Network Rail Buildings and Architecture

Built Environment Technology Roadmap

Contents

Section A

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ACRONYMS

AI	Artificial Intelligence
B&A	Buildings and Architecture
BIM	Building Information Monitoring
CCTV	Closed Circuit Television
CP	Control Period
CRM	Customer Relationship Management
DOS	Disk Operating System
EDP	Environmental Produce Declaration
FMECA	Failure Mode, Effects & Criticality Analysis
GIS	Geographic Information System
HVAC	Heating, Ventilation and Air Conditioning
ICE	Inventory of Carbon and Energy
IoT	Internet of things
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
LIDAR	Light Detection and Ranging
ML	Machine Learning
NDT	Non-Destructive Testing
NR	Network Rail
OPAS	Operational Property Asset System
ROC	Rail Operating Centre
SME	Small and Medium Enterprises
UK	United Kingdom

Introduction

Introduction

Our vision for the future built environment is one that is inclusive and exceeds the expectations of our passengers, customers, freight users and the local community. As well as delivering against our pledge to users and our local communities, we must also respond to the serious challenge of climate change. We want to deliver societies expectations for a sustainable future. We are responsible for one of the biggest building portfolios in the country. By implementing a world leading approach to managing our built environment, we strive to set an example for other industries for how assets can be maintained. We don't need to hope that future technology will solve the problems of today, this roadmap argues that the technology we require is available now. Our challenge is to coordinate our efforts to create a new business as usual, and this document provides a roadmap to do just that.

"Recent changes in the climate are widespread, rapid and intensifying, and unprecedented in thousands of years."

IPCC, 2021

This document introduces our technology roadmap for the built environment and will achieve the following:

- It provides the supporting rationale for the roadmap, showing how it is informed by existing strategies and objectives.
- It promotes the benefits of harmonising technology plans between operational and commercial buildings that we currently manage separately.
- It outlines a scope of purpose which goes beyond the investment in technological initiatives.

This wider scope places those responsible for the built environment into a position to influence the wider technology discussion and facilitate the early adoption of technology where the built environment provides a platform for doing so. Scope also needs to expand to establish and maintain a proactive dialogue with digital and technology communities internal and external to Network Rail as well as the community of users including customers, passengers, operations, and other key stakeholders.

Introduction

1.1

1.1 Strategic alignment

Those of us managing the built environment have previously published several strategic documents, and this roadmap acts as a central focal point by demonstrating how technology initiatives will enable outcomes and benefits that help to achieve the objectives of these strategies. The key objectives of the existing strategies are to promote and embed a Design and Asset Engineering approach for the railway built environment that improves the satisfaction and safety of passengers, freight users and the local community, and the stewardship and the sustainability of the built environment.

- **Stewardship** is about ensuring asset reliability and functionality do not fall below present standards. This also includes the impact of, say, climate change on resilience and reliability, which is covered under Sustainability. Flooding and long-term drought is likely to have a significant impact on the stewardship of assets in the future.
- **Safety** builds on positive stewardship with consideration of wider mental and physical health factors for passengers and staff. (For example, inadequate working environments for staff makes the network vulnerable and increases stressors or risk of injury, which has a knock-on effect on all users).
- **Satisfaction** builds on proper safety and is about generating loyalty and strengthening rail's role in the future by making rail travel desirable, convenient, and sustainable.
- **Sustainability** is about meeting the economic, environmental and social needs of the present without compromising the ability of future generations to meet their own needs.
- Optimise the **contribution from property assets** to fund the railway whilst enhancing the experience of our customers, neighbours and rail users and protecting the integrity of the operational railway by:
  - Using our property knowledge and expertise in partnership with the routes to improve experiences for passengers, reduce costs for the sector, secure new sources of funding and generating thriving areas and opportunities for businesses and communities.
  - Generating income to reinvest and create a better railway for a better Britain.
  - Helping to fund Network Rail's Railway Upgrade Plan by selling non-core operational assets.
  - Releasing land for housing to achieve government targets.
  - Satisfying our customers by putting them at the heart of everything we do.

While the existing strategies, taken together, provide the basis for the technology roadmap, we have identified certain areas which require an additional push to accelerate progress. These areas include:

- Improvements in safety for people using public spaces we manage.
- Elimination of gaps in building maintenance responsibilities where these responsibilities are held by more than one party.
- Minimisation of unplanned service disruption caused by failures of the built environment.
- Provision of better information to the travelling public about their travel options to enable them to update their journeys in real-time to avoid disruption and otherwise better meet their needs.
- The deployment of staff to better meet customer expectations.
- Increasing railway ridership and revenue.
- A clearer path to achieve net-zero carbon targets and objectives for air quality, biodiversity and climate resilience.
- Improving the satisfaction of building tenants and their customers.
- The realisation of greater community and socio-economic benefits from the built environment.

Introduction

1.2

1.2 An overview of our built environment

Operational and commercial buildings are currently managed separately within Network Rail. The Technical Authority for operational buildings is the Buildings and Architecture group and commercial properties are managed by Group Property. Building asset types can be categorised as operational, commercial, and 'adjacent' as follows:

Operational buildings including 2,500 stations, 20 'managed stations' and 16,000 other operational buildings including:

- Non-public occupied by Network Rail staff and third parties.
- ROCs, training centres.
- Maintenance depots building.
- Train maintenance depots building.
- Route services depots building.
- Track side equipment buildings.

