely and at lower cost. That means working with industry partners to improve current services (particularly the availability of real-time personalised travel information for passengers or consignment-specific information for freight) along with integration with other transport modes and enabling customers to make good use of their time while travelling.

Work to improve the customer experience will focus on two R&D portfolios.

Seamless end-to-end journeys
A key area of investment is to understand how customers use the railway as part of an end-to-end journey. In the longer term, that will help us rethink our services, understanding how we can realign, redefine and re-scope what we do to serve new and unfulfilled customer needs.

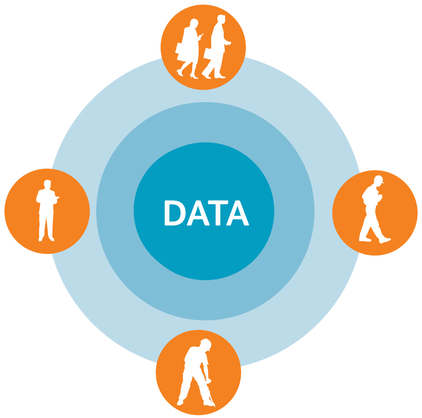
We will work with industry partners to achieve seamless end-to-end journeys using smart ticketing through mobile devices. The capability to overcome disruptions will be achieved through personalised travel solutions integrated with connecting transport services and services that make visible and mitigate the impact of disruption.

Value for customers is important and continuing to enhance the value of rail travel will ensure that rail continues to retain and attract new customers. For commuter, regional and long-distance journeys, a major source of value is to ensure that customers can make better use of time spent travelling by providing reliable train-based voice communications and broadband availability throughout the journey, on trains and at stations. The design of stations will be enhanced to support the use of time as well as to improve accessibility and safety.

Seamless end-to-end journey

Making use of customers' time

Open information sharing



Maximising existing telecommunications capacity

At present Our ambition

There is an opportunity to increase the market share for rail freight by increasing the reach and value of rail freight services. Making real-time information available to customers and locating freight interchanges to support freight customer operations will enhance our offer of this service.

Technologies will be developed to minimise disruption to services from enhancements and maintenance. These technologies will be particularly important to enable major potential programmes such as the conversion of DC third rail to AC overhead line electrification. In the long term, automated maintenance technologies will increase availability of the railway.

Increased data and information flow

Better customer information will rely on common and optimised information flow across the industry to get reliable, meaningful information to customers in real time, improved by real time exchange of open data with other transport modes.

The increase in data generated from automated monitoring and assessment of assets will be supported through enhancements to telecommunications capacity including voice and broadband.

Capacity

Our network will utilise new control systems enabling trains to run closer together. Our network will operate on an increasingly optimised basis, balancing the needs of passengers and freight and progressing towards real-time optimisation of the rail timetable linked to customer demand. This will reduce the need to build contingency into the timetable, making available more train paths. On high-demand suburban and commuter routes, we expect to enable metro-style services that operate on a frequency rather than a timed basis.

We will increase capacity with projects focused on three of the R&D portfolios.

Modelling and decision-support

Network capacity will be improved through better modelling techniques and layout design, with modelling closely linked to the design and outputs from enhanced testing capabilities. Network availability will be maximised using modelling and analytical tools that support non-disruptive inspection and targeted timely maintenance interventions, enabling testing of the impact of proposed changes to the timetable. Trade-offs, for example between capacity and performance, network availability and maintenance, renewals and revenue and resilience and costs, will be optimised through modelling and decision-support tools. Modelling tools will be developed with industry to make an integrated consideration of capacity enhancement options, using a combination of infrastructure and rolling stock interventions.

Summary
Themes
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Enablers
Next steps
Glossary

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Traffic management
We will work with industry partners to increase capacity through the development of real-time traffic management capability, initially with better traffic management from rolling stock performance improvements such as more predictable braking and acceleration, train positioning and Driver Advisory System (DAS). We will support the design of faster freight rolling stock to reduce its effective occupancy of the network and, in the longer term, we aim to see virtual coupling of rolling stock units to increase throughput by more efficient and flexible train configuration. This will ultimately achieve optimised real-time traffic management with dynamic train control, incorporating the Future Traffic Regulation Optimisation project (FuTRO), through self-learning intelligent IT systems integrated with traffic management.

To increase available train paths, we will work with train operators to reduce station dwell times, by maximising the efficiency of passenger boarding and alighting through minimised door opening and closing cycle times. We will work with train operators and their suppliers and partners to explore increasing the capacity of trains.

Better energy use
We will manage energy demand to ensure capacity is not constrained by the limitations of power supply. Where the acceleration and speed of trains is constrained by the electrification system, active pantograph design will be employed to mitigate this constraint.

Cost-efficiency

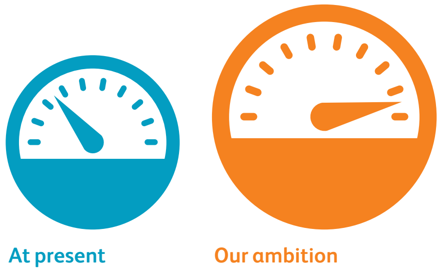
With 2012/13 annual maintenance costs at £0.9 billion, an early focus is to increase cost efficiency. We will improve the cost-effectiveness of our asset management by developing and applying our understanding of whole-life, whole-system issues and trade-offs.

We will innovate to reduce costs under five of the R&D portfolios.

Monitoring, assessment and optimised maintenance
We will work with industry partners to ensure that the railway is managed as a system, with interfaces between infrastructure and trains being modelled and predicted to control costs and increase asset life. To this end we will:

- Develop capabilities for non-disruptive inspection and targeted timely maintenance interventions of critical assets, including track, signalling, earthworks and bridges, with improved corrosion protection for bridges to reduce maintenance.
- Increase the cost-efficiency of increased monitoring of the infrastructure, and potentially rolling stock, through the use of telecommunications assets using fibre sensing and vehicle identification.
- Work with operators to reduce costs from infrastructure wear and energy costs arising from rolling stock – initially through better maintenance and, longer term, through lighter rolling stock design while also retaining crashworthiness and reducing rolling stock operating costs.

Better performance to increase capacity



Sensing train position

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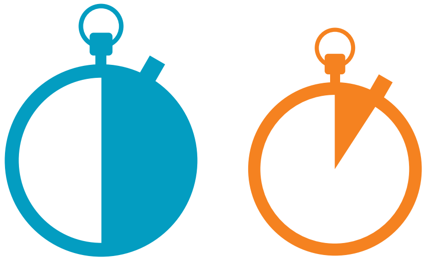
Reducing dwell times



At present

Our ambition

Automating inspection of assets

At present

Our ambition

Modelling and decision support

Through the development of modelling and analytical decision-support tools, we will increase our capability to optimise trade-offs from a whole system perspective. We will:

- Develop tools that support non-disruptive inspection and targeted timely maintenance interventions.
- Work with industry partners to advance the capability of our tools to assess and support optimised decisions based on whole-life cost.

Increased data and information flow

We will increase data and information flow, exploiting increasingly effective and efficient technologies to provide real-time information cost-effectively across the rail industry community.

Better energy use

To achieve improved energy use, we will:

- Develop our design and test capability to reduce the cost of infrastructure for electrically powered trains, including working with the industry to develop a more reliable, reduced-wear pantograph system that can operate at higher speed, and a cost-efficient means to convert DC third rail to AC overhead line.
- Reduce costs through efficient and resilient energy distribution using energy harvesting and smart power distribution grids.

Enhanced design

Enhancing the design of key assets will include:

- More robust and cost-effective design, test, installation and maintenance of conventional signalling infrastructure, using modular signalling and remote monitoring.
- Reduced costs for maintaining line-side infrastructure through developing and applying modern train-borne signalling systems, providing in-cab functionality and Automatic Train Protection through the European Train Control System.
- Improved design and materials including new track, sleeper and ballast/slab design and, in the longer term, a self-adjusting mechatronic railway.
- Working with operators to develop design requirements for modular train sub-systems, enabling cost effective procurement and upgrade, as the functioning of rolling stock and infrastructure become increasingly integrated.

Sustainability

The GB railway is central to a sustainable UK economy – driving economic growth, improving social opportunities and supporting a greener environment. We will work with industry partners to reduce carbon emissions, invest in energy-efficient assets and make progress towards sustained community support. Investing in R&D for sustainability will underpin Network Rail as a strong and prosperous business and a great place to work.

Investments in sustainability will be progressed through seven of the eight R&D portfolios. The eighth portfolio, modelling and decision-support, intrinsically develops our capability to make trade-offs based on consideration of the whole railway system in the wider social, economic and environmental context.

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Monitoring, assessment and optimised maintenance
We will work with operators to reduce costs from infrastructure wear arising from rolling stock – initially through better maintenance and longer term through lighter rolling stock design (while retaining crashworthiness, stability and performance) and through more radical solutions using mechatronics.

Traffic management
We will work with industry partners to achieve a reduction in energy use and carbon impact through the development of real-time traffic management capability. In the near term, better traffic management from rolling stock performance improvements will be achieved through more predictable braking and acceleration, train positioning and DAS, supported by the use of our telecommunications assets. In the longer term, energy use will be optimised through real-time traffic management with dynamic train control, incorporating FuTRO, along with self-learning intelligent IT systems integrated with traffic management.

Seamless end-to-end journeys
Transporting freight by rail is attractive from both an economic and environmental perspective. Developing our capability to optimise operational planning of services will increase our share of non-traditional markets, making better use of network capacity, reducing carbon emissions and increasing the economic sustainability of the railway. This will be supported by integrated planning information from beyond the terminal and distribution customer value chain to improve freight strategic planning. The attractiveness of rail freight will be further enhanced through longer, faster trains.

Increased data and information flow
We will develop approaches to secure and protect our information and systems, particularly in respect of cyber security, while supporting open data sharing. We will work with industry to share approaches and develop common information-sharing architectures, providing a sustainable platform for the future.

Better energy use
We will work with operators and other industry partners to reduce rolling stock energy use. In the longer term, lighter rolling stock will be designed while retaining crashworthiness, stability and performance.

We will work with industry to develop the capability to increase the proportion of the network that can be accessed using electrically powered trains. This will include the development of on-train energy storage, taking forward the development of the IPEMU, and associated research and development of supporting infrastructure. We also expect energy storage on trains to present opportunities to simplify the design of electrification infrastructure, making it more reliable and resilient with lower maintenance and renewals costs.

Energy use will be reduced and optimised through efficient and resilient energy management and distribution using new modelling capabilities and smart power distribution grids with energy harvesting to reduce reliance on external energy sources.

Enhanced design
We will work with industry to reduce the impact of introducing improvements to the infrastructure and rolling stock system. We will work with operators to develop the design requirements for modular train sub-systems that enable cost-effective procurement and upgrade as the functioning of the rolling stock and infrastructure become increasingly integrated.

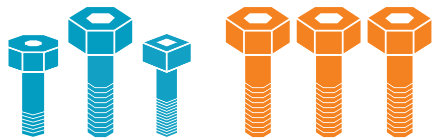
Transformation
Together with our industry partners, we will transform our approach to innovation through process, people and collaboration, driving the foundation of economic sustainability into all that we do.

More efficient and responsive information flow

Increasing energy storage and harvesting

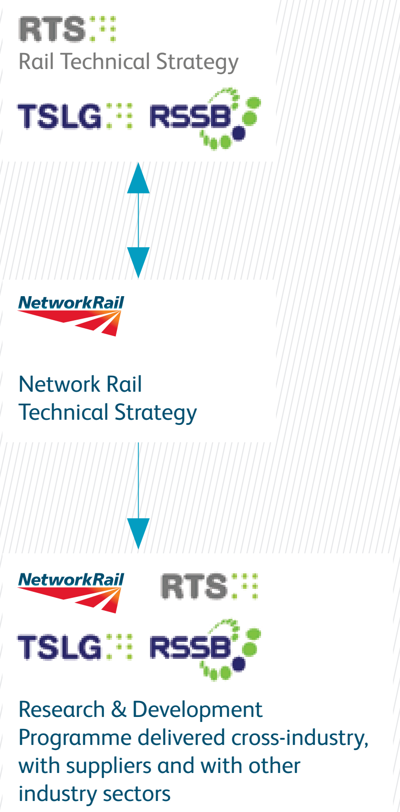
At present　Our ambition

Standardising rolling stock



At present　Our ambition

RTS, NRTS and industry research and development



Our enablers – innovation process, people, collaboration

We will engage in a cross-industry transformational change programme that will cover the costs of benchmarking and developing new, more efficient methods of innovation, research and development. We will increasingly collaborate with industry and universities to invest in R&D using an Open Innovation approach. We will co-ordinate the development of capabilities, exploiting technology from other sectors and breaking down the barriers between inventors, developers, implementers and decision-makers. We will continue to build our relationship with industry through our role in, and contribution to, the TSLG. We will continue to collaborate with our European railway partners, providing leadership and commitment particularly to the Shift^{2}Rail programme. The NRTS is aligned with roadmaps produced by the European Rail Research Advisory Council (ERRAC).

We will use tools to support collaboration, achieving transparency through easy-to-understand visualisations as the route to shared and managed data on R&D. We will also build our capability to successfully target investment through roadmaps that connect with the wider industry ambition to transform the GB railway.

Next steps

While the NRTS is driven by a long-term vision, our primary focus for this first iteration is to frame investments for our business planning and, where appropriate, the regulatory plans for CP5. Alongside the identification and initiation of R&D investment projects and programmes, a pressing challenge is to establish and embed the innovation process to increase the pace, quantity and quality of new and improved products and systems and to create a strong connection between R&D and its application to investments.

At this stage we are establishing early investment priorities within the portfolios, principally at the level of programmes. These priorities will include reducing risk to workers and the public; improving the cost-effective maintenance and renewal of assets; better customer information and passenger experience; and, for the longer term, increasing capacity while achieving better performance.

From these programmes, projects will be defined and a process of regular strategic and programme review will be established. Further information will be published in due course. Our first update to this strategy will take into account the conclusions from an industry study examining current and future capabilities and their sourcing and development; commercial approaches identified and recommended through our emerging product strategy; and progress with detailed technology roadmapping.

R&D investment summary table

The investment table below shows the eight portfolios under which the investment programmes are grouped along with key project examples drawn from the investment tables under each theme. It also shows the primary strategic outcomes to which the programme contributes, the degree of impact from the benefits of the programme and the likely magnitude of the required investment.

Portfolio	Investment programme	Key Project Examples	Theme	Strategic outcome	CP5 benefits of portfolio (large spot=high impact)	CP6+ benefits of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
Monitoring, assessment and optimised maintenance	Improving the safety of staff, passengers and the public at interfaces with signalling infrastructure	Obstacle detection and automated intervention Level crossing interface with other transport modes	Control and command	Safety			£££
	Robust and cost effective design, test, installation and maintenance of signalling infrastructure	Modular signalling Remote monitoring technology for critical assets	Control and command	Cost efficiency			££
	Safer inspection, repair and maintenance capability for electric traction infrastructure	Push button isolation and easy test for live overhead line and conductor rail	Energy	Safety Performance			£££
	Reduced cost and maximised track availability by non-disruptive inspection and targeted timely maintenance interventions	RCM, Health and Usage Monitoring Systems Mechatronic railway with self adjustment	Infrastructure	Performance Cost efficiency			££££
	Reduced cost and improved safety of earthworks by non-disruptive inspection and targeted timely maintenance interventions	Optical Fibres as general movement / performance sensor Detection Technology for earthworks stability	Infrastructure	Safety Cost efficiency			££
	Reduced cost and improved safety of structures and buildings by non-disruptive inspection and targeted timely maintenance interventions	Bridge corrosion detection – specifically developing and calibrating guided ultrasonic's technology Better corrosion protection systems	Infrastructure	Cost efficiency Safety			££
	Reduced infrastructure wear and energy costs arising from rolling stock whilst retaining rolling stock crashworthiness and reducing rolling stock operating costs	Refining and developing the wheel / rail interface including mechatronic bogies and running gear development Developing on train remote condition monitoring and instrumentation	Rolling stock	Sustainability Cost efficiency			£££
	Using telecommunications assets for reduced cost and maximised track availability	Remote monitoring technology for critical assets using fibre sensing Vehicle identification	Telecoms	Cost efficiency Performance			££
Modelling and decision support	Increased network capacity and performance through improved modelling techniques and layout design	Performance and operational modelling Differentiated railway	Whole systems approach	Capacity Performance			££££
	Modelling and analytical tools to support reduced cost and maximised network availability by non-disruptive inspection and targeted timely maintenance interventions	Integrated modelling capability – decision support tools Autonomous Intelligent Systems	Whole systems approach	Capacity Cost efficiency			£££
	Systems architecture, interfaces and test	Whole system testing centre	Control and command	Performance			£££

Level of impact

LOW · MEDIUM · HIGH · VERY HIGH

Portfolio	Investment programme	Key Project Examples	Theme	Strategic outcome	CP5 benefits of portfolio (large spot=high impact)	CP6+ benefits of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
Traffic management	Real-time traffic management capability for increased capacity, energy efficiency and sustainability	Vehicle positioning to increase the robustness of train location solutions (including COMPASS). Optimised traffic management (FuTRo)	Control and command	Capacity Sustainability	LOW	VERY HIGH	£££
	Optimising station dwell time to maximise passenger boarding and alighting and minimise door opening / closing cycle time	Optimising and reducing dwell times, including auto-opening, level platforms and train floors, adequate standbacks, number and position of doors, in service door failure management, train stopping position	Rolling stock	Capacity	HIGH	MEDIUM	££
	Improve the capacity and performance of rolling stock to increase network capacity, reliability and performance	Better traffic management from better braking and acceleration Faster freight	Rolling stock	Capacity Performance	HIGH	VERY HIGH	£££
	Using telecommunications assets for optimised traffic management	Capturing voice communications operational requirements for better traffic management	Telecoms	Performance Sustainability	MEDIUM	HIGH	££
End to end journey	Seamless end to end journey and overcoming disruptions – personalised travel solutions integrated with connecting transport services and services that mitigate the impact of disruption	Ticketing simplification and integration Better real time information for customers to minimise or overcome disruptions and across transport modes	Customer experience	Customer	HIGH	VERY HIGH	£££
	Competitive and attractive – cost effective, reliable and frequent services	Freight strategy	Customer experience	Customer Sustainability	MEDIUM	HIGH	££
	Making use of time – ease of navigation around stations and opportunity to use travel time to suit customer	Station design	Customer experience	Customer Safety	MEDIUM	MEDIUM	££
Increased data and information flow	Securing and protecting information and systems	Cyber security programme including: - Cross-Domain Risk Modelling - Cyber Security Organisation - Security Operations Centre - Secure Systems Development Model	Telecoms	Sustainability	HIGH	VERY HIGH	££
	Creating common information architectures and protocols		Information	Sustainability			££
	Exploiting rail information through commercial partnerships	Common and optimised information flow across industry Use of big data	Information	Cost efficiency	VERY HIGH	VERY HIGH	££
	Enabled next generation communication services including capacity enhancement	Telecommunications capacity enhancement including voice and broadband	Telecoms	Customer Performance	HIGH	HIGH	££

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Level of impact

● LOW ● MEDIUM ● HIGH ● VERY HIGH

Portfolio	Investment programme	Key Project Examples	Theme	Strategic outcome	**CP5 benefits of portfolio** (large spot=high impact)	**CP6+ benefits of portfolio** (large spot= high impact)	**Proposed CP5 R&D investment** (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
Better energy use	Capability to increase proportion of electric traction energy use	Independent power through on-train energy storage, recycling and optimised use of energy and charging facilities	Energy	Sustainability	LOW	VERY HIGH	£££
	Efficient and resilient energy distribution	Energy harvesting Smart power distribution grids	Energy	Sustainability Cost efficiency	MEDIUM	HIGH	£££
	Managing energy demand	Energy demand modelling Non-traction energy efficiency and storage	Energy	Sustainability Capacity	LOW	MEDIUM	££
Modelling and decision support	Modern signalling systems providing in-cab functionality and Automatic Train Protection and reducing lineside infrastructure	Freight train protection European Train Control System level 2/3 deployment	Control and command	Safety Cost efficiency	MEDIUM	HIGH	£££
	Design and test capability to improve reliability and reduce cost of electric traction infrastructure	Active pantograph and high voltage coupling of train units to enable operation with a single pantograph DC to AC conversion	Energy	Performance Cost efficiency	HIGH	HIGH	£££
	Increased track resilience and cost efficiency through improved design and materials	New materials for rail steel New track, sleeper and ballast/slab design Mechatronic railway with self-adjustment	Infrastructure	Performance Cost efficiency	MEDIUM	VERY HIGH	£££
	Modular train sub-systems for cost effective procurement and upgrade	Modular train design requirements for interface with infrastructure	Rolling stock	Cost efficiency Sustainability	LOW	HIGH	££
Transformation	Transformational change programme	Cross-industry collaboration Best practice R&D delivery process		Sustainability	VERY HIGH	VERY HIGH	£££

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Themes

The themes detailed on pages 18 to 29 relate to the way that customers use the railway and how all our assets work together with other railway assets as an integrated and interdependent system to meet customer needs. The asset themes on pages 30 to 74 explain Network Rail's Technical Strategy as it relates to the groups of assets: information, telecommunications, control and command, energy, infrastructure and rolling stock.

Customer experience

Our purpose at Network Rail is to generate outstanding value for taxpayers and customers by continually improving the railway. Although the customer relationship is generally managed by others, we play a major part in creating the customer experience. Value for customers is important and continuing to enhance the value of rail travel will ensure that rail continues to retain and attract new customers. We must play our part in delivering continual improvements and enhance the customer experience including reliable voice communication and broadband throughout the journey. We will work with our GB industry and European partners to increase rail's share of the transport market, with technical innovation driving better performance and capacity from the railway, which in turn will support better value to commuter, regional and long-distance passengers, freight users and taxpayers.

Goals before and after 2019

By 2019 we need to improve current services – particularly the availability of information both within the rail network and with other transport modes – with more train paths delivered reliably, safely and at lower cost.

Beyond 2019 we will need to rethink our services, understanding how we can realign, redefine and re-scope what we do to serve new and unfulfilled customer needs.

Scope

Technical innovation is key to a better customer experience. Customer experience, alongside our other strategic outcomes, depends on a successful whole-systems approach. Systems are improved, at heart, by people working collaboratively to develop and apply technologies to exploit physical and information assets. This relationship is illustrated on page 4.

Improving the customer experience covers five principal areas.

A competitive and attractive service
There needs to be a real–term, year-on-year improvement in the value of rail services with real-time traffic management optimising network capacity and rail freight attracting an increasing share of non-traditional markets.

Seamless end-to-end journeys
We want passengers, freight operators and passengers at major stations to benefit from an outstanding quality and range of services, including non-intrusive means to pay for their journeys. Rail services should be fully integrated within the transport system.

Confident experience with no surprises
Customers should be fully aware of the services available to them and understand how to select services to match their personal or business travel or transit needs. Real-time tracking should be available for freight customers.

Overcoming disruption
Real-time traffic management should enable rapid recovery from rare instances of disruption. In such cases, passengers and freight customers must be guided and supported to make alternative arrangements easily and in real time.

Passengers' use of time

Making use of time
Improved IT, information management and cross-industry collaboration will enable train, interchange and other transport operators to provide customers with personalised services.

Our challenges, opportunities and approach to technology

Our current technologies and applications present a number of challenges, in particular:

- Poor communication, particularly during times of disruption, due to a limited ability to present timely information to customers about the extent of problems and the availability of alternative routes.
- A multitude of ticketing options and means of procuring tickets. This results in barrier delays, customers not understanding their ticket restrictions, extensive staff resources to monitor tickets and potential loss of revenue for the industry.
- Barriers to freight growth including limited operating hours, total journey times and distribution limitations.

Our ambition is to develop a whole-system approach that consistently starts with the customers needs and fully reflects the customer experience in identifying opportunities and priorities for the technical strategy. This means developing appropriate technical capabilities to:

- Lead development to improve network capacity, reduce journey time and increase track availability.
- Develop techniques to improve real-time traffic management and improved network resilience to weather and other factors.
- Work with the industry to develop whole journey integration and information in conjunction with other transport modes and improve freight integration with passenger traffic to provide full network access for flexible supply routes.
- Work with information technology suppliers and the rail industry to develop and improve customer communication and disruption strategies, drawing on best practices from other industry models.
- Improve station facilities with the emphasis on ease of access, passenger flow and customer services and benefits.

What we're doing now

Passenger journey information

- Our capability to support better passenger information is being improved through the Darwin Customer Information Systems (DCIS) programme. DCIS is bringing together data from multiple sources to create a single data set that relies less on manual interventions and is nearer real time. DCIS includes the development of a specification to support further customer data integration. This is a key element in supporting the future development of mobile personalised information to be used by customers to overcome disruption.
- To ensure whole journey customer information, we're working with a consortium, part-funded by the Technology Strategy Board (TSB), to develop a new type of intermodal journey planner for rail and road, taking into account the real-time service conditions, the resilience and diversity of different journey choices and other important real-life factors for end-to-end journey planning such as parking availability.

Passenger voice and broadband

- We're working with a consortium, part-funded by the TSB, to provide continuous broadband and cellular connection on the train and to provide and manage a link between the train and trackside for a modern, reliable and consistent voice and data service.

Freight journey time

- We are participating in two European projects, SPECTRUM and SUSTRAIL, to improve end-to-end journey times for freight in order to open up new rail freight markets and improve the resilience of infrastructure for freight use while making freight vehicles less damaging. This will lead to reduced cost and increased competitiveness with other transport modes.

Understanding customer needs

- Under our Long Term Planning Process, we develop and publish market studies for passenger and freight which look at demand over the next 30 years.
- Passenger Focus undertakes passenger research as a core part of its role to look after the interests of rail passengers. Existing research offers insights into customer experience for specific passenger groups and situations including disabled passengers, engineering work, buying tickets and the use of social media for passenger information. A futures study undertaken in 2012 offers insights into potential passenger expectations over the next 30 years.
- Working closely with our industry partners through the ATOC led Customer Information Strategy Delivery Board, we will ensure customer R&D is appropriately led and aligns and fits with customer needs.
- Department for Transport research in 2010 on integrated passenger information identifies weaknesses in journey information throughout the end-to-end journey along with gaps in information including seat availability, queuing and real-time parking availability.

Freight journey time

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Seamless end-to-end journey
Integrated ticketing and connecting transport services, providing a personalised whole journey travel experience

Making use of customers' time
Reliable broadband and cellular services throughout the journey, ensuring customers are always connected

Requirements for the future

The needs are as follows:

A competitive and attractive service

- A cost-effective, reliable and frequent rail service with a strong focus on carbon efficiency that also caters for increases in capacity and accommodates customers' needs.
- A safe and secure service with readily available personalised journey information.
- A service in which customers can have confidence and in which high passenger expectations of facilities, capacity, security and transit to onward travel are always met.

Seamless end-to-end journey

- Personalised whole journey travel solutions.
- Integrated arrival and onward journey tickets for passenger journeys and connecting transport services for ease and elimination of travel barriers.
- Minimal disruptions that do not impact overall journey experience or freight transit.
- Where disruption occurs, easily accessible real time information in various forms enabling instant personalised journey re-planning.

Making use of time

- Facilities to allow easy navigation through stations and trains.
- Services to enhance passengers' journey experience and enable them to use their time as efficiently and freely as they please.

Information and communication will be the primary technology areas which are not rail industry driven but will be necessary to achieve:

- Provision of reliable broadband and cellular services throughout the customer's experience.
- Smart ticketing systems that allow access through virtual barriers and integrate with other transport modes.
- Real-time tracking of goods.
- Travel information and navigation at times of peak demand and disruption.

A critical aspect of improving the customer experience is to improve facilities and security including:

- Easy access and flow-through from the station entrance to station exit at the completion of the journey.
- Confidence in the security provision that is not obstructive to the working of the station.
- Improved capacity and whole journey time for freight traffic to open up new market opportunities.

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Table of indicative investments for customer experience

The table below shows the research and development programmes which could be managed under the customer experience theme. It shows indicative projects, their anticipated contribution to our strategic business outcomes, their current and future anticipated state of development and our degree of confidence. It also shows the programme benefits and likely magnitude of investment. Prioritisation, detailed definition and delivery approach have yet to be determined.

Level of impact
● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Seamless end to end journey – personalised travel solutions integrated with connecting transport services	Integration across transport modes	● HIGH		✓	✓✓			✓	C	C, I,	I, S	£££	✓	● HIGH	● VERY HIGH	£££
	Ticketing simplification and integration	● HIGH			✓✓		✓✓		C	C, I	I, S	££	✓			
	Information to be used by customers to minimise or overcome disruptions	● MEDIUM	✓		✓✓		✓		C	C, I,S	S	£	✓			
Competitive and attractive – cost effective, reliable and frequent services	Security at stations and on trains through a technology enabled environment	● HIGH	✓✓		✓✓				C	C, I,	I, S	££	✓	● MEDIUM	● VERY HIGH	££
	Understanding end to end journeys, in particular for freight customers including the optimised location of distribution hubs	● MEDIUM		✓	✓✓			✓		C, I	I, S	£	✓			
	Regulation of traffic in response to the customer, including understanding and modelling changes in customer demand drivers	● HIGH			✓	✓✓	✓			C, I	I, S	£	✓			
Making use of time – ease of navigation around stations and opportunity to use travel time to suit customer	Design to enable station improvements including accessibility and comfort	● MEDIUM	✓	✓	✓	✓			C	C, I, S	S	££	✓	● MEDIUM	● HIGH	££

Whole system approach

The railway is made up of many parts. Network Rail is responsible for a diverse set of assets from track, overhead line, telecommunications, signalling systems, property and structures through to systems that capture, communicate and exploit data to provide valuable information to passengers and those who manage and operate the railway. We use our assets to carry rolling stock that enables Train and Freight Operating Companies (TOCs and FOCs) to operate train services for passenger and freight customers.

Delivering performance to meet current and future demands of passenger and freight customers requires all these railway assets including rolling stock to be specified, deployed, improved, operated and maintained as a "whole system". The people operating the railway, and passenger and freight customers, are themselves part of the system. Our whole system view increasingly needs to extend beyond the railway to enable the railway to integrate with other transport modes.

Our vision is to evolve a whole-system approach that achieves the capacity to support twice as many customers in 30 years' time while improving safety, performance, customer experience, cost efficiency and sustainability.

Scope

The whole-systems approach links the strategy for individual assets under the asset themes set out on pages 18 to 74 to improving the customer experience set out on pages 18 to 22 and to our other strategic business outcomes listed on page 5. The following description of the scope of the work explains how R&D investments to evolve a whole-system approach will contribute to each of these outcomes.

Goals before and after 2019

To realise our vision for a whole-system approach, we need to complete the following by 2019.

- Embed whole-systems thinking across the organisation and the wider industry by embracing the whole-systems life-cycle management approach.
- Ensure the live railway system remains safe by developing a "safety by design" philosophy throughout the system life cycle.
- Develop our modelling capability to better understand and optimise trade-offs in railway systems operation.
- Develop our whole-life cost modelling capability and associated tools that can be exploited by both strategic planners and the Routes.
- Achieve rapid growth in decision-support that utilises available data to improve the quality of our engineering – enhancing safety, performance and cost – and the service we offer to customers.
- Accelerate our ability to turn the vast amounts of condition and use data that is available across the network into information that can be used to target rail investment decisions.
- Further develop GB test and trial facilities available to the whole industry so that new rail vehicles, plant, infrastructure, buildings and equipment can be thoroughly tested in realistic environments before they are deployed.
- Understand the potential impact of climate change and develop investment plans for implementation.
- World-wide collaboration, sharing and adoption of best practice.

Beyond 2019 we will need to undertake a more radical review of railway systems by:

- Increasing capacity to support twice as many customers in 30 years' time. This will require radical change and innovation across all parts of the railway system.
- Improving reliability, punctuality, availability, comfort, speed, ease of transfer and customer information systems. These all shape the passenger experience and will determine whether people choose rail over other transport modes in the future.
- Achieving a radical reduction in carbon emissions. This requires a whole-systems approach to decision-making that robustly performs system and technology trade-offs. Optimising these trade-offs increases the likelihood of achieving our long-term strategic goal while maintaining the performance of the railways.
- Building credible defences against the effects of climate change.

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Safety

Better management of system interfaces, particularly those between Network Rail assets and rolling stock, will improve safety for passengers, trackside workers and the general public. Improved decision support (i.e. remote condition monitoring, more capable measurement trains and on-board measurement systems, systems to automate the regular production of key performance indicators, hazard alert systems and surveillance systems) has a positive impact on the safety of our infrastructure.

Capacity and performance

Whole system rail models predict that an increase in capacity can only be achieved with acceptable performance through major changes to the way that assets function as a system[1]. Achieving higher capacity requires higher precision meaning, for example, that a ten minute delay is unacceptable in the future railway. A high precision railway industry is a finely tuned system with seamless integration between the diverse functions performed through people, processes and support systems. The future railway, driven by innovation, requires traditional engineering embedded in a systems framework where business process, information management, maintenance techniques and technical engineering are similarly precise, integrated, optimised and innovative.

Whole systems modelling and the use of systems techniques and processes should enable optimisation and precision to be achieved. The introduction of new railway assets should be supported through a robust development process, underpinned by modelling and thorough testing of all assets to eradicate their vulnerability to the climate and other external environments.

Improving the customer experience

Understanding the customer and articulating their needs as requirements is key to the success of the future railway and a fundamental part of the whole system approach. The development of whole system modelling enables “what-if” scenarios to be explored, ensuring that systems delivered into service are engineered to satisfy the needs of the customer.

Cost-efficiency

Identifying where savings can be made requires a much better understanding of the whole life cost of maintenance, renewal and enhancement interventions across the railway as a whole system, enabling the most cost-effective changes to be defined and implemented. Benefits may not necessarily accrue at the point of investment but elsewhere in the system and a drive to utilise off-the-shelf technology in all areas of the business will be employed.

Sustainability

Our aspiration is to support the rail industry in halving carbon emissions and this requires radical innovation. Following the proposed rail electrification programme, there is a view that providing electricity for operation – in addition to proposals for electric cars and buses – requires electricity generating capacity of around twice the current level[2]. Measures to enhance weather resilience using conventional technology, such as heating of switches and conductor rails, also require significant additional energy through the winter months. Accurate systems models and decision support tools will be necessary to ensure that cost (monetary and carbon) and value (capacity and reliability) can be quantified, enabling informed system level trade-offs.

The impact of extreme weather remains an on-going challenge to railway transport today and we need to prepare for further potential changes in climate. By developing our understanding of the impact of weather, the potential impacts of climate change can be assessed and effective adaptation strategies put in place for the future.

Trade-offs and decision support tools

1 Modelling the Future, Incose 2012.
2 No Oil in the Lamp: Fuel, Faith & the energy crisis by Andy Mellen 2012.

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Our challenges, opportunities and approach to technology

The main areas of opportunity are:

- **Whole system life cycle management**
  To safeguard the future performance of assets with long design lives, we anticipate a need for novel methods to achieve the effective whole life, whole system management of major projects. The GB railway was substantially built in the Victorian era and is increasingly threatened by climate change for which it was not designed.
- **Whole system performance modelling**
  There is an opportunity to reduce the time to forecast performance of a new scheme and to explore "what if" scenarios by refining the integration of models. Currently, for example, using these models to analyse the impacts of a timetable change during live operations is limited due to data inconsistencies. To optimise system performance there is an opportunity to improve the identification of key drivers for system performance by modelling the system as a whole.
- **Whole life cost models**
  Cost modelling capability is required to support business decisions and investment choices and we've embarked on a multi-phased project to develop whole-life cycle cost models. These models need to continue to be enhanced and validated. There is also a need to make these tools readily available to Routes, Infrastructure Projects and other suppliers to enable systematic consideration of whole-life-cost across both the business and the wider rail industry.
- **Trade-offs and decision-support tools**
  Robust trade-off studies will be a fundamental part of developing the future railway to radically reduce carbon emissions, increase capacity and performance, prepare for climate change and reduce cost. We expect to build our capability for evidence-based decision making by developing effective decision support tools based on real data to support trade studies. There are vast and increasing sources of data, internal to Network Rail and available from industry partners and more widely, that are not always easily accessible or exploitable. The decision support tools will support knowledge transfer from experienced specialists and analysts into the business, both to high-level strategic decision makers and to those who manage the everyday operation of the railway.
- **System integration and test**
  In modern engineering, the rapid development of successful products and systems is achieved through selecting proven technology and integrating these to satisfy the requirements of the customer. There is an opportunity to utilise more off-the-shelf technologies, for example sensor, communication, IT and software technologies, which offer the potential to transform the industry. Robust testing and trialling of these integrated solutions is fundamental to the success of this approach and we need to be able to access suitable facilities and skilled engineers to make this possible.

We will embrace opportunities from new technologies and new applications of existing technologies, both to optimise existing systems and to create new products and systems. We will adopt the following approaches to technology.

For safety, performance and sustainability, we will develop a whole systems model to:

- Identify and fill gaps in modelling capability.
- Integrate available models to provide a whole-systems model that can predict the complex relationship between capacity, timetabling, reliability and performance of the railway system, including the constraints designed to maintain the safe integrity of the railways.
- Validate these models by exploiting data derived from the operational railway.
- Optimise these models and consider "what-if" scenarios to develop an understanding of the constraints that prevent step change in overall system performance.
- Adopt an open architecture approach to model development that supports the use of commercial off-the-shelf software and external data sources.

For safety and performance, we will utilise proven technologies for decision support to include:

- Remote condition monitoring and sensor devices.
- Health Usage and Monitoring Systems (HUMS).
- Geographic Information System (GIS) development tools.
- Modern communication technologies such as mobile and wireless to collect and distribute data.
- Exploit proven commercial-off-the-shelf technology.
- Modern material technologies that are durable to the harsh railway environment and resilient against future change such as increased capacity or climate change.

For cost-efficiency, we will continue to develop cost models that can be used across the business to support investment decisions. These include:

- *Tier 1 models*. Strategic models which forecast work volumes, outputs and expenditure for a portfolio of assets. For example, the maintenance and renewal volumes for 8000km of overhead line electrification system.
- *Tier 2 models*: Strategic models which calculate the whole-life cost for a single asset type across a range of possible intervention options. For example, optimum whole-life inspection, maintenance and renewal intervention regime for axle counters.
- *Tier 3 models*: Tactical models that support the specification of physical maintenance and renewal work in route asset management plans. For example, the specification of maintenance schedules for a track section based on latest condition measures.

What we're doing now

Whole system modelling and optimisation

We utilise a range of methods and models to assess the expected performance of the operational railway assets:

- Methods to develop and test the robustness of the timetable
- Energy capacity models
- Signalling capacity models
- System reliability models.

Working with our Strategic University Partnerships, we're investing in closer and more dynamic integration of these methods and models to achieve a greater level of whole-systems optimisation. One of our objectives is to improve the robustness and reduce the time taken to complete system trade studies. Another is to develop high-level system models that can provide indicative performance of a system concept and which can be practicably undertaken at the very earliest stages of the decision-making process when detailed design is not available.

We've also collaborated with rail industry partners, DeFRA and the Met Office Flag in the TRaCCA (Tomorrow's Railway and Climate Change Adaptation) project which has informed our understanding of the factors to be included in operational and whole life cost modelling.

We are also participating in projects to improve capacity with European partners including the "On-Time" and CAPACITY4RAIL projects (see Control and Command).

Decision-support
We are using, and continuing to develop, many decision-support tools: Large scale developments such as Linear Asset Decision Support, which initially aims to support track asset management, and Remote Condition Monitoring programmes; to smaller scale developments to support the maintenance of conductor rail and overhead line systems. GIS systems have a key role to locate our assets and also to help us manage the impact of external events – such as flooding and extreme weather.

Whole-life cost
Network Rail has embarked on a multi-phased project to develop whole life cycle cost models for its top 30 assets including track, bridges, signalling, operational property, telecommunications, electrical power and earthworks. The assets selected account for 80-90 per cent of expenditure for maintenance and renewals and compensation costs for delay under Schedule 8 of Track Access Contracts.

System integration and test
We have continued to invest in our Rail Innovation and Development Centre (RIDC) which is a facility available for use by the whole industry. This now offers facilities to test and commission rolling stock, plant and processes on representative railway. It also undertakes integrated training of people required to work complex technology. We have in place advanced plans to extend our RIDC capability through a second site which will support high-speed and electrified test and trials.

Requirements for the future

We need to:

- Adopt a systems approach across the railway industry that is embraced by all stakeholders.
- Ensure a structured definition of the railway system through the use of formal requirements and architecture, including the investigation of differentiated railway principles and standards to support the Long Term Planning Process (LTPP). This will enable a common understanding of the system, to baseline the current performance and to promote innovative future design.
- Improve integrated and optimised modelling capability that can be used to assess new design schemes.
- Develop the railway to enable European interoperability where appropriate.
- Undertake robust studies into trade-offs so that high-level decisions are comprehensively considered with supporting evidence.
- Develop models that can be used to explore "what-if" scenarios as a consequence of changes in the operational timetable.
- Develop methods to measure the long-term sustainability of our assets and enable us to assess the future impact of climate change in whole life cost models.
- Whole-life carbon modelling to achieve radical reductions in carbon.
- Embed our capability to use whole life costs in everyday decision-making from strategic to route level.
- Analyse data to better understand railway risks, including risks from climate change, using decision-support tools to manage the process. In particular, to reduce delays and improve safety associated with landslides, overhead line electrification equipment and other adverse weather-related incidents.
- Targeted maintenance, identifying safety risks through increased exploitation of monitored data at systems interfaces. In particular, data associated with the wheel-rail interface and the interface between the train and electrical power systems (OLE and conductor rail).
- Build on our RCM capability to apply Health Usage and Monitoring (HUMS) technology across the asset base.
- Increase the testing of assets and systems through our RIDC, reducing the risk of changes into the live network, improving confidence for the faster introduction of more new products and improving asset reliability and performance.
- Work with the industry to establish an ongoing strategy for the development and use of test and trials capability that accurately reflects network conditions to support a whole-systems approach. Of particular importance are the provision of specialist test and incubator capability in track and signalling disciplines and accessibility of the facilities beyond traditional railway suppliers.
- Establish test and trial sites on the national network which can act as a final stage evaluation for initiatives where significant levels of traffic or gross tonnage are required.
- Develop and procure open and modular systems with standard interfaces to maximise our opportunity to exploit commercial off-the-shelf products and external data sources.

Increasing modelling and testing

Modelling capabilities to optimise trade-offs and support decision making and test facilities available to the whole industry to take R&D risks away from the live service environment

Reducing the risk to trackside workers

Improve decision-support using remote health and usage monitoring and manage system interfaces, reducing reliance on manual trackside inspections and reducing the exposure of trackside workers to risk

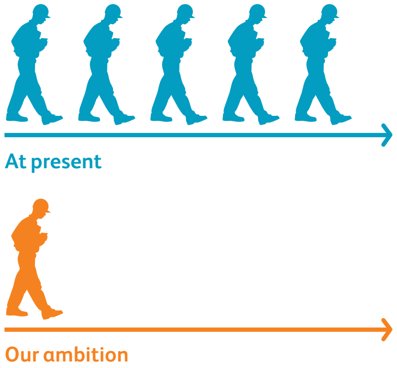

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Table of indicative investments for Whole system approach

The investment table shows the research and development programmes which could be managed under the whole-system approach theme. It shows indicative projects, their anticipated contribution to our strategic business outcomes, their current and future anticipated state of development and our degree of confidence. It also shows the programme benefits and likely magnitude of investment. Prioritisation, detailed definition and delivery approach have yet to be determined.

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
	Performance modelling and operational modelling	●		✓✓		✓✓			C	C, I, S	I, S	£££	✓			
Increasing network capacity and performance through improved modelling techniques and layout design	Investigation of differentiated railway principles and standards to support the LTPP	•				✓✓	✓✓		C	C, I	I, S	££	✓	•	●	£££
	Radical systems architecture	●	✓	✓		✓✓			C	C	I	£	✓			
	Autonomous Intelligent Systems – Robotics	●	✓	✓		✓	✓		C	C, I	I, S	££	✓			
	Autonomous Intelligent Systems – Analytics	●		✓		✓	✓✓		C	I, S	S	££	✓			
Modelling and analytical tools to support reduced cost and maximised network availability by non-disruptive inspection and targeted timely maintenance interventions	Engineering decision support	●		✓		✓	✓✓		C	I, S	I,S	££	✓	•	●	£££
	RCM, Health and Usage Monitoring Systems (see Infrastructure)	●				✓	✓✓	✓	C	I, S	I,S	£££	✓✓✓			
	Auto-self adjusting infrastructure from RCM data (see Infrastructure)	●				✓	✓✓	✓	C	C, I	I, S	££	✓✓✓			

Level of impact

● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Systems Architecture, Interfaces and Test	TSLG/SIC whole system Research and Development	●	✓				✓✓✓		C, I, S	S	S	££	✓	●	●	£££
	Architecture in whole systems	●	✓	✓	✓	✓	✓		C	C, I	S	£	✓			
	Information security (including cyber security) governance and processes and protective measures built into systems aligned to degree of information importance.	●	✓				✓	✓✓	C	C,I,S	S	££	✓✓			
	Whole system testing centre	●	✓	✓	✓		✓		C	I, S	S	£££	✓✓✓			

Information

Our vision is that information should be developed as a strategically critical resource, a corporate asset that is vital to the future of Network Rail and our industry partners. Information should increasingly be shared and its availability should be balanced with better security that takes into account the emerging cyber security threats. Information should be better exploited to underpin the operation of the railway and the interface with customers and with external communities, both national and pan-European.

Goals before and after 2019

The goal for 2019 is for high-quality information, readily available to people and systems, along with better industry collaboration and improved customer services and employee engagement. Information must be available securely on multiple types of devices and must keep pace with technology developments and innovation where these offer benefits.