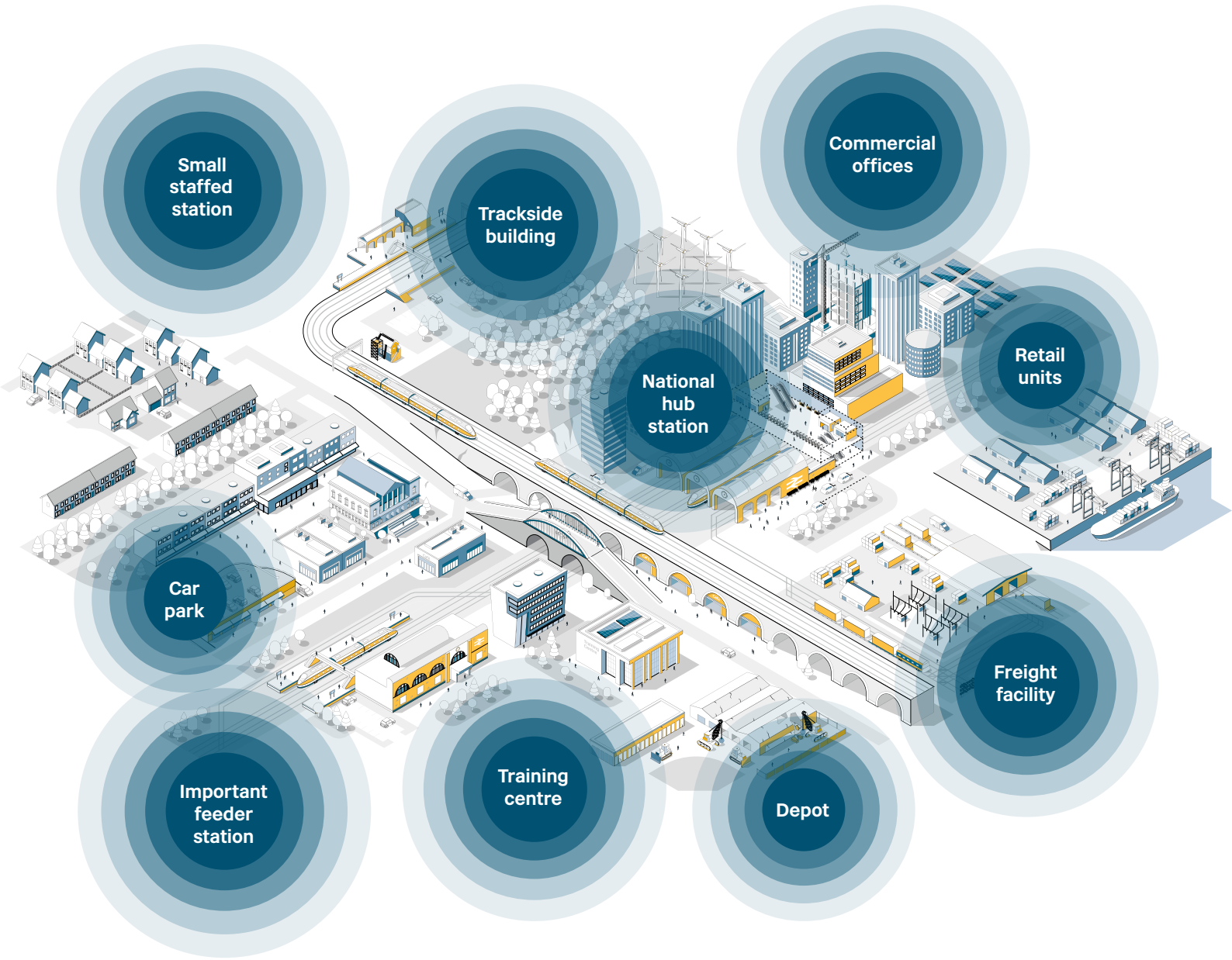
Commercial buildings of which there are 1,700 arches and 2,000 other commercial buildings including:

- Retail units.
- Managed workplaces.
- Freight facilities.
- Car parks and plots of land.
- Commercial assets (offices).

There also exist many spaces and buildings adjacent to the operational railway such as the 5,200 railway arches. While these are not directly managed by Network Rail, they represent a potential risk to railway safety and operations.

Introduction

1.2



Introduction

1.3

1.3 Scope and purpose

The purpose of this technology roadmap is to:

- Set the trajectory for research and development investment for the next 25 to 30 years.
- Present the near-term technology investment opportunities that align with our emerging harmonised asset strategy for the built environment.
- Map out a timeline that optimises technology research, development and implementation.
- Identify key enablers to position our built environment decision makers to be better informed and more influential in selecting technology solutions.

London Bridge © Network Rail

Introduction

1.4

1.4 Blockers to Innovation

The Network Rail Infrastructure Monitoring Strategy (25 Sep 2020) identifies several blockers to innovation that are relevant to this technology roadmap. Our ability to bring innovation to infrastructure monitoring is slowed by several factors. By addressing these we can accelerate the adoption of innovation and the benefit it brings:

- The pace of product approval from a supplier perspective can extend the time between innovation and commercial return, making the investment risky for small innovative firms.
- Standards that specify technology choices rather than outcomes lock us into methods that could be done better with new technology if we can prove that the new method is better and safer than the old.
- Current standards for exploiting new technology focus on the business case impacts of the change but say nothing about how to facilitate technology change.
- Reliance on third party technology (IP lock-in) is created inadvertently by non-sustainable procurement strategies that result in too few suppliers providing (new) technology.
- Technology enabled solutions often have complex interdependencies between elements. These can sometimes be missed due to gaps between project scopes. More attention to systems thinking to manage these complex interdependencies is needed.

Birmingham New Street Station © Network Rail

Introduction

1.5

1.5 Achieving predict and prevent

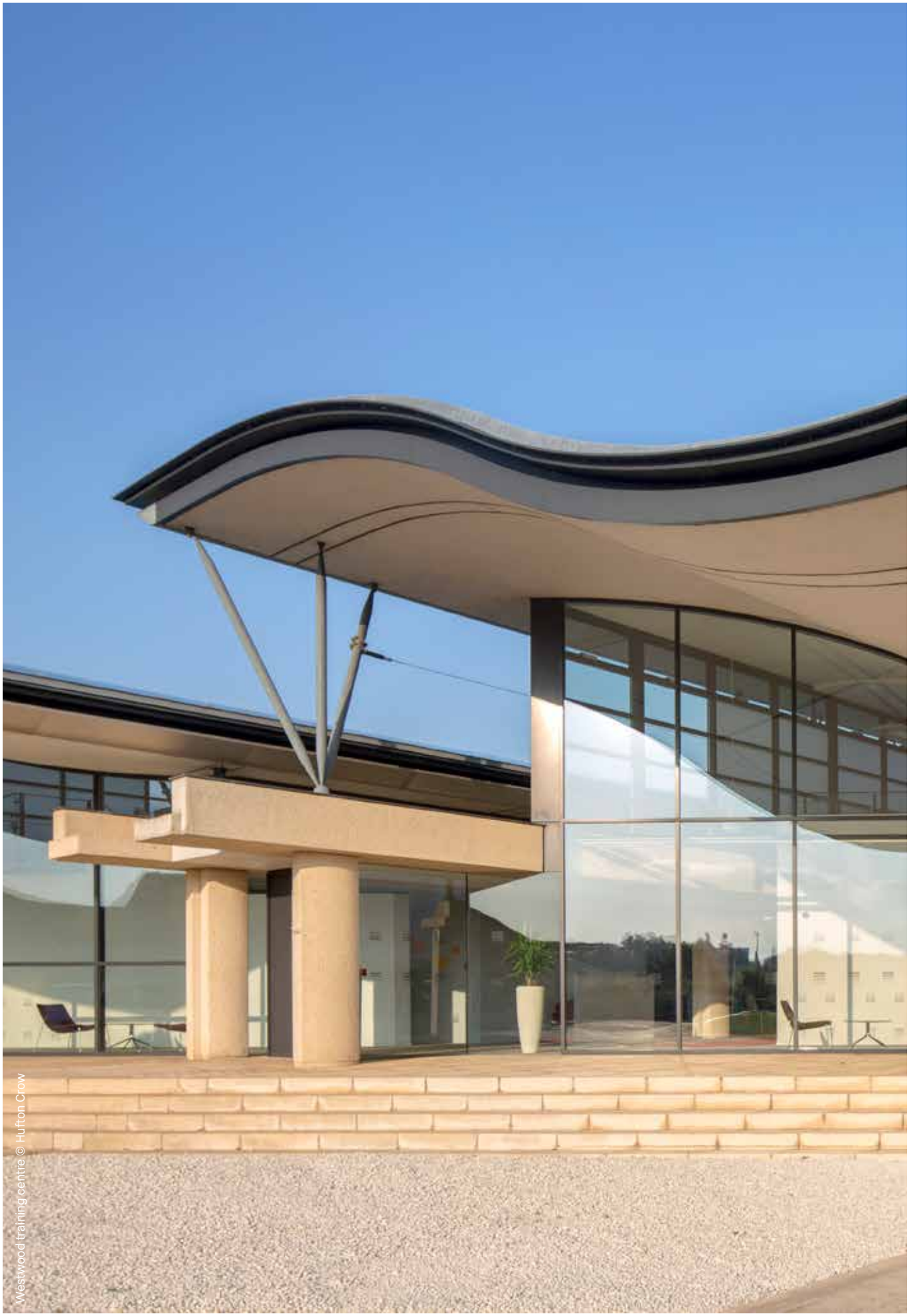
The Infrastructure Monitoring Strategy also provides guidance on achieving effective predict and prevent maintenance. A predict and prevent maintenance regime offers significant savings over a 'find and fix' approach. Infrastructure monitoring is a key requirement to achieve a predict and prevent approach to maintenance. However, in addition to knowing the asset condition there are other key requirements which need to be in place for predict and prevent to become a reality, these include:

- An asset degradation model supported by FMECA analysis.
- Data about the asset life, duty cycle.
- The asset's maintenance history.
- An asset cost model.
- Decision support tools.
- Asset performance analysis with double loop learning to achieve continuous improvements.

Therefore, any data collection decision needs to be made in the context of this end-to-end decision-making model. Circumstances could arise where the right quality data is being collected sufficiently and frequently, but in the absence of an accurate degradation model the data cannot be used to predict and prevent failure.

Our challenge is learning how to transition safely from a reliance on existing standards to new standards designed to deliver predict and prevent.