Beyond 2019, there will need to be further developments towards the integration of railway activities, optimising the overall system and showing how rail is critical to a fully integrated transport system. There will also be a move towards more timely information for rapid response to keeping the railway running and the customer informed.

Scope

Network Rail has built its asset-related information around a data-to-intelligence model already in use in other industries. It collects, evaluates, collates, analyses and communicates.

Information collection
Where possible, information collection is automated and platform (train, satellite, airborne) based. In circumstances where this is not possible, it is collected using handheld technology equipped with intelligent sensing devices.

Information distribution and communication
Devolution has increased the need for information interoperability and convergence and the ability to communicate effectively across the GB rail industry is essential. European legislation brings further requirements for message interchange across European rail operators and infrastructure managers.

Automation of information communication
Automation of appropriate information processes (reporting, information augmentation and data analytics, for example) and the utilisation of railway operations information is a key component of the information strategy.

Information culture of the community
This ranges from improving the perception and understanding of the rail industry community to the strategic importance of information and from the quality of data capture to the correct interpretation of the information by the decision maker.

Information standards, governance and security
These relate to the management of information as a business-critical resource through a life cycle with the appropriate information standards, governance and security structures, supporting the integrity of information across the rail industry.

Information integrity
Information integrity together with Governance and Standards are an integral part of excellent information management. Specifically from the railway industry perspective the integrity of information is paramount to safety, confidence in decisions and business justification of rail industry goals and plans.

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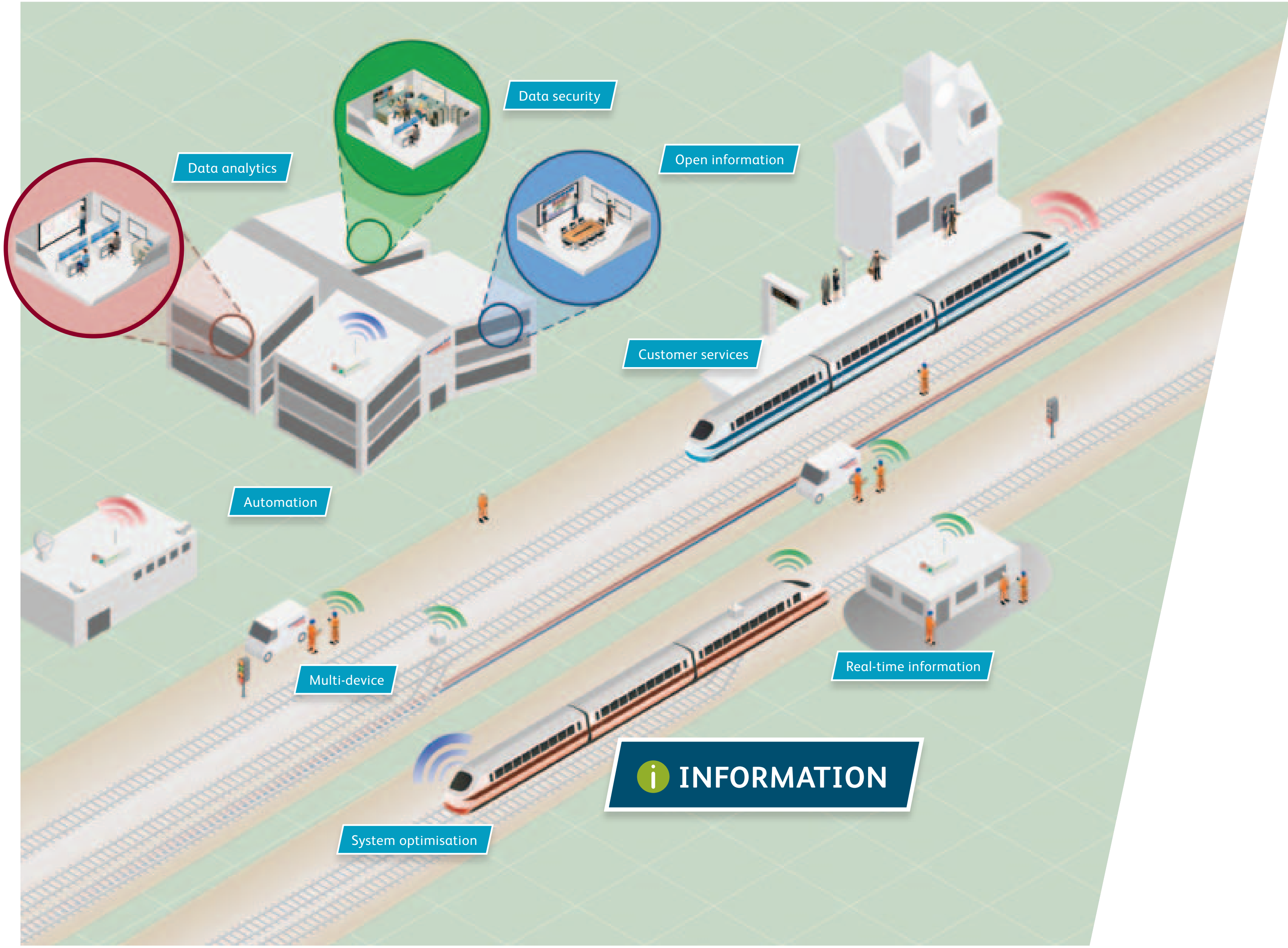


R&D investment will address:

- Creating common information architectures and protocols
- Exploiting rail information through commercial partnerships

Information should increasingly be shared and its availability should be balanced with better security that takes into account the emerging cyber security threats.

Technology and information innovation
With the rapid growth of distributed sources, a multitude of devices and sophisticated analytics need to be serviced increasingly in real time. The ability to distribute information through increased network bandwidths and mobile devices needs to be addressed with costs managed.

Our challenges, opportunities and approach to technology

Challenges we face in improving the information environment include:

- A low level of awareness and understanding in the rail industry currently of the strategic importance of information, of reliance on accurate and holistic information and of the need for improvements. This will require a cultural shift in perceptions and understanding within the community to recognise the importance of information as the lifeblood of the organisation.
- Considerable growth in data and information, particularly as a result of the introduction of new sources such as sensors and video cameras. This creates a major challenge to transmit, process, store and communicate through innovative technologies.
- Rapid changes created by the introduction of information systems with step changes in power and processing capability together with their ability to interpret information – and then the communication of more information through increased network bandwidths with portable devices.
- The need to provide the capability for real-time information across the rail industry. Although technologies are becoming more effective and efficient, the cost of this information explosion will need to be managed within justifiable financial parameters.
- The need to exploit investment in information management technology, including the ORBIS programme supported by the Asset Information organisation, in order to improve data integrity and appropriateness throughout the life cycle, from capture and creation to storage and use to archiving.

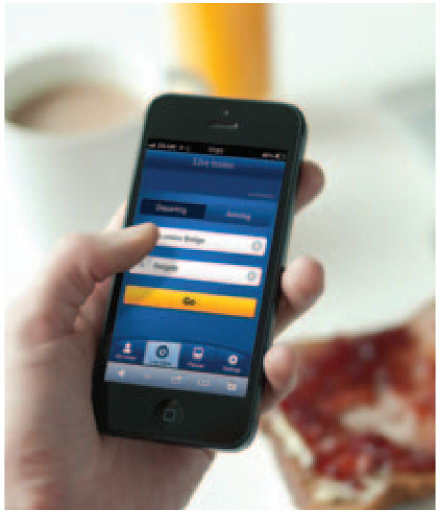
We will look to exploit existing technologies while evaluating new and emerging technologies to address the requirements for:

Information distribution and communication
Here we will identify and utilise distribution and communication technologies that can manage high volumes of information in a variety of channels. This will include innovation in information systems to deal with the exponential growth of information including the type, format, speed, accuracy, security and media channel (including social media).

Automation of information communication
We will automate information processes such as reporting (e.g. decision support systems and business performance dashboards), the augmentation of information and provision of information for analytics (e.g. predictive fault analysis) and the automation of processes that utilise information for operational use (e.g. signalling).

Information culture of the community
We will help people in the rail industry to become more aware of their reliance on information and the importance of data quality, ranging from accurate capture through to the correct interpretation of the information by the decision maker.

Better information flow to customers



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More efficient and responsive information flow Exploit increasingly effective and efficient technologies to provide real-time information cost-effectively across the rail industry, enabling a railway that is in tune with customers' and operational information needs 24 hours a day, 7 days a week

24:7

Information standards, governance and security
We will increase information security governance, systems and processes utilising mechanisms such as Master Data Management and Information Life cycle Management supporting the integrity of information across the rail industry.

Information integrity
We will improve the accuracy, reliability, speed (real-time), consistency, quality and relevance of information throughout the information life cycle from data capture/creation, storage and use through to eventual archive. The appropriate governance structures, processes and systems must be in place in support of data integrity.

Technology and information innovation will focus on:

- Identifying and utilising technologies to manage the transmission, capture, storage and communication of information from new sources such as sensors, video cameras and a mobile workforce using tablets, smart phones and handheld devices.
- Increasing the power and ability of information systems (e.g. intelligent systems) to interpret information (e.g. data analytics, predictive modelling and data augmentation) and then to communicate more information through increased network bandwidths.
- Exploiting technologies that are becoming more effective and efficient to provide real-time information across the rail industry community in a cost-effective way to enable better management of railway traffic and a better flow of information to customers.

What we're doing now

The ORBIS programme is making the capture of information easier through the deployment of mobile handheld devices and advanced train-borne systems, the provision of integrated information and decision-support tooling, better exploitation of geospatial information and the elimination of paperwork.

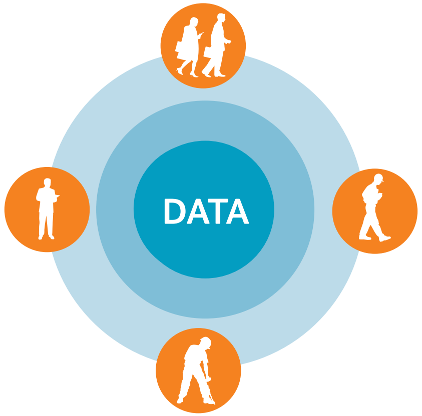
We are utilising an open Information Framework (MIKE2.0) as an approach to improve how information is managed across the rail industry, incorporating a common business strategy, technology architecture and delivery approach across information management projects.

We are developing the Network Rail Information System (NRIS) strategy document, setting out the future direction for information services over a ten-year time frame and defining how it will support Network Rail's strategic intentions and those of the wider rail industry. The NRIS strategy document will provide the definitive source on which all IS strategic activity will be based, covering technical, security and information strategies. It will set out, in general terms, Network Rail's applications, information and technology architecture components.

An underpinning factor in realising our technology ambitions will be the delivery of robust and proportionate protection from cyber security threats. To that end, we are establishing a Cyber Security Programme that will deliver the necessary protection for our business, rail operations, asset management and telecommunications systems. This will support us in realising the benefits of innovative, business-enabling technologies and help ensure the flow of open, highly available and reliable data that enhances value and improves the customer experience.

Mobile handheld devices

Open information sharing **Data sharing across the rail industry, enabling passengers, staff and frontline workers to make timely and accurate decisions on the move**



Balancing security and transparency

Secure and protect information and systems, particularly in respect of cyber security while making data transparent, and utilising opportunities from ‘big data’

Requirements for the future

The requirement is for information technology and associated processes that are able to achieve:

- Effective communication (real time and automated) of information from railway systems such as decision-support, business performance dashboards and train movements
- Effective, efficient, real-time and automated communication of information between customers, individuals, teams and organisations, making data open where appropriate
- Maximised data sharing, analysis and exploitation so that information is used effectively to enhance and drive decision-making processes using appropriate decision-support tools.
- Coherent management policies, protocols and identification of data ownership and secure information systems resilient to cyber attacks.
- The utilisation of European standards to harmonise procedures and information exchange between systems
- A structured process of innovation to exploit new technology for business benefit.

These requirements are closely connected with other themes detailed in this document:

Customer experience

- Easily accessible personalised journey information
- Work with the industry to develop whole journey integration and information in conjunction with other transport modes.

Whole system approach

- A systems approach to technology management
- A GB rail whole-system model
- Excellent asset knowledge and evidence-based decision making
- Industry collaboration.

Telecommunications and control and command

- Combine in-cab signalling with GSM communications
- Systems, tools and processes to enable efficiencies in the delivery of conventional multiple aspect signalling systems
- Increased availability of systems for train control.

Energy

- Matching passenger demand and train capacity reducing conflicts between services and better train location
- Line condition assessment and fault detection and optimisation of train/current interface including developments to enable pattern recognition
- Real-time rail energy consumption and generation information.

Infrastructure

- Understanding of whole system carbon impact
- Methods and technologies to facilitate automated monitoring of assets and detection of asset condition, enabling condition based inspection, service and maintenance regimes to be developed, extending the integrity and economic life of assets
- Automated asset monitoring via trains monitoring infrastructure and infrastructure monitoring trains.

Rolling Stock

- Automatic vehicle identification.
- Real-time positioning system based on GPS and Rail Infrastructure Network Model
- Unattended Measurement Systems on service trains
- Cross-industry commercial and technical framework allowing asset condition data to be shared and exploited
- Protocols and data schemas for the train-borne data capture system including train equipment and wireless communication.

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Table of indicative investments for Information

The investment table shows the research and development programmes which could be managed under the information asset theme. It shows indicative projects, their anticipated contribution to our strategic business outcomes, their current and future anticipated state of development and our degree of confidence. It also shows the programme benefits and likely magnitude of investment. Prioritisation, detailed definition and delivery approach have yet to be determined.

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Creating common information architectures and protocols	Formalised ownership of information making individuals accountable for the accuracy and timeliness	🟢	✓				✓✓	✓		C,I,S	S	£	✓✓✓	🟢	🟠	££
	Information mastered and classified in terms of sensitivity (Public, private or confidential)	🟢					✓		C	I,S	I,S	££	✓✓			
	Retention policies for information both structured and unstructured	🟢					✓✓	✓✓	C	C,I,S	I,S	£	✓✓			
	Information security (including cyber security) governance and processes and protective measures built into systems aligned to degree of information importance	🟠	✓				✓	✓✓	C	C,I,S	S	££	✓✓			
	Architectures, ontology, data dictionaries and protocols facilitating integration and information sharing	🟢					✓✓	✓✓	C	C,I,S	I,S	£	✓✓✓			

Level of impact

● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Exploiting rail information through commercial partnerships	Collaboration in the railway businesses to exploit information	●		✓	✓	✓	✓		C	C,I,S	I,S	£	✓✓	●	●	££
	Integration of a variety of information sources producing new information adapt rapidly to changing business strategies	●					✓	✓✓✓	C	I,S	S	£	✓✓✓			
	Ability to analyse of very large volumes of data in decision making activities including the deciphering information trends. Automated and customer generated reports from core strategic systems	●	✓	✓	✓		✓		C	C,I,S	S	££	✓✓✓			
	Innovative technologies to capture, store and communicate information through a variety of sources and systems, including handheld devices	●		✓	✓	✓	✓		C,I	C,I,S	S	£	✓✓			

Telecommunications

Our telecommunication network should serve the communication requirements of rail industry customers including passengers and increasingly beyond, Network Rail Telecommunications (NRT) will offer continuous improvement in service quality, value for money and delivery excellence. As a single, accountable, process-led organisation, NRT will achieve these objectives by managing telecommunications from a whole system, whole life perspective to support the rail industry's move towards increased localism.

The telecommunications network of the future will be safe, reliable and resilient. It will meet data capacity requirements in a timely manner, keeping pace with rapid technology advances and maximising asset utilisation.

Goals before and after 2019

By 2019, high-speed, high-bandwidth communications networks will be in use across the rail network and on trains, providing dependable connectivity for both operational and customer-facing applications for the railway and its customers.

Beyond 2019, innovation work conducted during CP5 will lead to the wide scale deployment of communications-enabled initiatives such as personalised, whole-journey support, increased levels of automated railway infrastructure monitoring and greater fusion and analytics of data, including CCTV.

Scope

The scope of telecommunications technologies addresses five principal outcome areas.

Improved service quality
Better service includes all aspects of provisioning and service management and allowing others to focus on what they do best.

Improved value for money
We will play our part in reducing government subsidy, potentially making the cost of railway telecommunications neutral or better.

Safety
We will proactively and aggressively address the challenges of supporting Critical National Infrastructure and safety systems on open communications networks.

Reliability and resilience
Communications service availability has a direct impact on our ability to manage the railway customer experience.

Maximised use of assets
We will derive further value from spare capacity to offset the funding challenges of a continuously evolving asset.

Improved service quality

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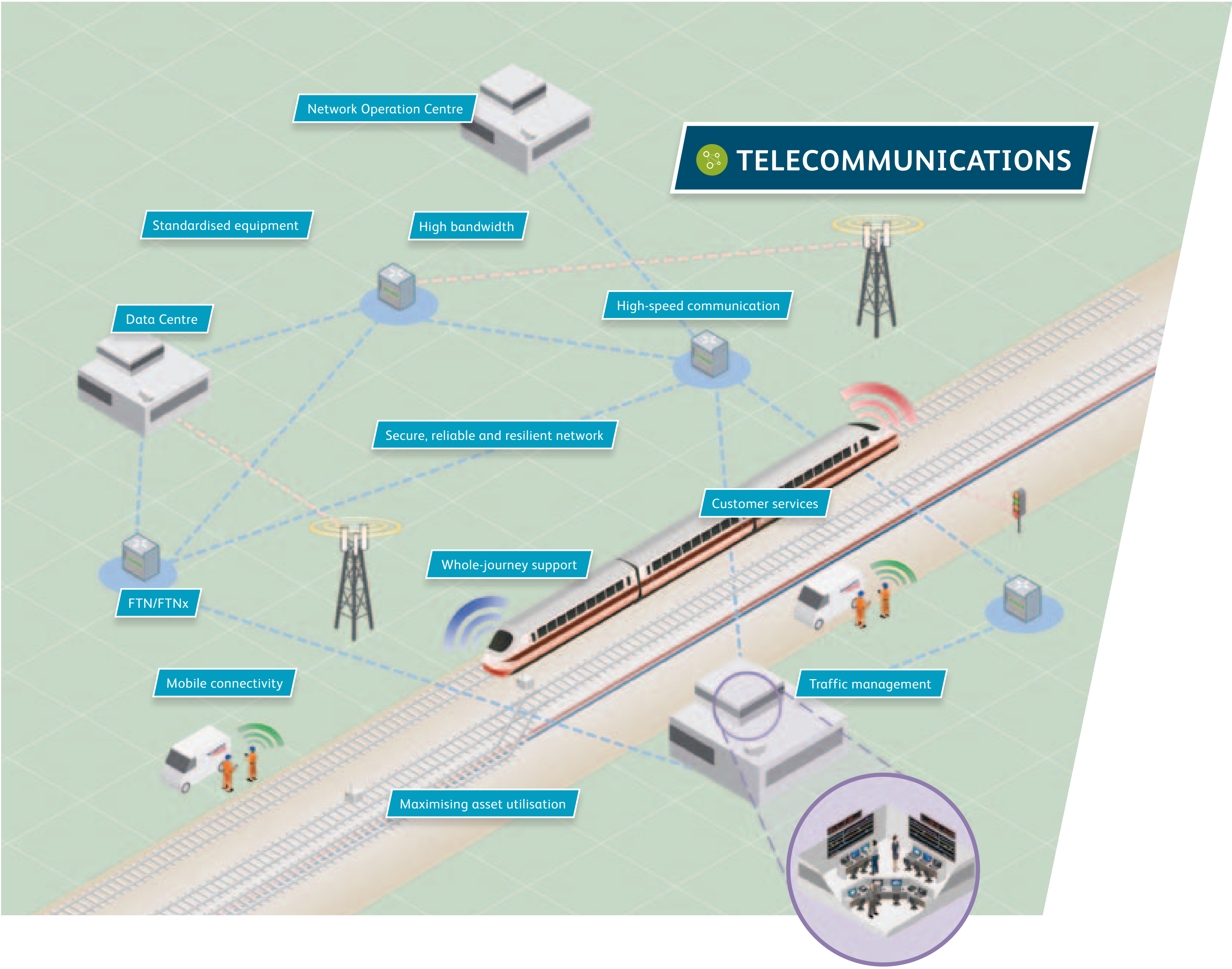

R&D investment will address:

- Using telecoms assets for reduced cost and maximised track availability
- Enabled next generation communication services including capacity enhancement
- Securing and protecting information and systems
- Using telecoms assets for optimised traffic management

The telecommunications network of the future will be safe, reliable and resilient. It will meet data capacity requirements in a timely manner, keeping pace with rapid technology advances and maximising asset utilisation.

Our challenges, opportunities and approach to technology

Current technologies and applications present a number of challenges.

- Current fibre-sensing products used for Remote Condition Monitoring (RCM), although passive, are expensive and the outputs require human assessment before alerts can be triggered.
- The planned replacement of assets will be increasingly driven by component, system and functionality obsolescence rather than asset condition and reliability factors.
- High volumes of data, specifically CCTV from Managed Stations, Driver Only Operated (DOO) CCTV and trackside security, are generated but are not brought together or analysed to extract more value for the industry.
- As we increase the volume and type of data we collect, analyse, share and use, cyber security will underpin many aspects of the railway, supporting and enhancing the telecommunications network.
- The radio interference threat to GSM-R from other mobile technologies in use on and around the rail infrastructure needs to be managed along with the associated operational impact.
- The capacity of GSM-R to carry additional services, particularly European Traffic Management System (ERTMS), is limited by the 2G technology, the GSM-R operating concept and the limited amount of radio spectrum available.
- We must work with Europe to define and implement a next-generation interoperable alternative to GSM-R voice and bearer for European Train Control System (ETCS) data between train and infrastructure before GSM-R becomes unsupportable.
- Next-generation mobile connectivity will require access to a significant amount of managed radio spectrum.
- Current station information and management systems lack the integration that could improve efficiency, safety and passenger experience.
- Service definition and demand forecasting, particularly for next-generation networks, are currently quite short-term, resulting in late deployment of upgrades and loss of early benefits.
- Third party telecommunications solutions must be displaced and traffic and services rapidly brought onto our own network.

Data centre

Maximise existing telecommunications capacity Enhancements to telecommunications capacity to handle more customer data, including voice and broadband, and more business data from control systems and health and usage monitoring of assets

Delivering future high bandwidth

What we're doing now

Delivering future high bandwidth

- To carry our bulk traffic, the current Fixed Telecommunications Network Next Generation (FTNx) programme is delivering a core and aggregation network of 25 nodes, strategically positioned to maximise availability and resilience. It also gives an initial deployment of network access nodes at the 14 Regional Operating Centres (ROC) and 17 managed stations. Further access network sites will be deployed where access capacity cannot be delivered by existing FTN nodes.
- Parallel programmes are delivering FTNx connectivity and operational voice communication systems to ROCs in a manner which is forward-compatible with the eventual migration to traffic management.
- We are working with the Supervisory Control And Data Acquisition (SCADA) programme to co-deploy an FTNx access network to serve trackside electrification assets and Electrical Control Rooms (ECR), including an IP Telephony voice solution for ECRs which will be capable of serving a wider user-base.