Manchester Picadilly Station © Network Rail



Westwood training centre © Hufton Crow

B

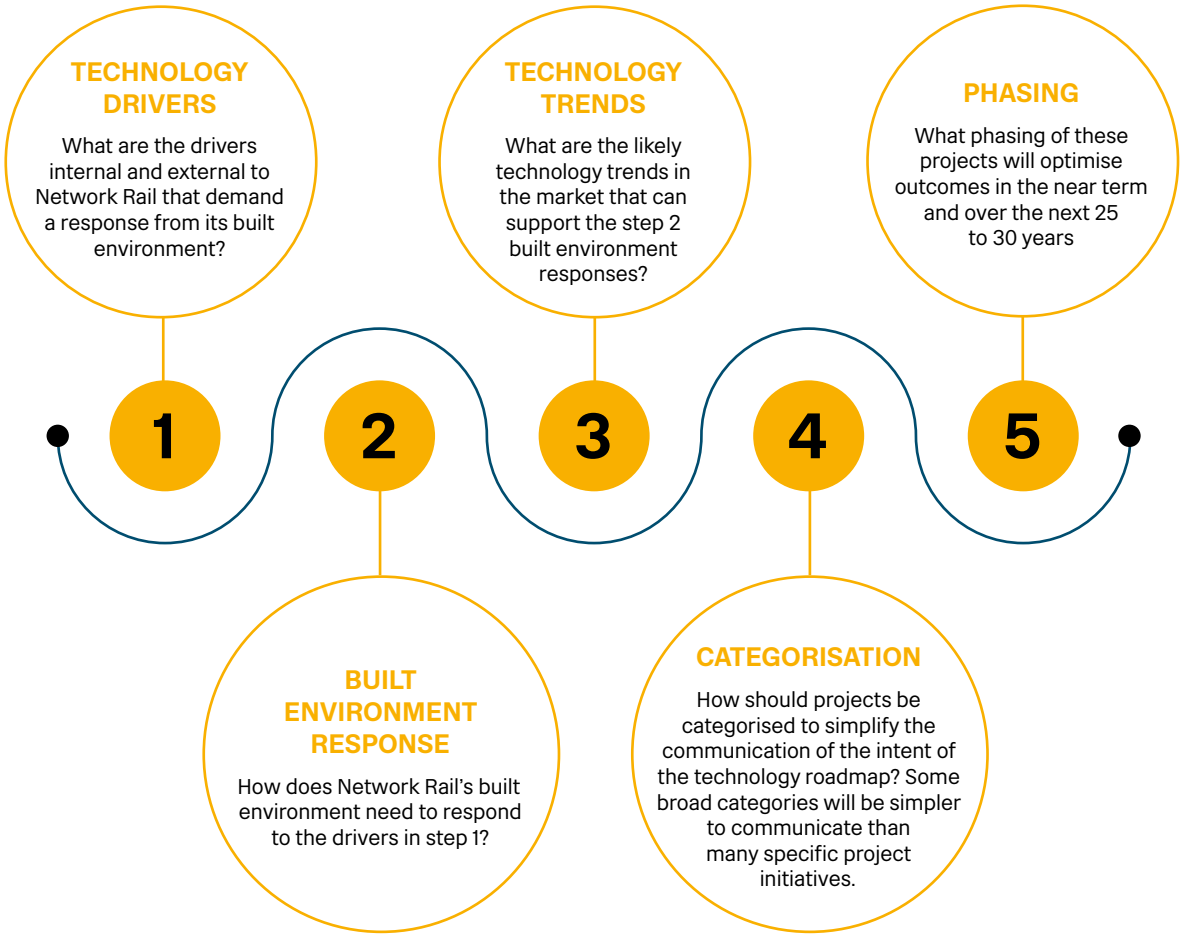
Design the Technology Roadmap

Designing the Technology Roadmap

The technology roadmap is derived by prioritising, selecting and phasing enabling projects, development projects and research projects. The project selection process is informed by the following five steps;

- Technology Drivers
- Built Environment Response
- Technology Trends
- Categorisation
- Phasing

These stages are somewhat iterative and require some professional judgments and workshops to select and prioritise. These steps are discussed in more detail in this chapter and chapter 3.



Designing the Technology Roadmap

2.1

2.1 Technology drivers

The application of any technology only has merit when it can be applied to improve efficiency or solve a known problem. Therefore, new and emerging problems and existing inefficiencies should act as the drivers for new technology. We have identified three categories of driver; existential risks, social expectations, and the drive to deliver our strategic objectives.

The diagram below shows how the built environment needs to respond to multiple drivers.

DRIVERS

Climate change.

RESPONSE FROM THE BUILT ENVIRONMENT

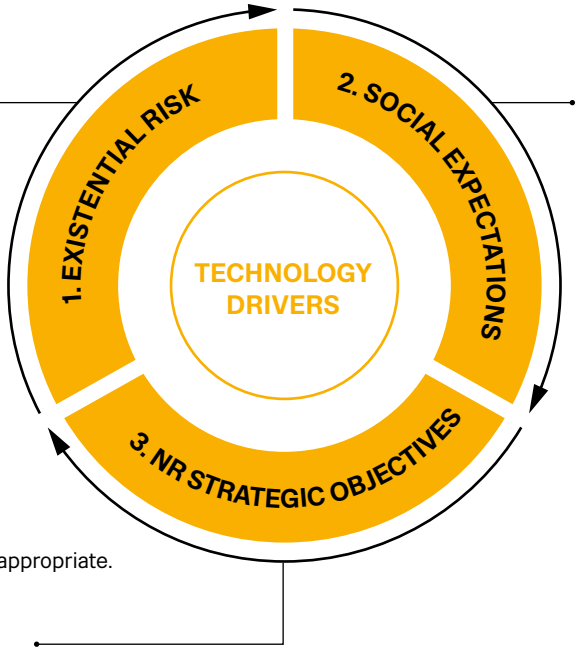
- Protect buildings and their users from weather extremes.
- Minimise the built environments climate impact.

DRIVERS

Sustainability, satisfaction, safety, stewardship, and commerciality.

RESPONSE FROM THE BUILT ENVIRONMENT

- Automate the design process where appropriate.
- Automate workflows.
- Develop digital asset management.
- Optimise land use.
- Generate crowd insights.
- Achieve a net-zero carbon asset lifecycle.
- Increase the resilience of buildings to weather extremes.
- Improve and automate asset condition monitoring.



DRIVERS

Expectations that organisations commit to measuring their social and environmental impact in addition to their financial performance. This sustainability measure is known as the triple bottom line.

RESPONSE FROM THE BUILT ENVIRONMENT

- Economic: Adapt to the new normal (post-covid), provide local economic growth, increase building resilience, reduce whole life asset cost.
- Environmental: Achieve a net-zero carbon asset lifecycle, promote the circular economy (recycle, reuse), increase biodiversity.
- Social: Increase inclusivity, increase people's safety, adapt to the new normal (post-covid), promote healthier lifestyles, provide local community benefits, increase building resilience, improve the experience of customers and passengers.