Delivering better service management

- We are continuing to introduce catalogue products and defined service levels through the end-to-end business process use of Operational Support System (OSS) within a newly created NRT Network Operating Centre (NOC), supporting a programme to build and manage new knowledge and skills in technical staff.

Accommodating capacity

- We are proving the use of Global Positioning Railway Satellite (GPRS) data on our GSM-R system at the Hertford North Integration Facility as a means of accommodating a greater density of trains operating under ERTMS.

Improving the interfaces for signallers

- The Frequentis Fixed Terminal Sub-System which today provides signallers' GSM-R dispatcher terminals is being evolved to meet the traffic management requirement to have all operational fixed and mobile calls presented on a single HMI interfaced to all traffic management systems.

Supporting communications for our people

- A recent trial of an alternative desktop Internet Protocol Telephony product proved the need to carefully select technologies to work in our wider voice network as this will continue to have unusual features for some time to come. We are now re-evaluating products and business approaches as part of a wider voice strategy programme.

Improving the reliability of communications services

- Our Voice Strategy programme includes a Call Centres thread which is designed to rapidly target a mix of systems that currently serve the National Delivery Service, Human Resources and Information Management help desks. Options which allow a reduction in product sets for these and other uses (e.g. ECRs and Integrated Control Centres (ICCs)) are being pursued.

Reducing cost and improving availability

- Much commercial and technical work has been undertaken to displace third party solutions to improve value for money. This has laid the foundations for rapid service migration and network consolidation to continue utilising the Voice Strategy and FTNx deliverables.
- Data centres are currently an expensive third party service which can be unreliable and not directly accessible by FTNx. A work programme to scope and investigate in-house data centres is evolving.

Requirements for the future

We expect to source technologies from the wider telecommunications industry. We will work with:

- Telecommunications innovators and manufacturers who offer developed products and solutions from the communications market which can be directly deployed to the benefit of the rail industry.
- Telecommunications service provider partners who offer new services and approaches which can become a part of the railway telecommunications service offering.
- Proactive cyber security protocols to support and enhance telecommunication systems, providing safe and secure functioning on the railway.
- Academia and specialist technical consultancies who can provide prediction and strategy input to allow the utilisation of commercial products to be a more clearly focussed activity.

We will embrace opportunities from new technologies and new applications of existing technologies both to optimise existing systems and to create new products and systems. Our approach to technology will be:

- To exploit the latent capacity in the installed fibre asset base, which is orders of magnitude greater than its current utilisation. Wave division multiplexing techniques will be employed to multi-use each optical fibre.
- To exploit the opportunities for enhanced rail vehicle identification and positioning as part of RCM and Traffic Management. There is also an opportunity to improve our view of how operational benefits connect together to underpin a stronger enabling business case.
- To lead a challenging innovation programme to ensure we have in place the new telecommunication products and services the rail community will require to deliver its own product and service advances.
- Wherever possible, to draw on communications industry product innovation to reduce capital costs and the risk of obsolescence.
- To consider commercialisation and partnering wherever this brings operational value and cost reduction through system and network evolution.
- To rapidly migrate services off legacy systems to allow them to be decommissioned and to maximise the potential gains offered through the features of next-generation technologies. These features include simplified infrastructure and "flattened" networks.

Upgradeable industry standard technology Move from customised railway technology to utilise standard telecommunication products, ensuring assets can directly benefit from technological developments and advancements in the communications market and efficient and cost effective upgrade of assets

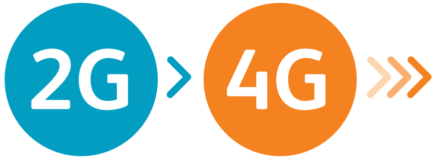

Table of indicative investments for Telecommunications

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Level of impact
● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Using telecommunications assets for reduced cost and maximised track availability	Fibre sensing	HIGH	✓✓	✓			✓		C	C, I, S	I, S	££	✓	HIGH	MEDIUM	££
	Research to allow automatic vehicle identification	HIGH		✓✓	✓	✓				C, I	I, S	££	✓✓			
Enabled next generation communication services including capacity enhancement	FTNx Test Bed	HIGH		✓✓	✓	✓			C, I	I,S	I,S	££	✓✓✓	HIGH	HIGH	££
	Automation of complex station management though intelligent systems and personal comms	MEDIUM	✓	✓✓		✓			C	I, S		£	✓✓			
	Next generation PA system – technology options for targeted and personalised information on station platforms rather than PA broadcasts	MEDIUM		✓	✓✓	✓			C	I, S		£	✓✓			
	Forecast next generation telecoms capabilities to support virtualisation and cloud computing	MEDIUM		✓	✓✓	✓				C, I	I, S	££	✓			
	Next generation of GSM-R e.g. 4G and 5G	MEDIUM	✓	✓	✓	✓				C, I	I, S	££	✓			
	Whole system networked CCTV and video analytics	HIGH	✓	✓	✓		✓		C	I,S	I,S	£	✓✓			
Securing and protecting information and systems	Addressing comms network (cyber) security through behavioural analysis and security forensics	HIGH	✓✓	✓	✓				C	I,S	I,S	£	✓✓	HIGH	VERY HIGH	£
Using telecommunications assets for optimised traffic management	Capture voice comms operational requirements	HIGH	✓	✓	✓	✓			C	I	S	£	✓✓	MEDIUM	HIGH	£

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Control and command

In the future, control and command technologies will enable a safer railway with greater capacity and reliability, lower costs and improved energy-efficiency. Signalling and control functionality will be migrated onto trains, reducing the need for lineside equipment while also providing greater capacity and operational flexibility, both during normal operations and in the event of disruptions.

Goals before and after 2019

By 2019 we aim to have achieved the following:

- The introduction of in-cab signalling systems to parts of the network without the need for lineside signals
- Further development of efficient signalling implementation methodologies
- The introduction of efficient technology-assisted design, test and processing tools and techniques
- Selective replacement of mechanical signalling with modular signalling
- A demonstrable year-on-year decrease in the safety risk associated with level crossings.

Beyond 2019 we will need to complete the national operating strategy with signalling controlled from 14 Route Operational Control (ROCs) along with the ongoing implementation of the European Rail Traffic Management System (ERTMS) at level 2 and progression towards level 3. From 2019 onwards, real-time traffic regulation of trains will begin to contribute substantially to the railway industry's 4C's objectives: increased capacity, reduced carbon, lower costs and improved customer satisfaction.

Scope

The scope of control and command technologies addresses four principal outcome areas.

Greater capacity and improved delivery of capability to operate trains

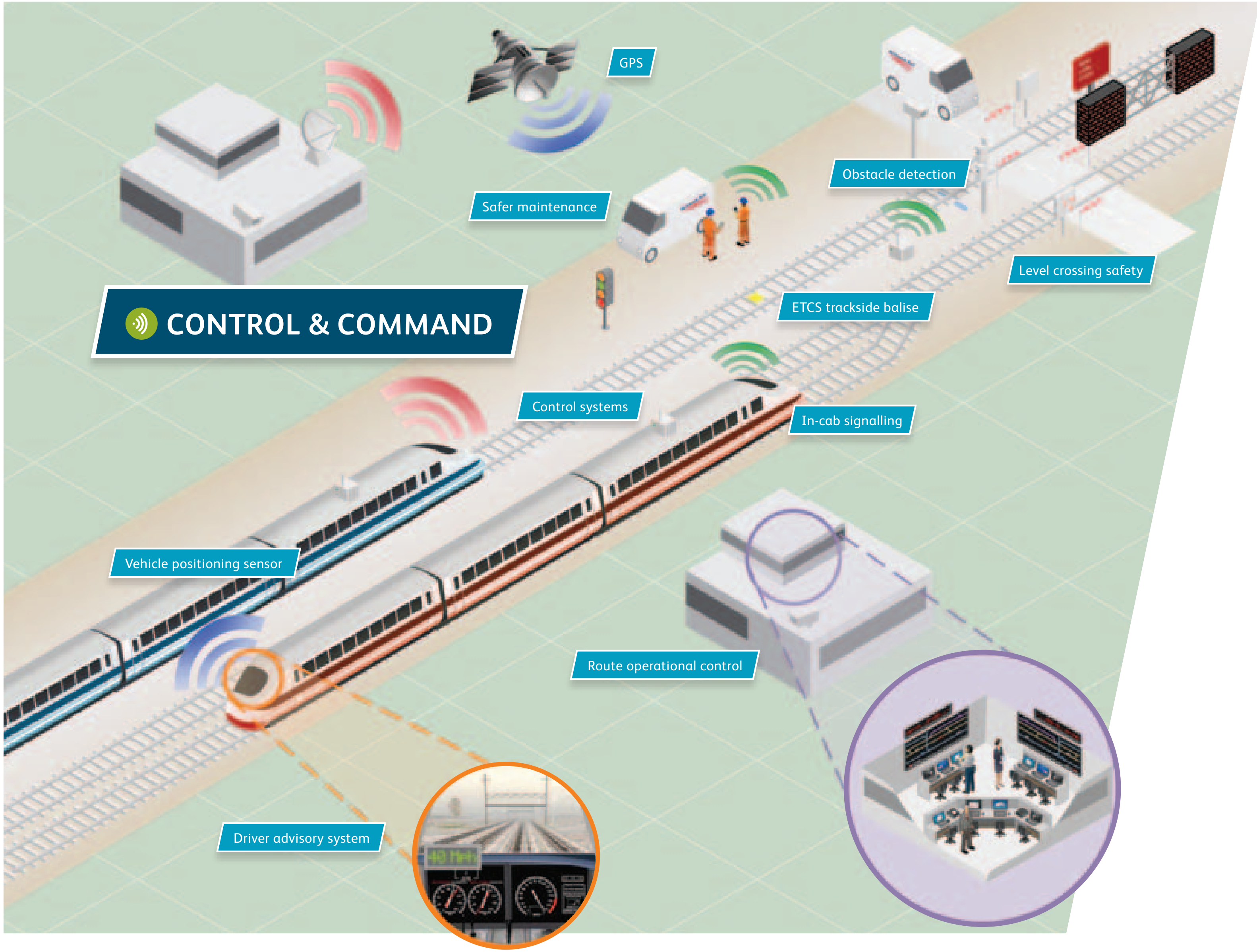
The shift away from fixed lineside infrastructure and the move towards European Train Control System (ETCS) level 2/3 – beginning with the Great Western Main Line (GWML) in 2019, followed by the East Coast Main Line (ECML) in 2020 – will provide the ability to increase capacity and manage railway operations in a more responsive manner.

Cost and energy-efficiency

The delivery of 14 ROCs replacing 800 signal boxes will deliver cost efficiencies of up to £250 million per annum. Improved methods of project delivery for signalling will reduce implementation costs while the adoption of new technologies will improve the energy-efficiency of lineside equipment.

Safe and sustainable railway operations

Over 6,000 level crossings operate on Network Rail infrastructure. Level crossings are the single biggest safety risk to members of the public and passengers, accounting for 80 per cent of all public fatality risk (non-trespasser) and 42 per cent of train accident risk. The total cost of ownership of level crossings, including maintenance and lifetime support, is over £10 million annually while the operational and management costs are over £30 million. Throughout CP5, Network Rail will invest in level crossing technologies to reduce safety risk and the costs required to operate and maintain them.



R&D investment will address:

- Improving the safety of staff, passengers and the public at interfaces with signalling infrastructure
- Real-time traffic management capability for increased capacity, energy efficiency and sustainability
- Robust and cost effective design, test, installation and maintenance of signalling infrastructure
- Modern signalling systems providing in-cab functionality and Automatic Train Protection and reducing lineside infrastructure

Signalling and control functionality will be migrated onto trains, reducing the need for lineside equipment while also providing greater capacity and operational flexibility.

Improved operational decision making for optimised train operation
The integration of control, routing and timetabling functionality is enabled through the Future Traffic Regulation Optimisation (FuTRO) programme. The ability to regulate trains in real-time, made possible by the FuTRO programme, is estimated to have the potential to save the rail industry between £200 million and £400 million annually.

Our challenges, opportunities and approach to technology

Current technologies and applications present a number of challenges:

Safe maintenance and inspection of signalling infrastructure
Improvements are required in the safety of signalling maintenance activities as well as in the interface between the railway and the public at level crossings.

Cost-effective design and deployment of signalling infrastructure
The costs associated with signalling design, test, implementation and maintenance need to be reduced.

The development and implementation of ETCS, DAS and ATO
Driver Advisory Systems (DAS) are currently being implemented to improve train punctuality and fuel consumption. More sophisticated DAS systems using real-time status information will further improve the ability to regulate trains. ATO for use with ETCS needs development work to enable the efficient control of mainline trains and the delivery of potential benefits. The realisation of ETCS Level 3 requires the development of systems to ensure passenger and freight trains are able to operate safely without track-based train detection.

The development of technologies for traffic management systems
Reductions in the number of signal control centres will not only provide operational efficiencies but will also enable the development of traffic management products leading to improvements in the performance of control and command systems.

Sustainability and energy-efficiency of signalling equipment
The reduction of lineside infrastructure and the development of low-power and self-powered signalling systems will reduce power demands.

Sustaining existing assets
There will be a continuing need to support and maintain existing systems and to develop the skills required to do so. In parallel, migration to newer technologies will change skills profiles. Integrated diagnostic and maintenance tools will change the way maintenance is carried out in future.

Resilience and risk
The development of diverse alternative means of control and command will focus on increasing network resilience and reducing risk from manual lineside working. Alternative signalling systems will allow signalled operations when primary systems are unavailable.

We will embrace opportunities from new technologies and new applications of existing technologies both to optimise existing systems and to create new products and systems. Our approach to technology will be:

- To investigate new architectures for cab signalling and control consistent with our efficiency initiatives and which minimise lineside equipment and cabling requirements.
- To reduce whole-life costs by investigating commercial technology for our signalling programmes and the use of products such as lightweight structures to reduce installation costs.
- To integrate signalling, control and communications systems in order to enhance their capability and functionality and improve the delivery of train services.
- To invest in technology that demonstrates a net reduction in risks posed by level crossings.

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What we're doing now

We're improving the safety of staff, passengers and the public at interfaces with control, command and communications infrastructure through:

- Deployment of Manually Controlled Barrier – Obstacle Detection (MCB-OD) level crossing systems across the network following trials.
- Deployment of Light Emitting Diode (LED) technology at signals and level crossings. This has the potential to considerably improve the visibility of hazards for all users of the railway.

We're working with industry partners to increase capacity, energy efficiency and sustainability by taking steps towards real-time traffic management through:

- Development of the FuTRO programme which seeks to optimise train traffic regulation.
- The ongoing Traffic Management programme which is improving the scope and capability of railway control.
- The development of advanced DAS and ATO systems to improve punctuality, regulation and energy efficiency.
- Further development of the COMPASS vehicle positioning solution as an enabling technology for alternative signalling systems, following on from the successful initial track infrastructure and on train equipment evaluation trials.

We are also participating in projects to improve capacity with European partners.

- "On-Time" is developing new methods and processes to increase capacity and reduce overall delays to increase customer satisfaction. The scope includes algorithms for improved timetabling, optimised and automated handling of small disturbances and processes for handling large disruptions.
- CAPACITY4RAIL is progressing the design and development of modern, fully integrated railway systems for freight and passengers. It aims to increase the capacity, availability and performance of the railway system through step changes to:
  - Asset design
  - Construction and maintenance (including advanced monitoring)
  - Operations management
  - Recovery from perturbation through real-time data management
  - Freight operations, with a particular focus on transhipment and improved specifications for rolling stock.

We're making signalling infrastructure more robust and cost-efficient by:

- Implementing Modular Signalling and ongoing renewal programmes which seek to replace signal boxes with modern signalling technology and further increase the use of axle counters for train detection.
- Progressing initiatives in areas such as automated design and testing, simplified functionality, lightweight structures and modular cabling.

We're increasing the capability of train protection systems while reducing costs. Projects include:

- The development of ETCS for application on GWML in overlay form and for ECML in level 2 without signals form.
- Steps towards the development of ATO and ETCS level 3.

Requirements for the future

The requirement is for railway specific technologies that will enable:

- The reduction of safety risks associated with level crossings and other interfaces between the railway and the public.
- Improvements in the efficiency of the design, inspection, maintenance and renewal of signalling systems.
- Increased network capacity, optimisation, flexibility and reliability including the development of models to optimise the regulation of train services.
- Reduced operating costs through the implementation of more efficient traffic management.
- Better network performance and more accurate journey times.
- Less disruption from perturbation and optimised driving techniques to reduce wear and tear and increase energy savings.
- Increased availability of systems for train control in the event of loss of a primary system.

Our vision for the rail industry in 2040 will require significant increases in efficiency and reductions in operational and whole life costs. These will be identified through:

- The FuTRO programme which will develop principles, concepts, requirements and architectures for the next generation of railway and integrated transport traffic management systems.
- The development of intelligent traffic management algorithms which optimise network capacity, reduce delay times from disruption and enable real-time tracking of railway operations.
- Further developments in train control systems beyond ETCS.

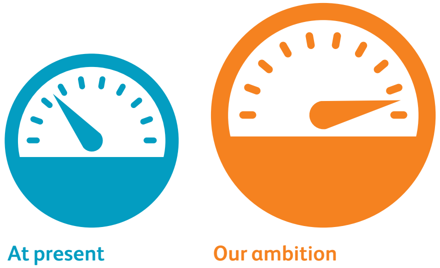
We will explore commercially available technologies for delivering efficient and robust signalling that:

- Supports risk based maintenance methods with reduced intrusive maintenance and inspection through remote condition monitoring;
- Lowers the cost of level crossing systems and enables development of alternative level crossing protection systems without compromising safety;
- Enables the use of commercial and industrial systems and components for use in level crossings and signalling equipment; and
- Provides accurate train position and location information as part of a wider set of tools to support better traffic management.

Reducing the amount of lineside signalling equipment is key to realising the Control and Command vision. This is facilitated through other asset themes by:

- Equipping the next generation of rolling stock for the move towards ERTMS level 2/3 capability for standardised signalling, train control and train protection (see Rolling stock);
- Consolidating the number and locations of signalling control boxes into 14 ROCs. The ROCs will introduce traffic management and provide modern SCADA systems for robust control of electrical control systems (see Telecommunications and Energy); and
- Ensuring that the move towards signalling and control technologies such as ETCS and traffic management will have the required bandwidth from our Fixed Telecommunications Network (see Telecommunications).

Better performance to increase capacity Improve the performance of the train and infrastructure whole system to increase capacity, including faster and more predictable braking and acceleration and systems to connect the movement of one train to another



Sensing train position Provision of more accurate train position and location information supporting better traffic management and utilising more capacity from the network

01 Level crossing control
02 Smarter controls

Asset themes
Control and command

Table of indicative investments for Control and Command

The investment table shows the research and development programmes which could be managed under the control and command asset theme. It shows indicative projects, their anticipated contribution to our strategic business outcomes, their current and future anticipated state of development and our degree of confidence. It also shows the programme benefits and likely magnitude of investment. Prioritisation, detailed definition and delivery approach have yet to be determined.

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Improving the safety of staff, passengers and the public at interfaces with signalling infrastructure	Obstacle detection at level crossings	●	✓✓	✓			✓		C, I	S		£	✓✓✓	●	•	£££
	Level crossing interface with other transport modes	●	✓✓✓		✓					C	I, S	£££	✓✓✓			
	Programmable Logic controller signalling and level crossings	●	✓✓				✓✓		C	I,S		£	✓✓✓			
	Software applications for handheld devices at user work crossings	•	✓✓✓		✓				C	I, S		£	✓✓			
	Track worker safety/warning system	●	✓✓✓	✓						C, I, S		£	✓✓			
Real-time traffic management capability for increased capacity, energy efficiency and sustainability	Future Traffic Regulation Optimisation (FuTRO) development work	●			✓	✓	✓	✓		C,I	S	££	✓✓	•	●	£££
	2030 vision – supplementary cost beyond the scope of FuTRO	●					✓✓✓	✓		C	I, S	£	✓✓			
	Algorithms for intelligent traffic management	●			✓	✓	✓	✓		C	I, S	££	✓✓			
	Junction algorithms development	●	✓	✓		✓	✓			C	I, S	£	✓✓			
	Capacity modelling	●			✓	✓✓✓			C	I,S		£	✓✓			
	Vehicle positioning in order to increase the robustness of train location solutions (including COMPASS)	●	✓✓			✓✓			C,I	I,S		£££	✓✓✓			

Level of impact

● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Robust and cost effective design, test, installation and maintenance of signalling infrastructure	Reduced cost of modular signalling	HIGH		✓			✓✓✓		C,I,S	C,I,S		££	✓✓✓	HIGH	LOW	££
	Factory/off-site testing and verification of signalling systems	HIGH	✓✓	✓			✓			C,I,S		££	✓✓✓			
	Simplifying signalling principles	HIGH	✓	✓			✓✓		C	I, S		£	✓✓✓			
	Remote condition monitoring for minimal routine intrusive maintenance and hence possession times	MEDIUM	✓	✓			✓✓		C, I	I, S		£	✓✓			
	RCM, Health and Usage Monitoring Systems (see Infrastructure)	HIGH				✓	✓✓	✓	C	I, S	I,S	£££	✓✓✓			
	Iterative steps to achieve intelligent traffic which provide driving profile information	HIGH			✓		✓	✓✓	C, I	S		££	✓✓			
Modern signalling systems providing in-cab functionality and Automatic Train Protection and reducing lineside infrastructure	Automatic train operation	HIGH		✓			✓✓✓		C	I, S		£££	✓✓✓	MEDIUM	HIGH	£££
	Freight train protection	HIGH		✓					C	I, S		£	✓✓			
	ETCS Level 2/Level 3 deployment	HIGH		✓		✓	✓	✓	C	I, S		££	✓✓✓			
	European signalling systems	MEDIUM		✓✓			✓✓		C	C, I	I, S	£	✓✓			

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Energy

Energy-related technologies will enable a railway that is safe, reliable, cost-efficient and energy efficient. In the railway of the future, power will be available and scalable as required, offering greater operational flexibility and supporting low disruption maintenance. Trains will increasingly be powered by electricity. Trains and buildings including depots and stations will benefit from greater use of energy harvesting, recycling and storage.

Goals before and after 2019

Objectives for 2019 include:

- Reducing risks to the lives of railway workers, and contribution to reduction in total delays
- The cost-efficient electrification of over 3,000km of track, contributing to reduced CO_2 emissions from rail and increasing track capacity.

Beyond 2019 we aim to see further reductions in CO_2 emissions and new approaches to enable the increased use of electrically powered train services.

Scope

The scope of energy technologies addresses four principal outcome areas.

Safe maintenance of electrical infrastructure

Today, 39 per cent of the network is currently electrified and services travelling on electrified routes pose a substantial risk to workers during inspection, maintenance and renewals and when dealing with incidents.

Reliable delivery of energy

At present, energy supply to electrified rolling stock is critically reliant on a proprietary conductor-collector system between train and infrastructure.