Designing the Technology Roadmap

2.2

2.2 Built environment response

The required response can be summarised and grouped by asset, people and community focus as shown in the following table. These responses are often supported by several technology trends. Where there are multiple technology trends supporting a required response, it is an indication that the action is an ideal candidate for inclusion in the technology roadmap. References to the supporting technology trends in the following table refer to the trends identified in the next section; they are shown here to make the best use of the table.

Responses required from the built environment			
Focus	**Ref**	**Action**	**Supporting Tech Trends** (see below for references)
Assets	A1	Minimise the built environments climate impact by achieving a net-zero carbon asset lifecycle (i.e., design, construct, operate, refurbish, reuse, dispose).	DT, QC, 34D, NT.
	A2	Enhance the design process through automation.	AI, BD, DT, NLP, QC.
	A3	Develop digital asset management.	AI, IoT, BD, DR, DT, NLP, 5G, CR, NT.
	A4	Improve and automate asset condition monitoring.	DT, IoT, BD, IS, ROB, AV, 5G, UAV, CR, NT.
	A5	Reduce whole life asset cost.	IoT, BD, DR, DT, NLP, ROB, 34D.
	A6	Analyse land use to optimise the reuse of vacant and redundant buildings and to assess options to increase biodiversity.	BD, NLP.
	A7	Protect buildings (and their users) by increasing the resilience of buildings to weather extremes.	IS, 34D.
People	P1	Adapt to changing commuter patterns, broader shoulders to the peak hours, increased leisure travel during evenings and weekends.	BD.
	P2	Generate crowd insights to improve safety and the experience of customers and passengers.	AI, IoT, BD, IP, DT, VFR, 5G, QC.
	P3	Improve the experience of passengers, freight users and the local community.	IoT, BD, IP, DR, VFR, AV, 5G, 34D.
	P4	Increase the safety of customers and passengers.	IoT, BD, IP, DR, VFR, AV, 5G, 34D, NT.
	P5	Promote healthier lifestyles.	BD.
	P6	Automate workflows to increase efficiency and improve customer service.	AI, BC, DT, NLP.
Community	C1	Increase the biodiversity of the built environment.	AI, BD.
	C2	Increase the inclusivity of buildings.	IS, DR, 5G.
	C3	Contribute to, promote and facilitate the circular economy (recycle, reuse).	AI, BD, ROB, 34D.
	C4	Provide local community benefits.	IS, AV, 5G.
	C5	Provide local economic growth.	BD, IS, BC, VFR, 5G.

Designing the Technology Roadmap

2.3

2.3 Relevant technology trends

The technology trends most relevant to our built environment are derived from a range of sources including our existing documentation, Industry 4.0, Arup SME contributions, and searches of the internet. The mapping between required responses and technology trends is also shown for each trend. The more responses supported by any trend indicate that it is worthy of being included in the technology roadmap.

ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING (ML)

Ref: AI

The increasing ability of machines to learn and act intelligently will transform the built environment. AI is a driving force behind many of the other trends in data analytics. AI enables the analysis of large quantities of historical data such as property leases, building designs and the analysis of data in real-time such as people's journey plans and movements as they interact with built environments and access services, and the analysis of data from growing numbers of smart devices.

AI will be essential for the efficient analysis of data from IoT devices.

AI will help optimise manufacturing and construction to make new build and renovation work safer, greener, and more economical.

Responses benefiting from trend

A2, A3, A4, P2, P6, C1, C3.

THE INTERNET OF THINGS (IOT)

Ref: IoT

IoT refers to the ever-growing number of "smart" devices and appliances that are connected to the internet. IoT devices are constantly gathering and transmitting data. IoT sensors will monitor and/or control; building performance, building condition, the movements of people in public spaces, the interactions people have with the built environment, environmental conditions with the built environment, environmental conditions outside the building. Bluetooth location beacons. The use of fixed, internet connected, high resolution cameras for inspections.

Responses benefiting from trend

A3, A4, A5, P2, P3, P4.

BIOMATERIALS

Ref: BM

The use of naturally derived building materials that provide structural and non-structural functions. Beyond the use of timber and wood-fibre products, the application of synthetic biology is being used to produce biomaterials such as mycelium panels and low carbon organic concrete.

Responses benefiting from trend

A1, A5, C3.

BIG DATA AND AUGMENTED ANALYTICS

Ref: BD

Sources of the built environment 'big data' will include historical data as well as real-time data. Historical data such as property leases and building designs will be accessible through AI using Natural Language Processing. Real-time data about people's journeys, movements, and interactions with the built environments, will also be accessible from IoT devices. Big data analysis will help power up BIM (Building Information Model) which in turn will deliver beneficial outcomes.

Responses benefiting from trend

A2, A3, A4, A5, A6, P1, P2, P3, P4, P5, C1, C3, C5.

BLOCKCHAIN

Ref: BC

The use of blockchain provides more robust lease management, lowering transaction costs and providing better value for customers. The accountabilities and responsibilities of all parties can be managed in a more transparent manner using blockchains that capture all payments, inspections, audits, and interventions.

Responses benefiting from trend

P6, C5.

INTELLIGENT SPACES AND SMART PLACES

Ref: IS

Connecting the data and analytics from IoT devices across spaces, buildings and rooms will create intelligent spaces and smart places. This will enhance people's experiences by enabling them to make more informed decisions and give them access to focused services (such as microservices, interchange information, route planning) in the spaces to enhance their experience. It will also provide information about how to adapt the space or environment to respond to the way people are using or interacting with it.

Responses benefiting from trend

A4, A7, P2, P3, P4, C2, C4, C5.

Designing the Technology Roadmap

2.3

DIGITAL EXTENDED REALITIES

Ref: DR

Encompassing virtual reality, augmented reality, and mixed reality, this trend highlights the move towards creating more immersive digital experiences. This will enable the provision of rich information to support those carrying out inspections and maintenance interventions in the built environment.

Responses benefiting from trend

A3, A5, P3, P4, C2.