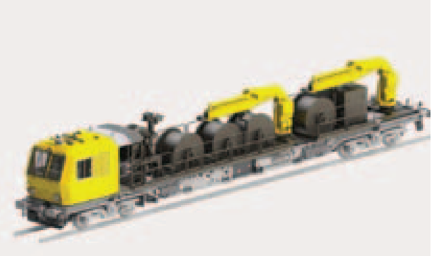
Cost-efficient acquisition and use of electricity

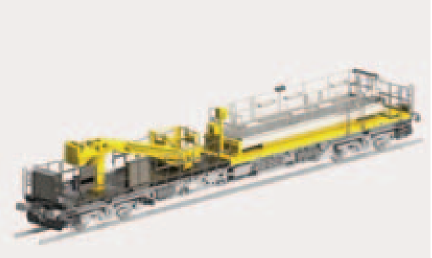
Electricity is the primary energy powering Britain's railway due to the 39 per cent electrified network carrying the majority of train services. Network Rail is one of the largest buyers of electricity in the UK, accounting for about 1 per cent of UK consumption. By the end of CP5, we expect to spend over £500 million annually on electricity.

Sustainable, efficient use of energy

Most of the total carbon emissions produced by the GB rail industry[1] (63 per cent) arises from powering trains and is the primary opportunity for efficiency. Other uses of energy such as stations, depots and lineside operations (signalling and heating equipment, for example) produce 15 per cent of carbon emissions while 22 per cent of carbon emissions arise from materials and products used to enhance, renew, maintain and operate the railway.

High output factory train





1 Whole life carbon footprint of the GB rail industry, September 2010

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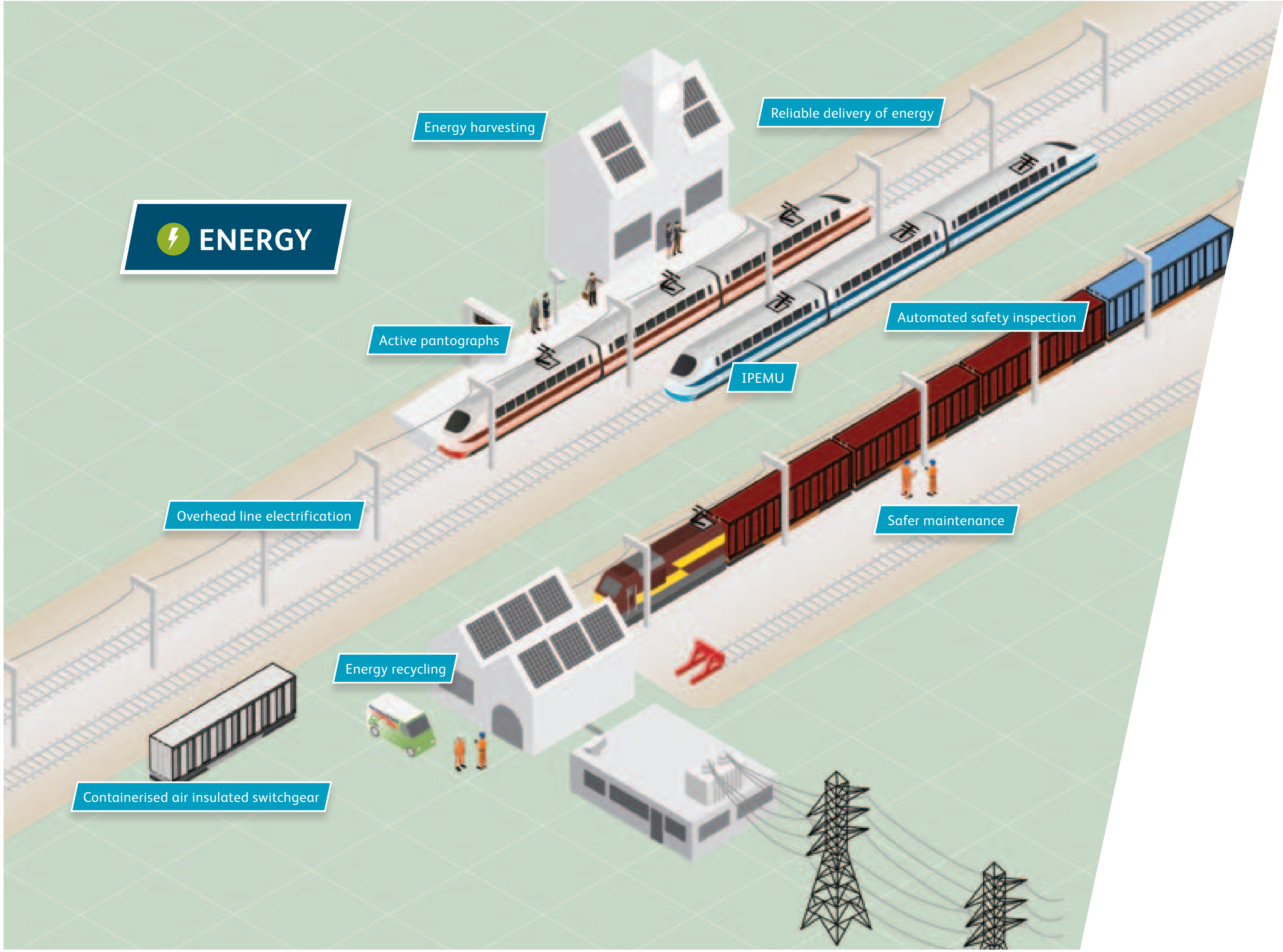


R&D investment will address:

- Safer inspection, repair and maintenance capability for electric traction infrastructure
- Design and test capability to improve reliability and reduce cost of electric traction infrastructure
- Capability to increase proportion of electric traction energy use
- Efficient and resilient energy distribution
- Managing energy demand

In the railway of the future, power will be available and scalable as required to a larger capacity network that offers greater operational flexibility and supports low-disruption maintenance.

Our challenges, opportunities and approach to technology

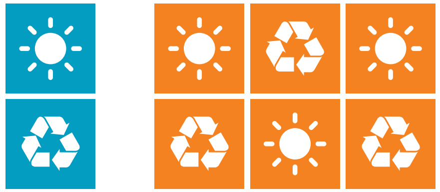
Current technologies and applications present a number of challenges.

- The current DC third rail infrastructure is constrained by the low system voltage and high power demands of longer, more frequent and heavier trains. It requires costly and closely spaced substations and is subject to substantial energy losses. It limits the performance of existing rolling stock by up to 50 per cent of the equivalent AC powered rolling stock and restricts electric freight operation. The physical location of the rail presents an obstacle to efficient track maintenance and an electrical safety hazard.
- The high voltage overhead conductor system for 25kV electrification is efficient but is vulnerable to failure, particularly at neutral sections. The existing system is difficult to inspect and constrains high speed operation of rolling stock with multiple pantographs.
- Electrically powered rolling stock requires continuous supply, creating inflexibility and a lack of resilience. It is expensive to install and maintain, so is not cost-effective for less busy routes.

We will embrace opportunities from new technologies and new applications of existing technologies both to optimise existing systems and to create new products and systems. Our approach to technology will be:

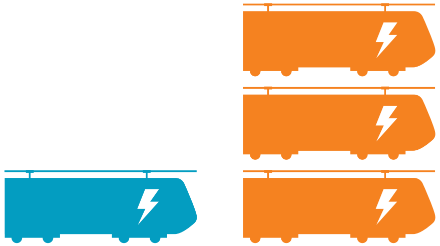
- To develop technologies that support systems of work to reduce contact time between workers and electrical assets and reduce the safety risks from those assets.
- To develop technologies that improve, optimise and monitor the contact between collector and conductor. Working with our industry partners we will reduce and ultimately manage out DC supply to improve efficiencies and reduce journey times.
- To apply smart grid technologies, such as IEC 61850, which will allow simplified substation configuration, reducing whole life costs.
- To develop techniques to reduce the cost and disruption from electrification renewals and enhancements.
- To apply energy storage and harvesting technologies to infrastructure and rolling stock, working with our industry partners.
- To apply energy efficiency products to railway premises and lineside for sustainable energy efficiency.
- To develop optimised traffic management technologies (see Control and command).

Increasing solar energy, energy recycling and storage **Apply sustainable energy efficient products to railway premises and lineside assets, enabling a reduction in carbon emissions and maximised efficiency in energy usage**



At present   Our ambition

More electric trains Exploit lower cost, more energy efficient electrification, contributing to a reduction in carbon emissions and increased flexibility across the network



Increasing energy storage and harvesting Apply energy storage and harvesting techniques to infrastructure and rolling stock, reducing demands on the energy network and reducing carbon emissions

What we're doing now

Electric traction infrastructure

- New overhead electrification will be installed using our high output factory train reducing construction times, disruption and cost. We expect the train to be able to install overhead line equipment at a significantly higher rate than previously achievable, while allowing adjacent tracks to remain open.
- Cameras are to be installed in the pantograph roof well to provide information on performance, this being the first step towards remote inspection.
- The design of overhead electrification will be improved. For example, by introducing spring tensioning equipment to individual overhead conductors to improve the resilience of conductor lines.

Traction energy

- Batteries are being manufactured and tested for use in a passenger train to operate on track sections without electrification infrastructure.

Energy distribution and management

- Working with industry, we're developing a project to create a decision support tool to help optimise the way that electrical sectioning is provided to enhance operational flexibility. We expect that the project outcomes will also improve electrical safety and the speed of isolating sections for repair and maintenance.
- We're developing efficient and sustainable energy distribution solutions. For example, we're phasing out the use of environmentally damaging SF6 gas in electrical switchgear and developing flexible, affordable Air Insulated Switchgear and other solutions.

Managing energy demand

- Embedded power generation techniques such as regenerative braking are readily available and increasingly utilised. We are already using solar generation techniques on the roofs of substations and stations in order to reduce demands on the energy network as well as to reduce carbon emissions.
- Our new SCADA system will allow energy transducers to be fitted to the network to allow greater understanding of capacity and efficiency optimisation leading to reduced distribution losses.

Network Rail has considered its strategy for future electrification of the network, including the potential implementation of developing technology, as part of the LTPP in the Network RUS: Electrification (2009) and the Network RUS: Alternative Solutions (2013). An updated 'Electrification Refresh' RUS is also being developed.

Requirements for the future

We need an electric traction infrastructure that achieves:

- Enhanced protected working environments.
- Increased efficiency of, and reduced losses from, DC third rail.
- Reduced train delays from faults in AC overhead line – for example, through the development of new principles and designs for electrical sectioning and the construction of neutral sections, enabled through increased knowledge.
- Removal of high-level intrusive inspection, with automated assessment of line condition for fault identification on AC overhead line to improve safety and to reduce costs and human error, enabled through developments to enable pattern recognition.
- Improved performance of AC overhead line, in particular by developing, testing and trialling new pantograph technologies to manage and optimise the contact force between the pantograph and conductor.
- Reductions in the whole-life cost of equipment and access requirements from new electrification schemes and renewals.

We also need traction energy use that achieves:

- A more economic energy supply on lightly used or non-electrified routes.
- Lower cost, energy efficient electrification covering an increasingly large proportion of network traffic.

We expect to source technologies and systems from other sectors to establish efficient and resilient energy distribution and management using capabilities largely drawn from the electrical supply industry. These will achieve:

- Increased operational flexibility, particularly for longer, high-speed multiple pantograph trains capable of speeds up to 140 mph, resulting in more capacity.
- Rapid restoration of energy availability following a fault.
- Optimised renewals through a better understanding of the deterioration of equipment, particularly insulation for switchgear and cables.
- A better understanding of system losses, energy consumption and the profile of energy use through the provision of real-time information on the energy efficiency of infrastructure as well as aligning standards with the electrical supply industry practices.

A critical aspect of achieving our vision for energy is to manage energy demand. Addressed under other themes in this document, energy demand is managed through:

- Applying and developing energy efficient products and strategies, including the use of buildings to harvest renewal energy.
- Regulating the speed and progress of trains in order to optimise traffic movements and reduce peak energy demand. (see Control and command).
- Forecasting and matching train capacity to passenger demand (see Whole system approach).
- More efficient rolling stock design and refurbishment (see Rolling stock).

Energy efficient products

Table of indicative investments for Energy

The investment table shows the research and development programmes which could be managed under the energy asset theme. It shows indicative projects, their anticipated contribution to our strategic business outcomes, their current and future anticipated state of development and our degree of confidence. It also shows the programme benefits and likely magnitude of investment. Prioritisation, detailed definition and delivery approach have yet to be determined.

Level of impact

● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	**Benefits of project** (large=high impact)	**Where project would impact** (each 'check' represents a quarter of the benefit)						**State of development** (C=Concept ready, I=Implementation ready, S=system ready)			**CP5 cost** (£1=<£1m, ££=£1m-£10m, £££=>£10m)	**Confidence** (✓✓✓=high)	**CP5 benefit of portfolio** (large spot=high impact)	**CP6+ benefit of portfolio** (large spot= high impact)	**Proposed CP5 R&D investment** (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Safer inspection, repair and maintenance capability for electric traction infrastructure	Instrumentation to monitor the overhead line and RFID tags on overhead line components	● MEDIUM	✓	✓✓			✓		C	C, I, S	I, S	££	✓	● HIGH	● MEDIUM	£££
	Robotic maintenance including Road Rail Vehicle and live line maintenance	● HIGH	✓✓	✓		✓				C, I	I, S	££	✓			
	Push button isolation and easy test for live overhead line and conductor rail	● MEDIUM	✓✓✓	✓						C, I, S		£	✓			
	RCM, Health and Usage Monitoring Systems (see Infrastructure)	● VERY HIGH	✓	✓✓			✓		C, I	C, I, S	I, S	£££	✓✓✓			

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Summary
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Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Design and test capability to improve reliability and reduce cost of electric traction infrastructure	Pantograph test rig for OLE, to bring testing facilities together	●		✓✓			✓✓		C	I, S		££	✓	●	●	£££
	Active pantograph and high voltage coupling of train units to enable operation with a single pantograph	•		✓✓		✓✓			C	I, S	S	££	✓✓✓			
	Carrier wire neutral section design	•		✓✓		✓✓				C, I, S	I, S	££	✓			
	Improved weather resilience of the DC third rail system	●		✓✓	✓✓					C, I	I, S	££	✓			
	Mitigate disruption for transitioning the conversion of infrastructure from DC third rail to AC overhead line, including the impact on rolling stock	•		✓✓			✓✓			C, I	I, S	££	✓			
	Low whole life cost overhead line which could include structures designed from materials such as plastics to achieve aesthetically improved low maintenance designs	●					✓✓	✓✓		C, I	I, S	££	✓			
	Simplified overhead line at switches and crossings	●					✓✓✓	✓	C	C, I	I, S	££	✓			

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Level of impact

● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Capability to increase proportion of electric traction energy use	Hybrid diesel and electric trains where independent energy solution is insufficient for the required range and performance	MEDIUM			✓			✓✓✓	C, I, S	C, I, S		££	✓	LOW	VERY HIGH	£££
	Independent power through on-train energy storage, recycling and optimised use of energy and charging facilities	HIGH			✓		✓	✓✓	C, I	I, S	S	£	✓			
Efficient and resilient energy distribution	Air insulated switch gear technology transfer from the electricity supply industry	MEDIUM					✓✓✓	✓		I, S		££	✓	MEDIUM	HIGH	£££
	Applications of smart grid solutions from the electricity supply industry	HIGH				✓	✓✓	✓		I, S	S	££	✓✓			
	Energy harvesting devices	HIGH					✓	✓✓✓	I	I, S		£	✓			
	Better energy self-sufficiency	MEDIUM					✓	✓✓✓	C	C, I	I, S	££	✓			
Managing energy demand	Non-traction energy efficiency; achieved through the application of innovative building management practice, for example applying energy management systems at stations	MEDIUM					✓	✓✓✓	I	I,S		££	✓	LOW	MEDIUM	££
	Energy demand modelling to understand and optimise supply and distribution	MEDIUM					✓✓	✓✓		C, I	I,S	££	✓			
	Future Traffic Regulation Optimisation to optimise the control of trains and to match train service provision to demand (see Control and command)	HIGH					✓✓	✓✓	C	C, I	C, I, S	£££	✓✓✓			

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Infrastructure

Infrastructure focuses on the track itself, and civil engineering assets that physically support and contain the track, enabling it to carry rolling stock through the landscape and townscape. Infrastructure should carry trains safely and reliably, it should be safely and efficiently maintained with a minimal amount of access for maintenance and efficient systems for renewals. The interfaces between the infrastructure and rolling stock should be optimised adopting a whole life cost approach. Technologies will be utilised to enable the infrastructure to monitor and adjust itself, with an increasing focus on interpreting data derived from low cost, low maintenance sources. Better resilience and a reduced need for maintenance will be achieved through new materials, further consideration of whole life cost and improved, efficient design. Infrastructure-related technologies will lead to greater safety, further cost efficiencies and better reliability. The result will be a sustainable asset contributing to an overall reduction in carbon emissions.

Goals before and after 2019

By 2019, success will be measured in terms of a greater consideration of whole life cost, a reduction in manual inspection through technology innovation and a greater knowledge of asset behaviour and failure criteria leading to more informed intervention.

Beyond 2019 we aim to adopt new approaches to asset management in order to better understand and inform asset behaviour and stewardship, making use of innovative inspection, management, construction, materials and maintenance processes.

Scope

The scope of infrastructure technologies addresses four principal outcome areas.

Safety

We aim to see a reduction in the manual inspection of infrastructure through the adoption of train-borne applications and greater use of intelligent infrastructure while increasing the mechanisation of maintenance tasks and improving safety for the general public at key interfaces such as stations and level crossings.

Sustainability

Whole life cycle management will enable us to consider new construction techniques and materials along with the recycling and reuse of assets.

Cost efficiencies

The combination of track and civil engineering infrastructure, signalling and electrification asset maintenance cost £0.9 billion in 2012/13. Greater understanding of whole life cost and increased asset knowledge will allow focused technology roll-out at a faster rate.

Performance and Reliability

The combination of track and civil engineering infrastructure, signalling and electrification asset failures accounts for three quarters of total annual delays in 2012/13. We aim to achieve greater reliability through a better understanding of asset behaviour, increased use of remote monitoring (moving to ‘predict and prevent’ rather than working reactively) and fewer asset failures.

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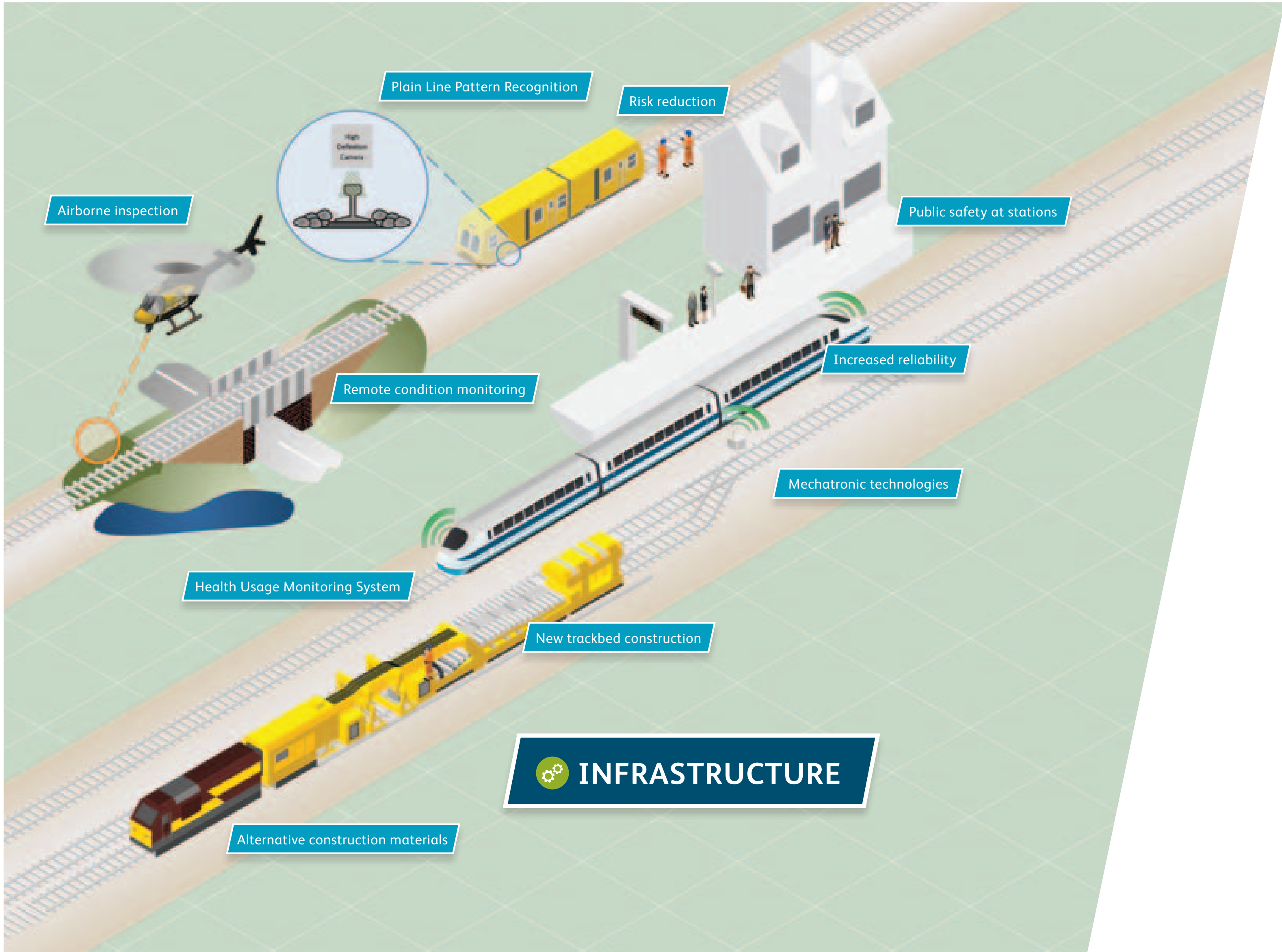


R&D investment will address:

- Increased track resilience and cost efficiency through improved design and materials
- Reduced cost and maximised track availability by non-disruptive inspection and targeted timely maintenance interventions
- Reduced cost and improved safety of earthworks by non-disruptive inspection and targeted timely maintenance interventions
- Reduced cost and improved safety of structures and buildings by non-disruptive inspection and targeted timely maintenance interventions

Technologies will be utilised to enable the infrastructure to monitor and adjust itself, with an increasing focus on interpreting data derived from low cost, low maintenance sources.