DIGITAL TWINS

Ref: DT

A digital twin is a digital copy of an actual physical object, product, process, or ecosystem. Digital twins can be used to simplify the intuitive collection and reporting of data and information concerning the built environment. Digital twins can be used to model the performance of design changes, the impact of maintenance and refurbishment and the reallocation or reuse of space.

Responses benefiting from trend

A1, A2, A3, A5, P2, P6.

NATURAL LANGUAGE PROCESSING

Ref: NLP

This technology allows machines to understand human language. It can be applied to analyse written data about buildings, design, inspection, maintenance, leases, responsibilities, and accountabilities.

Responses benefiting from trend

A2, A3, A5, A6, P6.

COMPUTER VISION AND FACIAL RECOGNITION

Ref: VFR

To monitor the movement of people through the space. However, regulation may curtail its adoption unless privacy concerns can be overcome.

Responses benefiting from trend

P2, P3, P4, C5.

ROBOTICS

Ref: ROB

Robots are more intelligent than ever, learning to respond to their environment and perform tasks without human intervention. Typical applications for robots in the built environment include construction, inspection, and maintenance.

Responses benefiting from trend

A4, A5, C3.

5G & WIFI6

Ref: 5G

The fifth generation of cellular network technology will give us faster, smarter, more stable wireless networking, thereby driving advances in many other trends (e.g., more connected devices and richer streams of data).

Responses benefiting from trend

A3, A4, P2, P3, P4, C2, C4, C5.

AUTONOMOUS VEHICLES

Ref: AV

Passengers and customers will be interchanging between rail and autonomous vehicles. In addition to people, transport autonomous vehicles can be used for inspection, maintenance and the processing of recyclable material, compostable material, and waste (autonomous vehicles to power waste bins). Autonomous vehicles will be used for stock deliveries to retail outlets. Space in and around buildings can be allocated between pedestrian and autonomous vehicles depending on the time of day and demand. The design of the built environment can be optimised for autonomous vehicle use.

Responses benefiting from trend

A4, P3, P4, C4.

DRONES AND UNMANNED AERIAL VEHICLES

Ref: UAV

Aircraft, which are piloted either remotely or autonomously can be used for inspections and maintenance in the built environment.

Responses benefiting from trend

A4.

Designing the Technology Roadmap

2.3

3D AND 4D PRINTING AND ADDITIVE MANUFACTURING

Ref: 34D

4D research in the Construction and Building Sector is developing "living biomaterials" that combine the structural properties of traditional building materials with the ability to proliferate, self-repair, and adapt to the environment. The engineering of structural features into cellular systems that function as living materials open up many new design opportunities such as increasing the energy efficiency of existing buildings.

Responses benefiting from trend

A1, A5, A7, P3, P4, C3.

CYBERSECURITY AND RESILIENCE

Ref: CR

Use of AI and crowd monitoring services to provide early warning of suspicious behaviour. Also, as building systems move more on-line and real-time, they become exposed to the threat of cybersecurity. Cybersecurity mesh is a form of architecture which provides an integrated approach to security. This concept could be incorporated into the building systems.

Responses benefiting from trend

A3, A4.

QUANTUM COMPUTING

Ref: QC

As quantum computing becomes a commercial reality, its application will create a step change in computing power that could benefit many computing applications. However, quantum computing also poses a major risk to security should it make passwords and encryption trivial to crack.

Based on press reports, it is anticipated that quantum computing will be commercially viable in ten years' time (2032). This creates an enormous opportunity for our built environment as well as an enormous risk. The opportunity arises from the ability of quantum computing to carry out some types of computations many hundreds of times faster than current digital computing. Impossibly complex system modelling involving the interaction between people and buildings will now be possible. But which systems will benefit the most from investments in quantum computing?

Alongside these opportunities is the risk that for every security system that currently relies on digital encryption, every password and all encrypted data set will become crackable. This problem is similar in some respects to Y2K or the 'millennium bug' caused by ubiquitous DOS software, which was not designed to handle dates beyond 1999. The software had to be patched to ensure critical systems would still function safely on January 1st 2000. Y2K created massive bow-wave of work to mitigate the problem in time, which delayed other development projects. Unlike Y2K, we don't know exactly when quantum computing will become available to any foreign or domestic agents who may benefit from causing disruption to UK's systems or economy.

The inevitability of commercially viable quantum computing leads us to conclude that we must develop our own a strategy to be both ready to optimise the opportunity it creates and more importantly to mitigate the risk it represents. The scale of the risk does in fact suggest the need for a coordinate government-led strategy so we need to be alert to this and ready to contribute.

Responses benefiting from trend

A1, A2, P2.

NANOTECHNOLOGY

Ref: NT

Nanotechnology can create chemical sensing devices to assess fire risks and air quality. It can also create coatings to measure strain in structures and improve the efficiency of solar panels.

Responses benefiting from trend

A1, A3, A4, P4.

Designing the Technology Roadmap

2.4

2.4 Technology categories

The following categories have been defined to simplify the communication of the technology roadmap. By grouping together related initiatives under these categories it is easier to see the technology roadmap's span of impact and if there are any significant omissions.

FOUNDATION

The foundation projects establish the platform to coordinate the currently diverse efforts across the organisation and support the harmonization process with consistent definition and development of project scopes. They also work to ensure end-to-end solutions are developed that consider the whole-life concept of operations. This ensures the delivery of 'technology enabled solutions' and not just the adoption of new technology for the sake of it.

PROGRESSIVE DESIGN

The application of parametric and generative design technology to achieve the desired design principles in more sustainable ways. Create flexible and optimised designs for common elements of the built environment that can be efficiently manufactured and rapidly constructed on site.

DIGITAL ASSET MANAGEMENT

Supporting the planning and recording of asset management activities. The creation of a building's digital twin, providing a model of operational and environmental performance and an intuitive interface to record asset data, asset management history and predict necessary interventions.

LAND USE

The analysis of a range of location-based data sources using AI and machine learning to determine land use. This information can be used to optimise the reuse of vacant and redundant buildings and to assess options to increase biodiversity.

NET-ZERO & CLIMATE

A range of tools to model the carbon emissions for building operation and the embedded carbon in existing buildings. Tools to quantify and monetize (where possible) social and sustainability benefits and carry out post-project reviews to measure benefits realization. Tools to assess options to incorporate prosumer energy solutions into existing buildings. Location-based forecasts of extreme weather, its impact on buildings and data to justify resilience improvement measures.

CROWD INSIGHTS

The analysis of a range of real-time location-based data such as those from mobile devices and CCTV to anonymously identify the activities of people. With AI and machine learning, this can provide real-time information to alert operations to people at risk and to determine how people are interacting with the built environment under changing circumstances such as weather, time of day, service disruption, local events etc. The information is also relevant to retail operators and the local business community.

CONDITION MONITORING

Measuring devices with IoT functionality to monitor the condition of assets and the environmental and duty conditions experienced by the assets. AI and ML analytics interpret the data to predict future failure and therefore optimise maintenance interventions. New technology to test critical hidden elements, achieve consistent inspection data to prioritise interventions effectively.

WORKFLOW AUTOMATION

The application of digital tools to improve the efficiency and effectiveness of workflow tasks.

Designing the Technology Roadmap

2.5

2.5 Example initiatives by category

The following examples illustrate the current state of technology readiness of the key categories.

- Progressive Design
- Digital Asset Management
- Land Use
- Net-Zero & Climate
- Crowd Insights
- Condition Monitoring
- Workflow Automation

Progressive Design

SPECKLE

Speckle is a flexible solution for geometric interoperability between popular 3D modelling and analysis packages and tracking changes to design data. Direct interaction with cloud helping to share design data across teams and connect it to automation tools and scripts. The tool allows for interoperability between design software and custom workflows. Speckle has been utilised on bridge design works to allow the structural design to progress in parallel with highway design.

Digital Asset Management

MATTERPORT DIGITAL TWIN

MATTERPORT utilizes Cortex Artificial Intelligence (AI) software to create 3D digital twins and automate many of the 3D customization steps. Cortex is a deep learning neural network, with measurements generally accurate to within 1% of reality under normal operating conditions.

Designing the Technology Roadmap

2.5

Land Use

TERRAIN

TerrAIn is a tool that can help planners and authorities to understand how land is being used, bringing the power of data analytics, machine learning and automation to satellite imagery. It helps define the scale of opportunities for nature-based solutions, enabling clients to deliver in a sustainable, efficient and informed manner. TerrAIn was used to undertake a rapid assessment of the potential of different land uses in Mansfield to accommodate nature-based solutions and mitigate surface water flood risk.

Net-Zero and Carbon

FCBS CARBON

FCBS Carbon is a whole life carbon review tool, designed to estimate the whole life carbon of a building to inform design decisions prior to detailed design. Rather than create a detailed model of each building, using nine key parameters the tool uses a series of algorithms to generate a representative building that can be used to test changes to materials and building forms. Using benchmarked data from the ICE Database and EPDs, the tool is designed to give design teams insight into the whole life carbon impact of a building from the very outset of a project.

Designing the Technology Roadmap

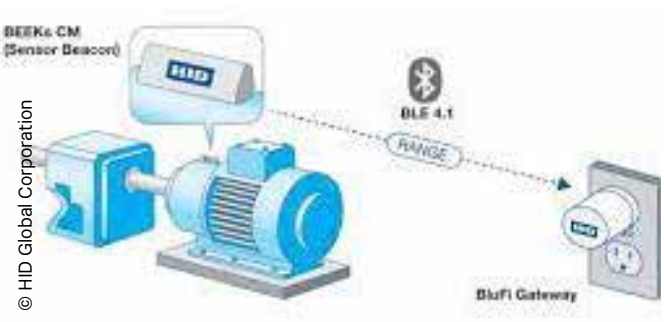
2.5

Crowd Insights

TAOGLAS CROWD INSIGHTS

Taoglas CROWD insights is a people movement analytics platform that utilizes existing Wi-Fi infrastructure to measure, monitor and predict the numbers, flows and dwell times of people in public areas and sets thresholds to alarm if an intervention is necessary. Data can be displayed in real-time on the platform dashboard in forms such as heatmaps and motion flows. This solution was deployed by DCU Alpha to assist with managing crowds during the Covid-19 pandemic.

Condition Monitoring



HID CONDITION MONITORING

HID Condition Monitoring is a real-time monitoring platform to assess the health and performance of industrial equipment such as manufacturing equipment, HVAC, elevators and other rotating equipment. Each asset is equipped with bluetooth beacons, which ultimately transfers data to the cloud via gateways that utilize existing Wi-Fi infrastructure. The system enables stronger predictive maintenance, reducing machine downtime and avoiding unnecessary inspections.

Workflow Automation

METHOD GRID

Method Grid's connected assurance platform combines knowledge management, project management and task management to enhance productivity, project control, executive oversight and allow for consistent delivery. The platform allows delivery frameworks to be built upon a grid of industry best-practice to ensure higher quality outputs are produced more efficiently. The dashboard also contains various other features such as allowing tasks to be assigned, scheduled and tracked with built-in assurance.

C

Technology Initiatives

Technology Initiatives

The roadmap is compiled by consolidating initiatives from several source documents from Buildings and Architecture, Group Property and from priorities and initiatives co-created by the two groups as part of a strategy harmonisation study. As part of that study, the outcomes needed to help accelerate progress in key areas of strategy were identified. The list below describes the initiative and the resulting outcome it enables. The project descriptions outline the key concepts which will need further definition and development during the roadmap delivery phase.