Our challenges, opportunities and approach to technology

Challenges we face under our current technologies and applications include:

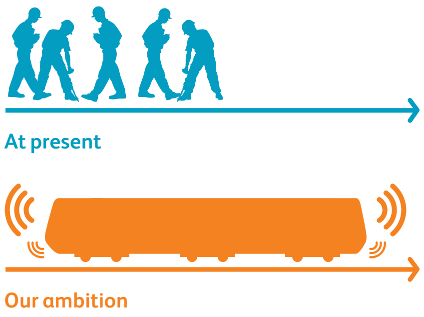
- Reducing the workforce's exposure to risk during construction, inspection and maintenance; ensuring greater safety for third parties and passengers, reinforced by lifesaving rules that ensure everyone arrives home safe every day.
- Realising the benefits of adopting new design and construction techniques; exploiting opportunities for the standardisation and simplification of components.
- Challenging current design parameters to increase asset life through the use of innovation; delivering reliable infrastructure, equipment and products, designed to deliver appropriate levels of reliability.
- Increasing the use of automated monitoring solutions; enabling trains to monitor the infrastructure and for the infrastructure to monitor trains, along with automated tasks, other diagnostic equipment and use of modelling techniques, will improve asset reliability and support risk-based maintenance regimes, extending the economic life of our assets and maximising availability of the network.
- Mechanising and automating tasks to increase efficiency and reduce workforce risk.
- Introducing new design and construction techniques to benefit whole-life costs, so prolonging asset service life while reducing the carbon footprint.

We will embrace new technology and the application of existing technologies to optimise existing systems, while creating new products and systems. Our approach will be:

- To innovate and develop technology to understand and monitor real-time performance of structures and earthworks asset.
- To develop further train-borne inspection and monitoring methods and technology for inspecting underwater assets.
- To gain greater understanding of environmental factors on the asset along with an improved approach to product acceptance and providing enhanced assurance.
- To continue to develop technology for non-intrusive and non-destructive inspection and management of the asset.
- To encourage the use of new or alternative materials during construction and maintenance within the principles of whole-life cost.

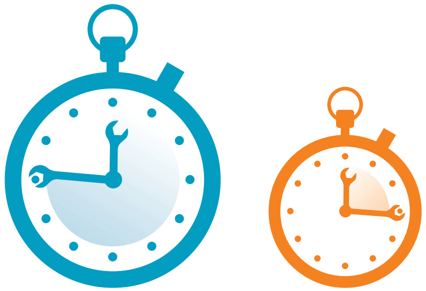
Automating inspection of assets

Remotely monitor the health, condition and usage of assets from trackside and on trains, reducing the need for trackside inspection and reducing the risk to the workforce



Increase efficiency and reduce risk

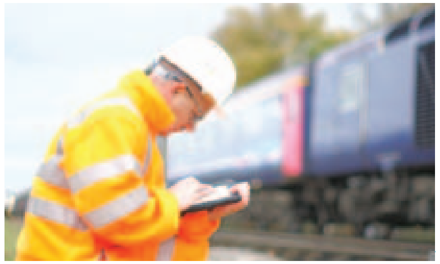
Reducing the duration and impact of maintenance More planned, less reactive maintenance achieved by better understanding asset condition with new and renewed assets designed for less maintenance



At present

Our ambition

Mobile handheld devices



What we're doing now

Through risk-based maintenance (a form of Reliability Centred Maintenance), we're challenging existing asset inspection and intervention timescales. Trials are already planned with partial or complete adoption possible within CP5.

For plain line track inspection, we're currently trialling a train-borne alternative, 'Plain Line Pattern Recognition' (PLPR). PLPR has the potential to provide not only consistent and repeatable asset information but also major safety benefits, for example, removing workforce from on-track exposure. If the trials prove successful, this approach will be embedded across more of the network. Its application to automated level crossing surveys will also be considered.

Work is nearing completion on reducing the carbon footprint of railway sleepers. An 11 per cent reduction has been achieved through testing and this is likely to be adopted on the infrastructure before the end of CP4.

We are involved in early stage deployment of remote monitoring systems with the earthworks asset to inform asset performance, reduce risk and increase asset management efficiency.

We are reducing maintenance volumes across the network by implementing managed track position systems involving the use of design, maintenance and inspection techniques to ensure that track assets remain in their designated position and gauge.

We participate in a number of European (e.g. SUSTRAIL) and UK (e.g. Track 21) based projects. Track 21 for example, improves understanding of the complex mechanisms of railway track behaviour governing stiffness, robustness, longevity, noise and vibration performance to allow us to optimise the track system. These projects are undertaken in partnership with government, academic and industrial organisations to bring about improvements in capacity, infrastructure performance and sustainability by developing new design, construction, monitoring and maintenance techniques.

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Requirements for the future

We will work with industry partners to investigate the opportunities to optimise interfaces through a differentiated railway (see Whole Systems Approach) that could enhance capacity for individual routes and may offer more consistent and simplified performance and platform to train interfaces.

We need track and civil engineering infrastructure which achieves:

- Workforce safety improvements
- Real-time monitoring of assets to provide early warning of potential safety impact on train operations
- Non-disruptive inspection and maintenance interventions to reduce costs and improve the safety of infrastructure assets
- Optimised infrastructure-train interface.

Increase track resilience:

- The development of manufacturing techniques, rail products and alternative materials that provide greater reliability and cost efficiency from reduced wear and tear, contributing to a 10 per cent reduction in carbon usage
- A reduction in whole-life costs associated with design, installation, operation and maintenance
- A greater understanding of whole system carbon impact
- Innovative track designs for better geometry, reduced tamping and improved longevity
- Infrastructure which considers the use of Mechatronic technologies which may unlock new design concepts in switch and crossings design.
- Lower maintenance costs from earthworks failures with longer asset life and a reduction in the impact of climate change on the network.

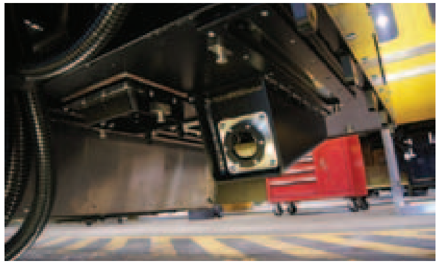
Maximise track availability:

- A reduction in ad hoc maintenance to increase network availability
- More efficient, accurate monitoring of the asset to detect faults and inform decision making, building on our Intelligent Infrastructure programme (see collaboration case study)
- Greater available capacity with the existing assets, increasing asset service life at minimal costs
- The ability to test and evaluate new and innovative structural instrumentation techniques against known conditions and parameters

A critical aspect of achieving our vision for infrastructure is to manage capacity at stations and demand for energy. These are addressed under other themes and include:

- The accommodation of more passengers without increasing station size. Solutions need to be identified to extend capacity without the need for larger spaces (see Rolling stock).
- Understanding the changes to station design needed to cope with intensive train service patterns (see Rolling stock).
- A greater understanding of whole-system energy and carbon impacts (see Energy).
- Continuing development of decision support tools which analyse infrastructure data and improve the whole-system infrastructure reliability (see Whole System Approach).

Seven HD cameras take up to 70,000 pictures a second, along with 3D and thermal images



Computer algorithms recognise areas of current and future concern

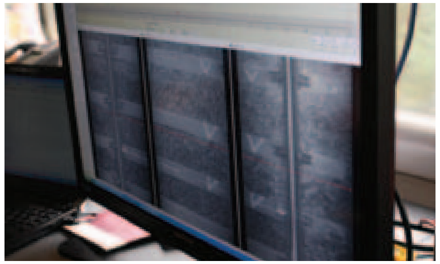


Table of indicative investments for Infrastructure

The investment table shows the research and development programmes which could be managed under the infrastructure asset theme. It shows indicative projects, their anticipated contribution to our strategic business outcomes, their current and future anticipated state of development and our degree of confidence. It also shows the programme benefits and likely magnitude of investment. Prioritisation, detailed definition and delivery approach have yet to be determined.

Level of impact

● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Increased track resilience and cost efficiency through improved design and materials	New track and sleeper design – continuous support, sleeper & pads and derailment protection	●	✓✓				✓✓		C	I	S	££	✓	●	●	£££
	Combined ballast & slab design	●	✓			✓	✓✓✓		C	I	S	££	✓			
	Rail steel materials, wear, RCF, self healing, longer life, non-homogenous	●		✓			✓✓✓		C	I,S	S	£	✓✓			
	Mechatronics rules (including for example trains curving at the right speed) and S&C re-design for mechatronics	●					✓✓✓✓			C	I	£	✓			

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Reduced cost and maximised track availability by non-disruptive inspection and targeted timely maintenance interventions	Eddy current monitoring	•	✓				✓✓✓		C	I,S	S	£	✓	●	●	££££
	Mechatronic railway with self adjustment	•		✓		✓	✓✓		C	I, S	S	££	✓✓			
	RCM, Health and Usage Monitoring Systems	●				✓	✓✓	✓	C	I, S	I,S	£££	✓✓✓			
	Auto-self adjusting Infrastructure from RCM data	●				✓	✓✓	✓	C	C, I	I, S	££	✓✓✓			
	Autonomous intelligent systems – Robotics (see whole systems approach)	●	✓	✓		✓	✓		C	C, I	I, S	££	✓			
Reduced cost and improved safety of earthworks by non-disruptive inspection and targeted timely maintenance interventions	Earthworks monitoring smart pebbles	●	✓				✓✓	✓	C, I	I, S	S	£	✓	•	●	££
	Optical fibres as general movement / performance sensor	●	✓				✓✓	✓	C, I, S	I, S	S	£	✓			
	Detection technology for earthworks stability	●	✓				✓✓	✓	C, I, S	I, S	S	£	✓			
	RCM, Health and Usage Monitoring Systems (see above)	●				✓	✓✓	✓	C	I, S	I,S	£££	✓✓✓			
	Embankment re-engineering, water profiling and soil stabilisation	•	✓				✓✓✓		C	C, I	S	£	✓			

Level of impact

LOW MEDIUM HIGH VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Reduced cost and improved safety of structures and buildings by non-disruptive inspection and targeted timely maintenance interventions	Bridge corrosion detection – specifically developing and calibrating guided ultrasonic's technology		✓				✓✓✓		C,	I, S	S	£	✓			££
	Better corrosion protection systems						✓✓✓	✓	C, I	S	S	£	✓			
	RCM, Health and Usage Monitoring Systems (see above)					✓	✓✓	✓	C	I, S	I,S	£££	✓✓✓			
	Development of additional examination 'toolkit'						✓✓✓	✓	C	C,I	I,S	££	✓✓			
	Masonry arch behaviour development			✓			✓✓	✓	C,I	I,S	S	£	✓✓			
	New build review of RCM during design and construction			✓			✓✓	✓	C,I	I	I,S	£	✓✓			

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Rolling stock

Rolling stock lies at the heart of the railway system – the container for carrying the goods and passengers that services the economy and provides the railway's income. Whilst we don't own or operate the passenger and commercial freight rolling stock, the way that rolling stock is specified, deployed, operated, improved and maintained fundamentally affects the outcomes we can achieve for our customers. We will work with industry partners to support a vision for rolling stock that is fully integrated with our vision for other railway system assets and their function.

Rolling stock should be safe, reliable, efficient, an optimised lighter weight with low levels of predictable wear to the infrastructure and routinely monitoring the railway assets. It should be designed using modular concepts to facilitate flexible use, providing users with an experience that exceeds expectation. Interfaces between the rolling stock and other railway assets should be optimised, adopting a whole life cost approach and maximising train capacity and the capacity of the network. Vehicle designs should be capable of cost-effective upgrades to maximise utilisation of the routes on which they operate, effectively managing obsolescence from the outset. This vision is articulated as part of the LTPP, developed by cross-industry stakeholders, in the Network RUS: Passenger Rolling Stock published in 2011.

Goals before and after 2019

In the period to 2019, we expect to support industry partners to lay down foundations for future rolling stock designs. We expect to determine, for example, the value of improved traction and braking performance and faster boarding and alighting time on metro type operations to increase capacity. And to progress condition monitoring between rolling stock and Network Rail assets and feedback on the infrastructure while establishing the rolling stock versus infrastructure costs relating to the whole life costs of operating trains.

Beyond 2019, the future rolling stock designs will start to be embedded into subsequent generations of rolling stock in a gradual and progressive manner. Pre-production prototypes and testing and trials will be used to develop new technologies to a mature state for use on production vehicles to minimise risks to the operator.

Scope

The scope of rolling stock technologies addresses the following principal areas:

Maintaining safety

The rail industry has a shared commitment to improve safety. As a minimum, the safety and security of rolling stock and its users will be maintained without increasing weight or energy consumption.

Reducing costs and carbon

The cost of maintaining the UK rolling stock fleet is around £0.4 billion per annum – 3 per cent of the cost of operating the railways. The energy bill for electric traction energy alone represents two thirds of the anticipated £500 million per annum spend on electricity by 2019. The typical weight for a passenger vehicle, depending on factors including whether it is powered, breaks down as: bodyshell 20-30 per cent, running gear 20-30 per cent, equipment 10-20 per cent, furnishings 12-30 per cent and traction 0-25 per cent.

Increasing capacity

Capacity can be increased by enhancing the load carrying capability of the rolling stock. A further key opportunity to increase capacity can be achieved by industry working together to manage the flow of passengers on and off trains to reduce station dwell times. For example, a ten-second reduction in dwell time at six stations on an inner core, Thameslink type, 24 trains per hour operation over two hour morning and evening weekday peak periods operated with eight-car trains carrying 500 passengers could realise a passenger benefit approaching £10 million per annum[1].

1 Monetary values for passenger time are based on cost per hour per rail passenger from DfT TAG Unit 3.5.6.

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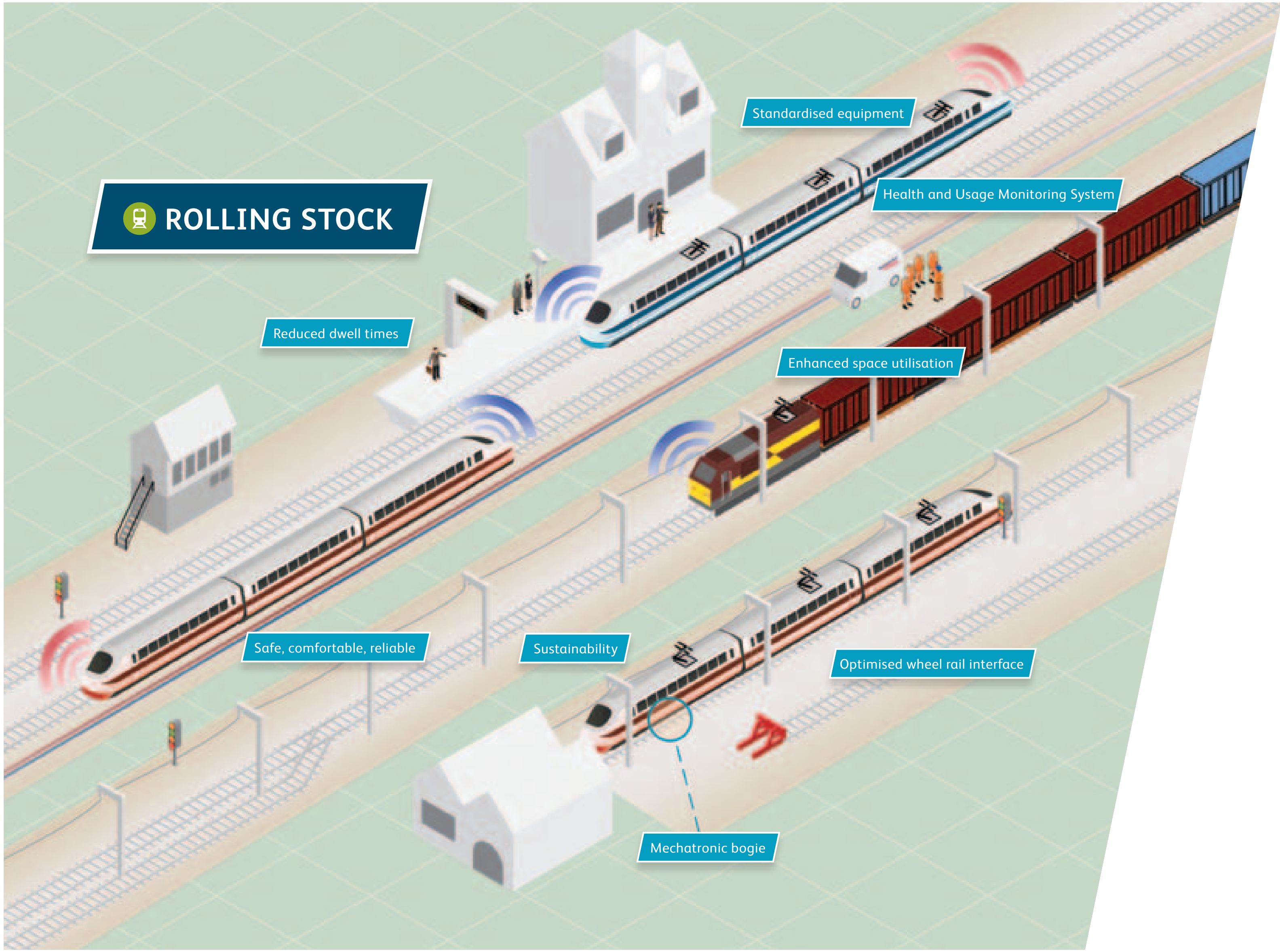


R&D investment will address:

- Reducing infrastructure wear and energy costs arising from rolling stock whilst retaining rolling stock crashworthiness and reducing rolling stock operating costs
- Modular train sub-systems for cost effective procurement and upgrade
- Optimising station dwell time to maximise passenger boarding and alighting and minimise door opening / closing cycle time
- Improving the capacity and performance of rolling stock to increase network capacity, reliability and performance

We will work with industry partners to support a vision for rolling stock that is fully integrated with our vision for other railway system assets and their function.

Reliability and recovery from perturbation
Reducing operational perturbation recovery time has a substantial cost benefit. Rolling stock reliability data from the ATOC ReFocus (Reliability Focus) group suggest that, annually, rolling stock failures account for a quarter of total annual delays.

Our challenges, opportunities and approach to technology

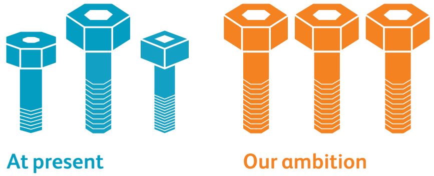
We will work with and support our industry partners, across the scope identified above, recognising the following challenges and opportunities.

- Maintaining passenger safety, security and comfort by employing smart designs to provide crashworthy, comfortable rolling stock without increasing weight, cost and energy use.
- Systematically reducing energy consumption, reducing tare vehicle weight and optimising interfaces.
- Improving traction and braking capability without increasing weight by: Investigating brakes that are independent of friction; providing consistent wheel-rail adhesion for high performance friction brakes and traction; and developing the traction and braking equipment needed to achieve the enhanced performance capability.
- Providing obsolescence resilience and optimised interfaces within normal procurement timescales by obtaining interface protocol specifications against manufacturer Intellectual Property Right (IPR) demands.
- Demonstrating the cost-effectiveness of reduced dwell times and train start-up times along with effective management of in-service failures and the provision of rolling stock, operational procedures and interfaces to achieve these objectives.

The technology approach to be adopted will include:

- New materials and methods. These will be investigated where benefits may be gained from their use in an appropriate time frame for the readiness of the technology.
- Optimised interfaces. Whole life costing techniques will be used to optimise the entire system with other industry partners in a collaborative manner.
- Standardised modular equipment and associated protocol specifications. These will reduce costs while providing obsolescence resilience.

Standardising rolling stock
Modular rolling stock sub-systems to reduce the ease and cost of procurement, maintenance and upgrade



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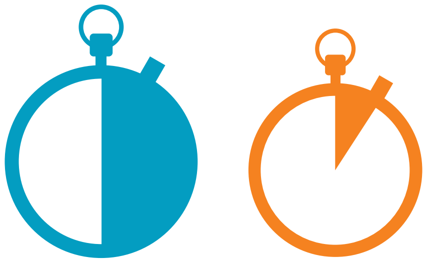
Reducing dwell times

Optimise the design of passenger flow, platforms and rolling stock to work together to provide more train paths and increase capacity



At present

Our ambition

What we're doing now

Work currently known to be under way includes:

Maintaining safety

- Various European-sponsored projects have been undertaken to investigate rail vehicle safety from both a structural and an interiors perspective. Examples of such projects include EURailSafe and Aljoin which investigated rail vehicle crashworthiness.

Reducing costs and carbon

- Embedded power generation techniques such as regenerative braking are readily available and increasingly utilised.
- Train manufacturers are developing advanced drive architectures both to reduce train weight and to improve train efficiency. Examples include:
  - The Bombardier MITRAC permanent magnet motor and Flexx tronic bogie.
  - The Siemens Syntegra bogie.
  - Hitachi lithium ion battery hybrid drive technology.
  - Ultra high-strength steels used by Ford cars and ArcelorMittal for E71 wagon. (These have reduced empty wagon weight by 33 per cent and material costs by 34 per cent.)
  - MODTRAIN – European research into modular train equipment.
  - Steerable (track friendly) bogie designs, already adopted on a number of stock with varying degrees of success.
- RSSB has managed numerous projects on reducing vehicle mass, all-electric vehicles and sharing remote condition data.
- A variety of lineside-based remote condition monitoring tools have been installed across the network, monitoring wheels, pantographs and axle bearings. For example, Gotcha and WILDE are used for wheel impact detection whilst hot axle box detectors (HABD) and Railbam acoustic bearing monitoring are used for axle bearing monitoring.

Increasing capacity

- Friction modifiers are already in use on the throat of Euston station to provide consistent rail head conditions to provide predictable traction and braking performance.
- Electric Current for Traction (EC4T) energy meters and Driver Advisory System (DAS) installations already provide potential tools for increasing capacity by maintaining right time arrival and minimising overall energy consumption. First Scotrail DAS predict Class 170 fuel use will reduce by 7 per cent; 6 per cent fuel savings have already been achieved with driver education and reduced engine idling.
- Boarding, alighting and station dwell times research is under way in association with the Thameslink project.
- Research has been carried out into operating trains at high speed with several pantographs raised. Preliminary research has also been conducted into the use of active pantographs.
- Solutions for radio-controlled operation of multiple working of freight locomotives have been investigated with the aim of optimising the use of freight train paths. A case in point is the EDIP (European Distributed Power control) project which provides a potential solution for radio control of multiple locomotive freight trains.
- Theoretical studies have been carried out to investigate the aerodynamic efficiency and issues arising from intermodal freight train operation.

Reliability and recovery from perturbation

- RSSB projects have explored the maximisation of rolling stock and whole-system reliability respectively.

Expectations for the future

We will work with industry partners to progress the following.

- Investigate the opportunities to optimise interfaces through a differentiated railway (see Whole system approach) that could enhance capacity for individual routes and may offer more consistent and simplified timetabling, performance, signalling, traction power and platform to train interfaces.

Maintaining safety

- Optimised lighter weight crashworthiness to maintain passenger safety and security.
- Traction and rolling stock maintenance facilities, configured to maintain rolling stock in a safe state.

Reducing costs and carbon

- Energy recovery to build on regenerative braking – hybrid drives, batteries, super-capacitor, compressed gas and flywheel storage.
- New high power, high efficiency traction drive architectures including switched reluctance and permanent magnet motors, pancake motors independently driving each rail wheel, mechatronic bogies and running gear, active suspensions, friction modification at the wheel-rail interface and active high speed current collection.
- Optimised interfaces and whole life costing to account for costs across interfaces. Interface areas include wheel to rail, pantograph to overhead line (see Energy), shoe gear to third rail (see Energy), rail vehicle to structure gauge, rail vehicle to power supply, rail vehicle to train control and signalling system and train-to-train interfaces.
- The use of standardised modular equipment – for example, auxiliary convertors, traction drive equipment, on-train signalling equipment, train radio, passenger train doors, passenger information systems, bogies, wheelsets, brake equipment and current collection apparatus. Benefits accrue from reduced design costs, testing, approvals, compatibility assessments, maintenance training, maintenance competence management and spares inventory.
- Very high efficiency thermal insulation, reducing the energy required to heat passenger trains in winter and minimising the cooling load in summer.
- Altered passenger environment control algorithms combined with passive and forced heating and ventilation systems to reduce the energy and weight penalty of air conditioning.
- Improved Passenger Information Technology, using the latest technology in displays and public address systems to reduce train energy load.
- Newer, lightweight, high strength materials such as carbon fibre, bonded aluminium and ultra high-strength steel.

Increasing capacity

- Right time arrival at points of conflict, facilitated by ERTMS, ATO, DAS and ETCS on new rolling stock.
- The levelling of power supply demand by staggered train starting.
- Reduced station dwell times and train start-up times, facilitated by appropriate rolling stock and interfaces. For example level platforms and train floors, adequate stand-backs within vehicles, door opening times, numbers and positions of doors, amount of seating, in-service door failure management and train stopping position.
- Enhanced space utilisation on rolling stock for load carrying.
- The provision of power to facilitate the operation of high performance trains.
- Improved, consistent braking capability involving a whole system approach to vehicle braking, the potential use of lightweight actuators, braking that is not reliant on the wheel-rail interface, maximising dynamic brake and enhancing performance from adhesion management including the use of friction modifiers.

Reliability and recovery from perturbation

- Reduced delays and increased capacity facilitated by train crew fault finding hosted via mobile phone technology, reduced dwell times, maximised capacity of trains and network, reduced train start-up times and improved train performance.
- Standardised and modularised equipment with adequately documented protocol specifications and maintenance documentation to improve safety, reliability, availability and maintainability of traction and rolling stock equipment with a systematic focus on reliability-centred maintenance and remote condition monitoring.
- Greater reliability through adequate testing of traction and rolling stock systems and equipment prior to service use.

Table of indicative investments for Rolling Stock

The investment table shows the research and development programmes which could be managed under the rolling stock asset theme. It shows indicative projects, their anticipated contribution to our strategic business outcomes, their current and future anticipated state of development and our degree of confidence. It also shows the programme benefits and likely magnitude of investment. Prioritisation, detailed definition and delivery approach have yet to be determined.

Level of impact

● LOW ● MEDIUM ● HIGH ● VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Reducing infrastructure wear and energy costs arising from rolling stock whilst retaining rolling stock crashworthiness and reducing rolling stock operating costs	Developing light weight trains which maintain crashworthiness	HIGH	✓✓	✓			✓		C	C	I	££	✓✓	HIGH	VERY HIGH	£££
	Refining and developing the wheel / rail interface including mechatronic bogies and running gear development	HIGH		✓			✓✓✓		C	I	S	££	✓✓			
	Next generation trains incorporating: – High strength lightweight materials – Energy recovery during braking – High efficiency traction drives – High efficiency thermal insulation – High efficiency heating and ventilation – High efficiency PIS & PA and associated appropriate maintenance facilities	HIGH	✓	✓			✓	✓	C	I	S	££	✓✓			
	Developing on train remote condition monitoring and instrumentation	MEDIUM		✓	✓	✓	✓		C	I	S	£££	✓✓✓			
	RCM, Health and Usage Monitoring Systems (see Infrastructure)	VERY HIGH				✓	✓✓	✓	C	I, S	I,S	£££	✓✓✓			
Modular train sub-systems for cost effective procurement and upgrade	Developing generation +1 of trains including: – Modular and standardised train equipment and systems – Systematically designed to optimise vehicle/ infrastructure interfaces and maximise railway system reliability	HIGH		✓			✓✓	✓	C	C, I	I, S	££	✓✓	LOW	HIGH	££

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Level of impact

LOW · MEDIUM · HIGH · VERY HIGH

Investment programme	Indicative projects	Benefits of project (large=high impact)	Where project would impact (each 'check' represents a quarter of the benefit)						State of development (C=Concept ready, I=Implementation ready, S=system ready)			CP5 cost (£1=<£1m, ££=£1m-£10m, £££=>£10m)	Confidence (✓✓✓=high)	CP5 benefit of portfolio (large spot=high impact)	CP6+ benefit of portfolio (large spot= high impact)	Proposed CP5 R&D investment (£1=<£1m, ££=£1m-£10m, £££=>£10m, ££££>£50m)
			Safety	Performance	Customer	Capacity	Cost efficiency	Sustainability	Now	CP5	CP6+					
Optimising station dwell time to maximise passenger boarding and alighting and minimise door opening / closing cycle time	Optimising and reducing dwell times, including: – auto-opening – level platforms and train floors – adequate stand-backs number of doors – position of doors – in service door failure management – train stopping position	HIGH	✓	✓	✓	✓			C	I, S	S	££	✓✓✓	HIGH	MEDIUM	££
Improving the capacity and performance of rolling stock to increase network capacity, reliability and performance	Speeding up freight and enhanced train utilisation	HIGH		✓	✓	✓✓			C	C	I	£	✓✓	HIGH	VERY HIGH	£££
	Developing high capacity crashworthy trains; and keeping trains from hitting one another including ETCS.	HIGH	✓✓		✓	✓			I	S	S	£	✓✓			
	Developing lightweight brake systems for trains	HIGH	✓	✓		✓	✓		C	I	S	£	✓			
	Right time arrival at points of conflict. Development of: – ERTMS – ATO – DAS	HIGH		✓	✓	✓	✓		C	I	S	££	✓✓✓			
	Developing a tactical approach to adhesion using existing technologies	MEDIUM	✓	✓		✓	✓		I	S	S	££	✓✓✓			
	Development of light rail whole system opportunity	HIGH			✓✓	✓	✓		C	I	S	££	✓✓			
	Improving reliability through: – train crew fault finding information via mobile technology – reduced train start up time – enhanced operational plans for train system failure – train design facilitating train system fault management	HIGH	✓	✓	✓		✓		C	C, I	I,S	£££	✓✓			

Enablers

Pages 75 to 88 describe our 'enablers' – the innovation process, the people and the collaborative approach by which we will achieve our objectives.

Enablers

Innovation process

This strategy focuses on the opportunities to exploit technical ideas to help achieve our strategic business outcomes and support our long-term business planning. Innovation is broader than the exploitation of technical ideas and is the process of generating all business improvement ideas and transforming those ideas into commercially successful products and systems. The ambition for our innovation process is to intelligently research, develop and apply technology, taking account of the whole railway system within which it is being introduced including the people and relationships that form part of the system.

Innovation – a challenging journey

We will achieve our ambitions for innovation in three main ways.

Managing research and development
Our innovation process will manage research and development (R&D) projects in response to the strategy outlined in this document. For some projects we will lead the R&D agenda. To do this we will put in place new management systems and processes to enable efficient and effective investment in, and delivery of, R&D projects and programmes. For other projects we will become an intelligent customer for R&D led by others from partners across the industry. Many of the programmes identified in this strategy include opportunities for projects led by suppliers. We will develop a market engagement strategy to understand where to target investment in R&D.

Collaborating across the industry and through the supply chain
We need to routinely collaborate across the rail industry sector and with other non-rail industry sectors to:

- Transfer technologies
- Combine efforts for mutual benefit
- Play our part, where appropriate, in strengthening the capability of the UK rail industry to supply international markets.

Other industry sectors have already demonstrated successful collaborations and there is much that we can learn from them. One of the keys to successful collaboration is Open Innovation, an idea well established in the mainstream where knowledge is shared and traded across and between organisations. The key benefits of Open Innovation are:

- Reducing the cost of technology acquisition by leveraging investment by others
- Improving the return on leveraging internal investment through exploitation with others
- Maximising the pool of technology and innovation from which to draw
- Increasing the flexibility and depth of the R&D and supply base.

We're drawing on Open Innovation principles to develop our emerging Product Strategy where we're already working with industry to identify an approach to product management interventions that achieves optimum whole life cycle management.

Connecting with wider business and cross-industry process
To successfully exploit technology, we also need to look to opportunities from changes to the regulatory and compliance environment, identifying and removing barriers to innovation without compromising safety. We expect our current reviews, including the simplification of standards and product acceptance, to deliver a significant impact. Our innovation process will keep under review the connections between technical opportunities and the wider business and cross-industry process.

Where are we now?

We are using a four stage challenge-driven framework to research, develop and apply technical solutions – as illustrated below.

We have introduced a range of mechanisms to support the success of innovation projects within this framework. These are already starting to deliver a return on investment in the form of the following:

- A seedcorn fund allocated to sub-£50,000 investments to support early exploration and testing to enable rapid failure or business case creation
- A portal on the Network Rail website for suppliers to post their capability in response to our innovation challenges
- Online tools to post and rate ideas to solve a challenge
- An innovation broker service to identify capability from other sectors to solve our challenges
- An internal innovation consultancy to systematically characterise problems, generate solutions and plan approaches to development and delivery.

Many of these were established before devolution of the business and are undergoing a process of review to realign with structural changes in the organisation. The return on investment achieved in CP4 with projects that utilise these early innovation support mechanisms indicates a benefits-to-cost ratio of 11:1. As the scale of activity increases, and as the portfolio expands to include a broader mix of projects, we expect this ratio to fall. Industry benchmarks suggest a long-term ratio of 5:1 is realistic.

We have now created a technical strategy and indicative plan that fits with the rail industry technical strategy. We have established a technical strategy and roadmapping team that will mature the processes to maintain and review the strategy, working closely with technical leads across Network Rail. We are working with the industry's technical leadership community to review the indicative plan and to define and initiate the first tranche of priority projects. We have also started to create a product strategy to ensure that the risks and rewards associated with technology research, development and application are appropriately managed through our supply chain.

We are connected with the industry through our role in, and contribution to, the Technical Strategy Leadership Group (TSLG). TSLG co-ordinates the development of cross-industry technology and innovation, and falls within the governance of the Rail Delivery Group (RDG) and the Rail Safety and Standards Board (RSSB). TSLG is supported by five System Interface Committees and a support group, and is steered by a Core Group.

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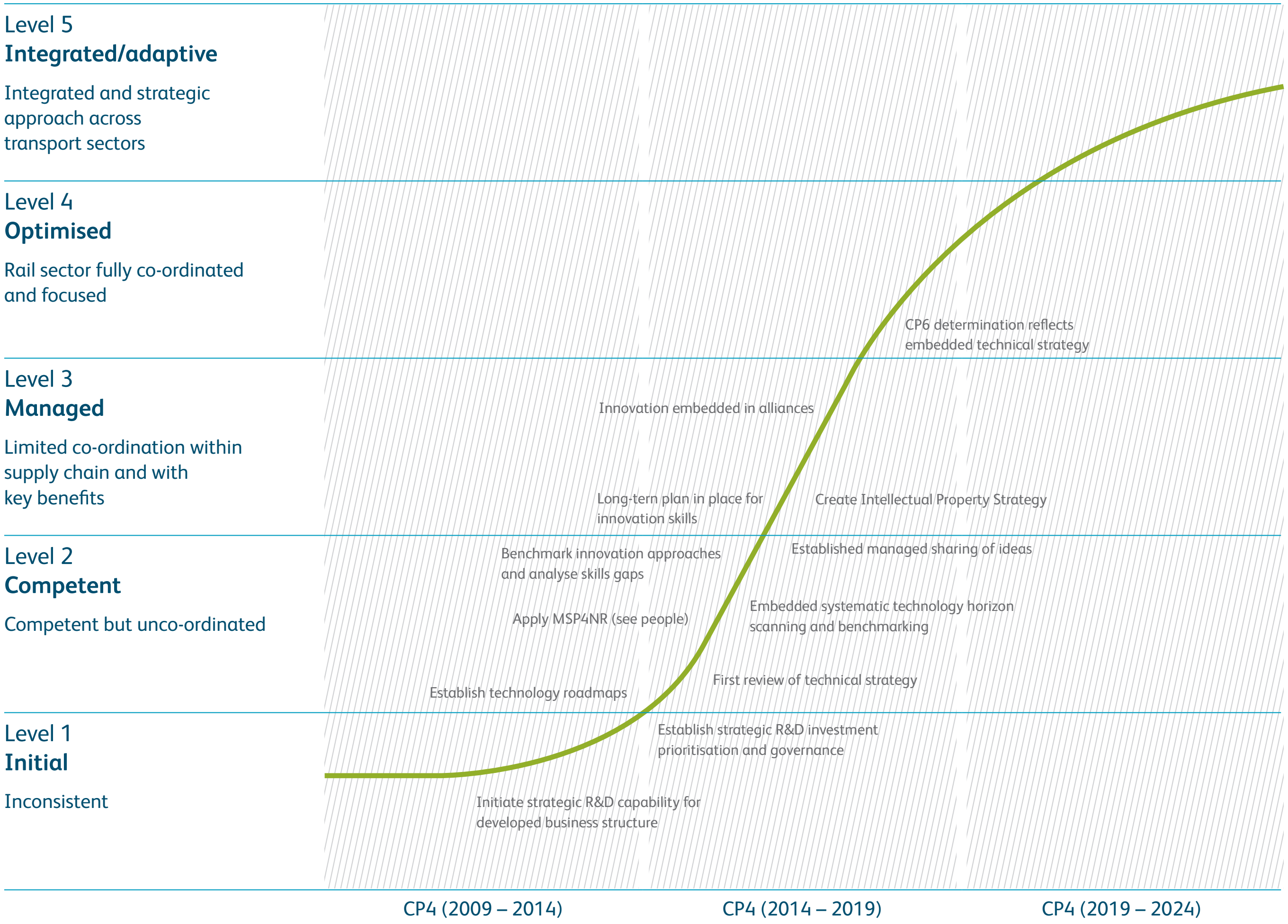
Maturing our innovation capability



The journey ahead

Having put this strategy in place, the journey ahead includes establishing processes to enable more engagement in innovation activities and to connect existing activities within a common framework. Key business processes are being put in place to effectively govern a strategic R&D investment programme. Historic under-investment in R&D combined with unprecedented opportunity means that we have a large pool of potential investments. Our priority is to press ahead with a mix of R&D, most of which will deliver high impacts in the short and medium term and some of which will deliver high impacts in the long term.

We recognise that we are part of an industry that is still at an early stage in maturing its innovation capability. So alongside urgent progress in stepping up the level of investment in, and delivery of, research and development, we need to invest to build our innovation capability.

Existing and potential methods for innovation will be considered and evaluated over time. Methods will be selected to meet our overall business needs and be introduced and aligned to serve our devolved business structure. We will continue our engagement with cross-industry innovation groups to identify best practices and to introduce approaches to a time frame that fits the rate at which we and other industry parties mature capability. Examples of current good practices used outside the rail industry include the use of incubators to develop and refine ideas and internal consultants to help us crystallise challenges and identify technologies that may lead to solutions.

On page 77, we indicate how we expect our innovation capability to develop over CP5, which is in line with the ambitions set out in the industry RTS. The new management systems and processes we plan to put in place to enable efficient and effective investment in, and delivery of, R&D projects and programmes fall under the following three headings.

Developing our innovation capability
Our innovation capability will include.

- **Utilising strategy** – assessing market and technology trends in order to target areas for innovation, to direct resources, to measure overall performance and to articulate business constraints. A key early step is to establish technology roadmaps. These will capture current R&D and set out the paths and dependencies to research, develop and implement new technologies.
- **Prioritisation and governance** – efficiently managing investment into portfolios, programmes and projects to support short and longer term outcomes including the definition and optimisation of investment criteria. A key early step is to establish an investment process attuned to the risk profile of R&D activity with appropriate scorecards, benefits estimation and measurement criteria.
- **Generating and managing ideas** – putting in place creative and collaborative environments to establish innovation needs and opportunities. A key early step is to build on our early use of a technology broker service to aid early-stage investigation of ideas and problems, to shape or undertake initial investigation work and to embed systematic horizon scanning for technology opportunities.
- **Taking ideas to concept readiness and implementation readiness** – quickly and efficiently developing solutions using cross-functional, cross-industry collaborative teams, prototyping, testing and Open Innovation to measure and optimise delivery. A key early step here is to benchmark innovation approaches to enable the introduction of a suite of suitable capabilities and working methods.
- **Nurturing people** – creating enabling organisational structures, job designs and hiring and training policies alongside a company culture of constant innovation. A key early step will be to analyse skills gaps in response to technology roadmapping and to work with industry to ensure we nurture the right skills available for the industry as a whole.

Process for technology development and project management
Our Governing Rail Investment Projects (GRIP) process is not ideally suited to managing technology development. Our preliminary design of a more appropriate process for technology development is based on methods used in the automotive sector. It considers the development of technology to have three key stages, broadly correlating with Technology Readiness Levels (TRLs).

- **TRL 1 to 3**. The technology moves on from initial scientific observations to demonstrating the capability of separate elements of the technology in isolation. Once this is complete, a technology is considered to be “concept ready[1]” in that the potential to deliver the basic functionality has been demonstrated. This may be undertaken as sole or collaborative research, carried out in universities, research technology organisations or company labs.
- **TRL 4 to 7**. The technology is advanced through increasingly costly stages of integration, testing, validation and refinement, leading to a first full prototype demonstrated in a real operating environment. At this point, a technology is considered “implementation ready” in that it can then be subjected to trial on the network and so start to be brought under the GRIP process.
- **TRL 8 to 9**. GRIP can start to be applied to implement the new technology, although further development and optimisation are needed to achieve “System Readiness” at which point it can be implemented as a standard solution on the network.

The TRL process will be used in conjunction with Managing Successful Programmes for Network Rail (MSP4NR) (see People).

1 D.H. Stamatis, Six Sigma and Beyond: Design for Six Sigma

Driving simulation

Process for prioritisation, investment and portfolio management

We will implement a stage-gated investment process to enable resources to be allocated over the full innovation cycle from identifying a challenge to implementing newly developed systems. This will include investing in the early-stage scoping and investigation activities needed to build the business case for full investment. The process will be collaborative with industry, with risks being shared and co-investment being sought appropriate to the opportunities with each business case. The process will be developed to allow efficient handling of a diversity of types of research and development projects – taking into account, for example:

- That longer-term R&D is by nature higher risk than short-term R&D and is likely to have less well defined benefits and route to market.
- That there is likely to be substantial variation in the risks and opportunities attached to short-term R&D and that projects should therefore be selected on a range of criteria.

We expect up to a fifth of our R&D investment to be targeted at long-term strategic research and development. This investment will predominantly be looking to achieve concept readiness for solutions that offer step changes and game changes to the way we achieve our strategic outcomes.

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People

The capability of people is central to our move to a more technology and innovation enabled railway, allowing us to shorten development cycles and rapidly deploy the best available technologies. To secure and maintain the right level and capability of people in the right environment, we need talent to deliver the immediate and ongoing changes, skills to operate in the new innovation environment and cultural change to enable high-performance innovation. A clear talent proposition and resourcing strategy forms part of our people outcome, set out in our SBP, to fulfil our long-term requirements.

Skills and capabilities

With our devolved organisation in place, we will refine our organisational structure and the design of roles to include new and strengthened skills for innovation. We will develop and acquire the skills we need through a clearly defined and communicated talent proposition and resourcing strategy. A key early step to achieve this will be to undertake a skills analysis against the emerging technology roadmaps and innovation benchmarking to identify skills gaps.

We will increasingly need to engage and collaborate with the rail industry and other sectors and respond to change effectively and quickly. Examples of areas where we expect to build our capability to support these changes are:

- Design thinking and managing innovation
- Managing intellectual property
- Collaborative development and Open Innovation to support innovation life cycles which in some areas of technology will be less than one year
- Managing new complexities from the rapid change and ambiguity associated with R&D projects
- Sourcing the optimum delivery route and resources
- Project management for research (TRLs 1-4), development (TRLs 4-7), demonstration and system readiness for implementation (TRLs 7-9).

Innovations will also have an impact on people who deploy, operate and maintain the network including the devolved routes and supply chain. New capabilities and skills will be required to exploit the full benefit from new technical capabilities, improving safety and performance. A key example being the area of cyber security.

We have recently developed a tool for use with all types of programmes called Managing Successful Programmes for Network Rail (MSP4NR). This blends our programme management methodology, Managing Successful Programmes (MSP), with a change management methodology, People Centred Implementation (PCI). MSP provides the framework for effective control and governance to support the delivery of programmes. PCI provides change management tools to support the successful implementation and adoption of the change. MSP4NR ensures we are properly positioned to exploit and embed the change, increasing the likelihood of realising benefits.

Our innovation process will make use of the MSP4NR process and toolset in conjunction with the TRL process to manage technology development and implementation to ensure it is fully accepted and effectively embedded by users within and outside Network Rail.

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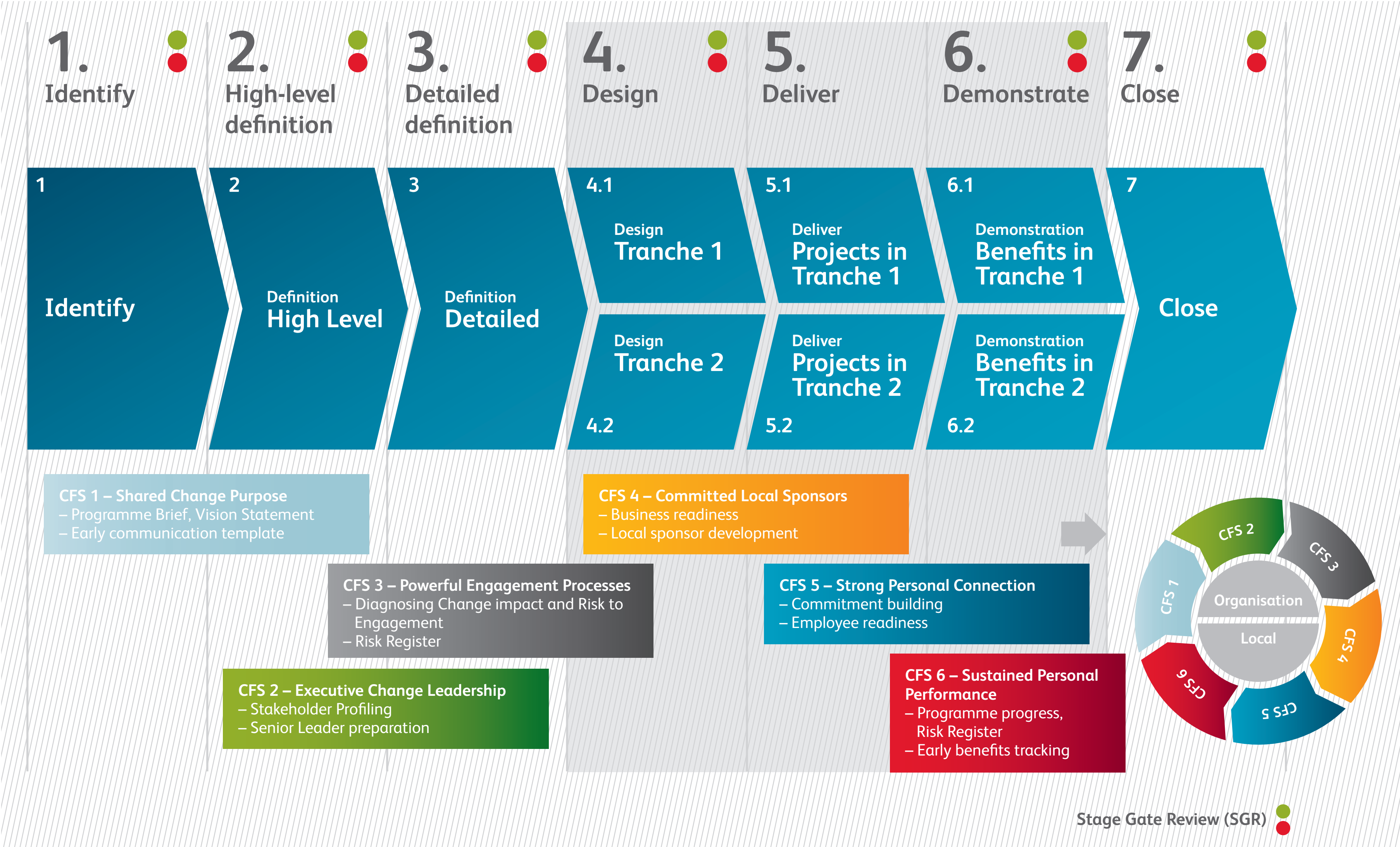
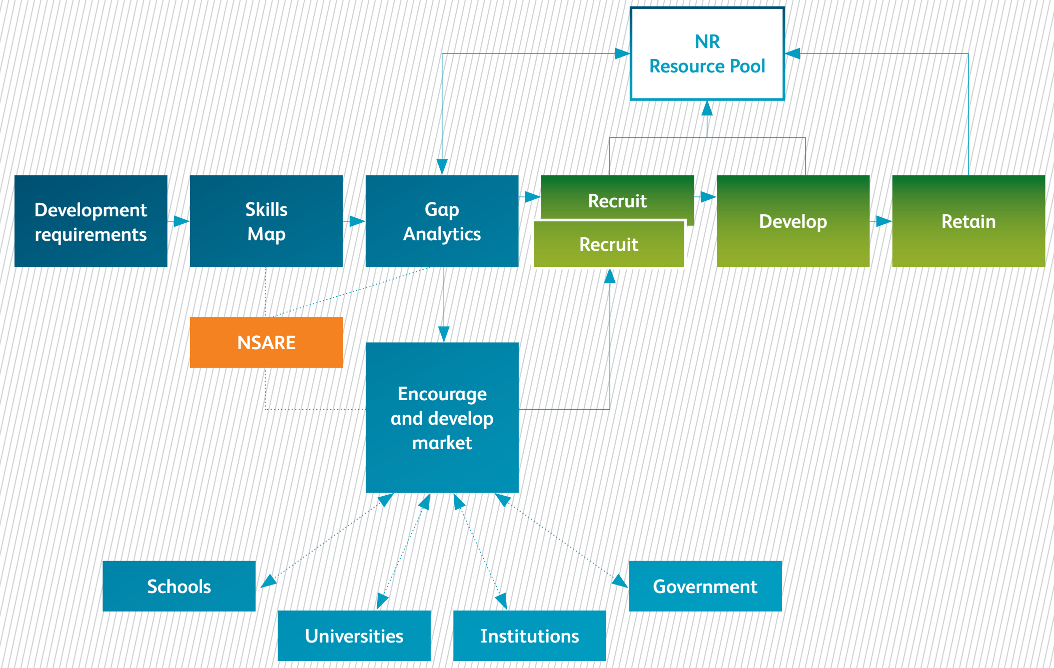
Managing Successful Programmes for Network Rail (MSP4NR)



Recruiting, developing and retaining people



Recruiting, developing and retaining people

We will recruit, develop and retain people to meet current and future technical needs. Having defined the specific requirements, we will map skills for the capability to deliver steady state railway operation and to support innovative change. Having defined the capabilities, we will analyse gaps against our resource pool.

We anticipate a challenge to secure the calibre and quantity of people needed both to drive the innovation process and to deliver the benefits. Such resources will be needed throughout the supply chain, including within the universities and companies that may provide external support to the innovation process.

We are already pursuing a proactive process to encourage and develop the resources market. Initiatives under development include:

- Liaison with schools, academies and university technical colleges (UTCs) to:
  - promote awareness of the railway industry as a future employer
  - start the process of developing the necessary skills
  - exploit the opportunities for education and training through vocational curriculums focused on one or more engineering disciplines
  - Partnerships with university departments
  - contributing to the curriculum in return for offering a path into employment in the railway industry for the right candidates
  - establishing MSc courses in asset management to build international excellence.
- Supporting a track and train graduate programme.
- Contributing to cross-industry collaboration for the EPSRC Centres for Doctoral Training.
- Working with the professional institutions to ensure the priorities of the railway industry are reflected in their professional qualifications and standards.
- Influencing government policy to deliver support to a development and training agenda.

The linkage between skill requirements and developing labour supply is already supported by the National Skills Academy for Railway Engineering (NSARE). Clearly this element of our resourcing programme needs to link closely with, or utilise, NSARE as a mechanism for developing the supply of the required resources and capabilities. We are committed to creating a more open, diverse and inclusive organisation that is a great place to work and we will work with the wider industry to promote the rail sector as a whole as a great place to work.

We expect the outcome to be a climate that attracts high quality people to the railway industry, develops and retains them and supports recruitment to the level required. Recruitment should include a structured process that recognises the need for technical and professional development as well as management development.

Enablers

Collaboration

To drive up the level of innovation and successfully implement new technologies, we need to routinely collaborate within Network Rail and with others from across the rail industry and other industry sectors such as automotive, telecommunications and space. This section presents two case studies where collaboration has been key to success and shows how we are already innovating to apply different technologies to create a better railway. That said, we need to work together to develop and apply more innovative technology solutions at a faster rate and to bring them into use to reap the benefits. This section also summarises our collaborative R&D.

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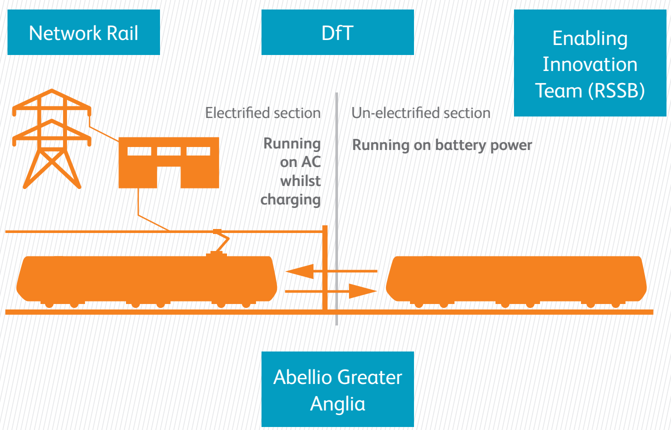
Participants in the IPEMU project



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Case study 1

Demonstration of a battery powered train – the Independently Powered Electric Multiple Unit (IPEMU)

Our electrification strategy, set out in the 2009 Network Route Utilisation Strategy (RUS), is looking for greater use of electric traction as an efficient form of energy that can reduce emissions. To achieve this in a cost-effective way, our strategy demands new solutions to supplement conventional continuous overhead electrification. A key contender, as proposed in our shortly to be published Alternative Solutions RUS, is to store energy on trains. If we can create an energy-storage capability for trains, electric traction can be made more affordable by optimising electricity supply and storage as part of an integrated system.

Energy-storage technologies exist and the automotive industry has delivered hybrid and electric production models for cars and buses. Battery technologies are rapidly developing and the UK is at the forefront in this field. But there is a big leap from designing batteries with theoretically sufficient energy characteristics to committing parts of the future railway to reliance on battery storage in order to function.

The IPEMU project took up the challenge to show that passenger service operation could be achieved using battery power. While modelling, testing and trialling could all be undertaken away from normal service operation, the battery-powered train has ultimately to be shown to operate a real service. That requires the collaboration of train operator, train owner, infrastructure manager, funders and the Government as the franchising authority.

Collaboration requires all the parties to understand how they can derive benefit from participating. And to keep the collaboration working, each party needs to clearly understand what the others are expecting to achieve, how risks and rewards are shared and how the project will be governed.

The parties initially developed a Memorandum of Understanding (MOU), setting out expectations and success criteria for every stage of the project. This was subsequently developed into a set of contractual binding agreements. The steering group will provide collaborative cross-industry leadership and governance as the IPEMU project moves forward.

The view of the participants

Abellio as the train operator entered into this venture to support innovation in the rail industry.

The quotes below from some of those participating express what they hope to get from the project.

"Electrification provides a wide range of environmental and operational benefits. Electric trains are generally cheaper to buy, operate and maintain than diesels as well as being cleaner, quieter and lower carbon. But electrification is expensive to do, so DfT is interested in alternative approaches such as energy storage that can deliver similar benefits at lower cost. We are contributing to the project through our funding of the Enabling Innovation Team and through our management of the Greater Anglia franchise where the IPEMU will be trialled in passenger service."
Mark Gaynor, DfT

"Energy-storage on trains is a typical example of a development that's good for passengers, taxpayers and the long-term future of the railway, but where it is difficult for individual businesses to make the business case to invest in the technology. To help prove the business case and enable this innovation, we are funding up to 30 per cent of the technology demonstration. We see the IPEMU project as a good example of something that will work according to the R&D but no one will invest in without seeing a full scale demonstrator. By supporting this programme we are helping to take innovation out of the lab and de-risk its potential introduction on to the railway."
David Clarke, Enabling Innovation Team, RSSB

"As the principal funder and delivery manager for the IPEMU, we have the largest stake in the project's success and, in turn, the primary responsibility to build confidence with the cross-industry team. To achieve that, prior to initiating the project, we invested in feasibility work to identify and sift the technologies and to examine areas where parties were known to have concerns. We see the IPEMU project as vital to develop industry capability so that we can progress our strategy of sustainability from more widespread electrification while reducing the burden on the taxpayer."
Richard Eccles, Network Rail

The IPEMU project is set to take energy-storage on trains to Technology Readiness Level 7, demonstrating that the technology can successfully operate with acceptable performance and reliability. The cross-industry team will be working together to build confidence for the further investment that will be required to take this solution to full implementation.

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Our Intelligent Infrastructure programme is a clever mix of technology, business processes and information systems that makes it possible to detect and fix emerging faults on the railway infrastructure before a failure occurs.

Case study 2

Intelligent Infrastructure programme

Intelligent Infrastructure is our transformation programme for Remote Condition Monitoring (RCM) of rail infrastructure. Here we see how collaboration between our staff, coupled with RCM technology, delivers benefits in performance and long-term asset management.

Our Intelligent Infrastructure programme is a clever mix of technology, business processes and information systems that makes it possible to detect and fix emerging faults on the railway infrastructure before a failure occurs. The programme involves the extensive application of Remote Condition Monitoring (RCM) technology to key assets including points, track circuits (which provide train detection in the signalling system), signalling power supplies and points heating.

During normal operation, the system monitors certain parameters of the asset that can be used to indicate a deterioration in its function. In such an event, the Intelligent Infrastructure system generates alarms which trigger a response process to correct the fault before a failure occurs and affects the service. For example, the system measures patterns of electrical current flow through point operating equipment as well as the time taken to move the points. This provides an indication of the onset of a number of different failure modes including back drive adjustment or worn motor brushes.

To manage the business process that goes with the Intelligent Infrastructure system, we have implemented the role of Intelligent Infrastructure Manager, the so-called "flight engineer". These experienced technicians are located in each of Network Rail's routes and monitor the system around the clock, leading the appropriate response to alarms and alerts.

One of the key success factors of the system has been the collaboration of Route Control and Technical staff. The flight engineers are co-located in the Route Control centres and, by working together with Control staff, are jointly able to agree on the best course of action when an alarm is raised, ultimately providing the best outcome for our customers – train operating companies and rail passengers.

The importance of the process should not be underestimated. Business Process Re-engineering coupled with effective Change Management strategies is absolutely essential in a successful deployment. This is particularly the case in the rail industry where geography, numbers of people and organisation structures tend to be large and complex.

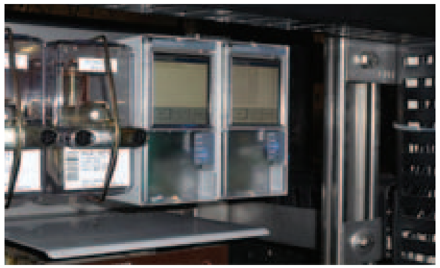
Collaboration in action

Giles Baxtor, Operations Manager, Wessex explains how collaborative working between Route Control, Maintenance and signalling staff in the Wessex Route prevented a significant incident.

"At 16:22, the Wessex Integrated Control Centre received an alarm from RCM equipment on clamp lock 513 points at Northern Junction. The flight engineer's analysis of the current trace indicated the point motor was taking longer than expected to move the points. Failure seemed imminent. This would completely block the line to passenger and freight trains travelling towards Southampton from London, with a potential delay of up to 45 minutes.

Control staff immediately asked the Eastleigh Maintenance S&T response team to attend the site, then told the signaller to avoid moving the points. The response team arrived at the points at 16:45, diagnosed a tight lock and fixed the problem in 15 minutes. As a result, no trains delayed and hundreds of passengers were not inconvenienced at the start of the weekend."

Giles Baxtor, Operations Manager, Wessex



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Collaborative R&D

We participate in European and UK based projects with government, academic and industrial partners, in particular including members of the TSLG (see glossary). This allows us to share best practice and innovations and share the costs and benefits of research. These projects support a wide range of research topics including

- Future infrastructure systems
- Maintenance improvements to reduce costs and increase capacity through lean processes and novel condition monitoring methods,
- Maintenance, renewal and improvement of rail infrastructure via improved degradation models and mitigation methods for life extension of infrastructure.
- Improved capacity and utilisation through improved traffic management.
- Long range ultrasonic method for the detection of rail foot faults. Continuous monitoring system for use in high risk corrosion sites.
- Eddy current brake compatibility
- Sustainable and intelligent management of energy via an integrated management system to optimise energy use.
- Opportunities to enhance competitiveness of transport by rail in unexploited markets.
- Cross-accepted certification for Electro Magnetic Compatibility of rolling stock across Europe
- Autonomous Intelligent Systems.

We also contributed to the development of the European Rail Research Advisory Council (ERRAC) roadmaps which will feed into the European Union funded Horizon 2020 programme which will provide circa €8 billion to transport research from 2014 to 2020.

Complementing the extensive research being undertaken in collaborative ventures both in the UK and in Europe, we also have four Strategic University Partnerships (see glossary).

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Next steps

While the NRTS is pulled by long-term vision, our primary focus for this first iteration is to frame investments for our business planning and, where appropriate, the regulatory plans for CP5. Alongside the identification and initiation of R&D investment projects and programmes, a pressing challenge is to establish and embed the innovation process to increase the pace and quantity of new and improved products and systems and to create a strong connection between R&D and its application to investments.

At this stage we are establishing early investment priorities, principally at the level of programmes. From these programmes, projects will be prioritised and defined and detailed requirements will be developed taking into account knowledge from existing R&D projects across the rail industry and Europe. We will work with industry partners to identify the most appropriate lead and delivery mechanism for each project.

A process of regular strategic and programme review will be established. Further information will be published in due course. The first strategic review will be undertaken in 2014. It will take into account the conclusions from an industry study examining current and future capabilities and their sourcing and development; commercial approaches identified and recommended through our product strategy; and progress with detailed technology roadmapping.

"We look forward to continuing to work closely with our partners, suppliers, academics and other stakeholders from across the rail industry to implement this strategy."

Richard Parry-Jones
Chairman

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A

AC Alternating Current

ATO Automatic Train Operation

ATOC Association of Train Operating Companies

ATP Automatic Train Protection. ATP systems ensure trains do not exceed their permitted movement authority by continuously monitoring their trajectory against a run-profile calculated to ensure they stop at a defined point. ATP systems may operate in conjunction with, or without, lineside signals. ERTMS (ETCS) is an ATP system which uses standard protocols for track to train communication.

B

BT British Telecommunications

C

CCC Change Control and Communication

CCTV Closed Circuit Television

COMPASS COMbined Position Alternative Signalling System. The concept of combining a number of low integrity systems to provide precise train location. These systems exploit a layered architecture from independent equipments located on the track, track / train and train borne which allow a 'Tactical Picture' to be generated in real time. This gives a trains speed, location and direction of travel which is delivered to a control centre.

CP Control Period

CR Concept Ready

D

DAS Driver Advisory System. Providing train drivers with information to allow them to optimise fuel efficiency, arrival time and other parameters. Standalone DAS (S-DAS) relies on the train comparing its progress with route and timetable information held within the system. Connected DAS (C-DAS) may update the system's knowledge and improve its decision making capability by providing real-time information such operational parameters or signal aspect information.

DC Direct Current

DCIS Darwin Customer Information Systems programme

Defra Department for Environment, Food and Rural Affairs

DfT Department for Transport

DOO Driver Only Operation

E

EC4T Electric Current for Traction

ECML East Coast Main Line

ECR Electrical Control Room

EMU Electric Multiple Unit

EPSRC Engineering and Physical Sciences Research Council

ERRAC European Rail Research Advisory Council

ERTMS European Railway Traffic Management System

ETCS European Train Control System

F

FOC Freight Operating Company

FTN Fixed Telecommunications Network

FTNx Fixed Telecommunications Network Next Generation Programme

FuTRO Future Traffic Regulation Optimisation. A programme to identify technologies to control the future integrated railway based on the global direction of research and obsolescence of materials and technology, including elements which will cease to be available or useful to the railway industry. This reflects the next generation of traffic management technologies beyond installations under the current operating strategy and therefore embodies sustainability as one of its core principles. The programme looks at migration strategies from today's technologies to future technologies including quick wins. The programme aims to introduce new suppliers to the rail market sector and to leverage benefit from technologies proposed for other sectors to avoid rail bearing the full research and development costs of new technology.

G

GB Great Britain

GIS Geographical Information System

GPRS Global Positioning Railway Satellite

GPS Global Positioning Satellite

GRIP Governance for Railway Investment Projects

GSM Global Satellite Monitoring

GSM-R Global Satellite Monitoring for Rail

GWML Great Western Main Line

H

HR Human Resources

HMI human machine interface

HUMS Health Usage and Monitoring System

I

ICC Infrastructure Control Centre

IM Information Management

IP Infrastructure Projects

IPEMU Independently Powered Electric Multiple Unit

IPR Intellectual Property Right

IR Implementation Ready

IT Information Technology

K

KPI Key Performance Indicator

L

LED Light Emitting Diode

LTPP Long Term Planning Process

M

Mechatronics A multidisciplinary field of engineering that integrates mechanics, electronics, control theory and computer science in order to improve functionality of a system.

MCB-OD Manually Controlled Barrier – Obstacle Detection. System for level crossings that use radar and laser technology to scan the crossing area to ensure it is clear before allowing trains to pass. This is the functional equivalent of a signaller viewing the crossing on a CCTV screen and operating a crossing clear button.

MIKE2.0 Method for an Integrated Knowledge Environment. MIKE provides a delivery framework that can be used to develop an industry wide information strategy. It is then used to drive efforts such as building and managing effective Information Technology solutions to meet new challenges, organisational change and improve information processes around compliance, policies, practices and measurement.

MODTRAIN. European research programme for modular train equipment.

MSP4NR Managing Successful Programmes for Network Rail

N

NDS National Delivery Service

NFRIP National Fleet Reliability programme

NOC Network Operating Centre

NR Network Rail

NRIS Network Rail Information System

NRT Network Rail Telecommunications

NRTS Network Rail Technical Strategy

NRUS Network Route Utilisation Strategy. Part of the Long Term Planning Process and considers issues which potentially affect the entire rail network of Great Britain. Its network wide perspective is supported by a stakeholder group with wide expertise which enables the development of a consistent approach on a number of key strategic issues which underpin the future development of the network.

NRUS: Alternative Solutions. Alternative solutions to accommodate future rail passenger demand cost effectively. The geographic scope relates to those services which are regional commuter, regional and rural passenger services rather than long distance high speed, London and South East or inter-regional.

NSARE The National Skills Academy for Railway Engineering

O

OLE Overhead Line Equipment/Electrification

ON-TIME European project to improve capacity and railway utilisation through improved traffic management systems

ORBIS Offering Rail Better Information Services

An asset information-led programme that enables improvements in railway efficiency, safety and capacity by changing the way in which we collect, store and utilise asset information

ORR Office of Rail Regulation

OSS Operating Support System

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P

PA Public Announcement

PCI People Centred Implementation

PIS Passenger Information System

PLPR Plain Line Pattern Recognition. PLPR replaces Basic Visual Inspection with a train borne method of inspection that captures images of track assets and identifies associated defects.

R

R&D Research and Development

RCF Rolling contract fatigue

RCM Remote Condition Monitoring

RDG Rail Delivery Group

ReFocus Reliability Focus Group hosted by ATOC. Formerly the National Fleet Reliability Improvement Programme

RFID Radio Frequency Identification

RIDC Rail Innovation and Development Centre

ROC Rail Operating Centre

RSSB Rail Safety and Standards Board

RTS Rail Technical Strategy

RUS Route Utilisation Strategy

S

S&T Signalling and telecommunications

SBP Strategic Business Plan

SCADA Supervisory Control And Data Acquisition. SCADA systems remotely monitor and control electrical power transmission and distribution equipment.

Shift²Rail A joint technology initiative for european rail industry to collaborate to make rail transport more attractive to, and have the capacity to accommodate, passenger and freight users.

SIC System Interface Committees

SPECTRUM. European project to enhance competitiveness of transport by rail in unexploited markets to improve the viability of rail freight

SUSTRAIL. European project to make rolling stock less damaging to infrastructure and infrastructure more resilient

T

Thameslink project A £6 billion programme which offers more trains and better journeys for passengers on the Thameslink route stretching from Bedford to Brighton.

TOC Train Operating Company

TM Traffic Management

TRL Technology Readiness Level

TSB Technology Strategy Board

TSLG Technical Strategy Leadership Group, with members including ORR, DfT, Transport for Scotland, RSSB, ATOC, RIA, TOC, FOC, RoSCo, rolling stock manufacturers, TSB, RRUKA, TfL, London Underground, Crossrail, HS2 and Network Rail.

U

UTC University Technical College

UOMS Unattended Overhead Measurement System is a vehicle mounted overhead monitoring system that can identify defects associated with interface between overhead wire and the pantograph.

V

Voice Strategy Programme is a wide-ranging programme to update, simplify and reduce costs associated with Network Rail's complex telecoms network as well as the cost of third-party elements that deliver a dialled voice network.

Network Rail Limited
Kings Place
90 York Way
London N1 9AG

Tel: 020 3356 9595

www.networkrail.co.uk