Category	Project Title	Description	Ref
Foundation	Joint working group	Establish a joint Built Environment Technology working group between Buildings and Architecture and Group Property. Remit this group to build an influence network within Network Rail to facilitate the early adoption of technology where the built environment provides a platform for doing so. The group should also coordinate an active dialogue with the digital / technology community and the community of users including customers, passengers, operations, and other key stakeholders.	F1
	Minimise innovation blockers	Define and develop a range of initiatives focused on reducing or eliminating blockers to innovation.	F2
	Support predict and prevent maintenance	Define and develop guidance to achieve effective predict and prevent maintenance that goes beyond monitoring the asset condition to consider an end-to-end solution.	F3
	Quantum computing strategy	Develop a strategic response in anticipation of quantum computing becoming commercially viable. Strategic response to assess ways in which benefits of quantum computing can be exploited and risks mitigated.	F4
Digital Asset Management	Harmonization of Asset Management systems	Harmonization of Asset Management systems including Horizon, Oracle, SAP, OPAS, Citadel and incorporating the OPAS chat box helpdesk initiative. These systems do more than just the management of physical assets. For instance, Horizon manages all of Group Property's customer data, billing/ invoicing and reporting of all commercial activities. Given the current level of implementation and investment in the existing systems, harmonisation of these systems will be challenging. Establish a platform to support predict and prevent maintenance.	DAM1
	Harmonization of Data Analytics & exploitation	Harmonization of data analytics and exploitation systems including Horizon, Oracle, SAP, OPAS, Citadel. Apply ML to condition monitoring data, inspection and intervention data sets help achieve the aim of fully automated examinations and predict and prevent maintenance.	DAM2
	Consolidate and augment building information	Improve data quality of building drawing archives to create an accessible as-built drawing database, develop building digital twins using scanning technology and push the BIM initiative. Strive to create a single source of truth for asset data. Provides easy access to as-built designs (especially for older buildings). Allowing designs to be assessed against modern or emerging safety and resilience requirements (such as asbestos, fire safety, flood, snow loading etc). This leads to a better understanding of operational risk and investments to improve building resilience.	DAM3
	Automatic recognition of assets and faults	Develop automatic asset recognition applications that combine asset GIS location data, feature extraction data from images and data from LIDAR scans to enable auto-recognition of asserts to simplify and speed up inspection and maintenance and to highlight visual changes in the asset that predict the need for intervention.	DAM4

Technology Initiatives

Category	Project Title	Description	Ref
Condition Monitoring	Harmonise strategy for Smart Buildings	Harmonise Strategy for Smart Buildings incorporating operational and commercial buildings and the IoT lifts and escalator initiative.	CM1
	Smart Buildings implementation	Implementation of emerging and harmonised Smart Building strategies to create new, reliable and easily accessible data sources to build a baseline of building services performance.	CM2
	Remote building condition monitoring	Remote condition monitoring is implemented to eliminate unsafe working conditions such as those associated with confined spaces, high places and moving equipment.	CM3
	Remote inspections development	Development of robust remote inspection technologies linked to examination standards. Produce a suite of specifications to allow the regions to utilise remote technology to undertake inspections.	CM4
	Crack IT 2 continuous development	Continuous improvement of the Crack IT 2 system which incorporates AI and ML to deliver methods to fully understand the condition of existing assets with maximum safety and minimum cost and disruption.	CM5
	NDT technologies market scanning	Market scanning for NDT technologies to inspect hidden critical elements to fully understand the condition of its existing assets with maximum safety and minimum cost and disruption.	CM6
Net-Zero & Climate	Minimise embodied carbon	Development of a catalogue of assets which are carbon negative and a toolbox on how they can be deployed to help achieve the 2050 net-zero vision. Develop digital tools to model the embedded carbon in existing buildings. Embodied carbon of new designs is minimised.	ZC1
	Minimise carbon emissions	Develop digital tools to model the carbon emissions for building operations. Carbon emission from operations is minimised.	ZC2
	Carbon assessment tool	Development and/or validation of a low/zero carbon assessment tool suitable to use for Buildings and Architecture projects/schemes.	ZC3
	Whole-life carbon analysis	Assessment of whole-life carbon costs of typical assets to determine options for life-extension via increased maintenance or earlier renewals for better energy efficiency.	ZC4
	Built environment carbon benchmarking	Analysis and cross industry benchmarking of both embodied and operational carbon associated with the top five Buildings and Architecture renewals and actions necessary to achieve net-zero outcomes.	ZC5
	Prosumer energy solutions	Develop digital tools to assess options to incorporate prosumer energy solutions into existing buildings. Enabling prosumer energy solutions to be adopted in the built environment including electricity generation from footfall within station environments.	ZC6
	Lighting of the future	Development of a standard to ensure low energy lighting standards and guidance is available for the Network Rail regions to implement in their stations, depots and delivery unit projects and asset management works.	ZC7
	Increase biodiversity	Identify opportunities for increasing biodiversity and community engagement at stations. Pilot product to ensure the built environment activities in public spaces is linked to Network Rail's biodiversity strategies.	ZC8
	Quantify social and sustainability benefits	Project to quantify and monetize (where possible) social and sustainability benefits and carry out post-project reviews to measure benefits realization. Enables the quantification or monetization and measurement of social benefit so that business cases account for sustainability and justify investments in sustainability outcomes. Also supports the development of affordable sustainability improvements.	ZC9

Technology Initiatives

Category	Project Title	Description	Ref
Progressive Design	Level boarding platform system	Development of a standard level boarding system to use across the UK network as there are fragmented poor designed solutions currently available.	PD1
	Automated generative design	Automated / generative design for built environment industrialised items. Use of automated design tools for key Network Rail designs e.g., stations and footbridges	PD2
	Building services planning and design tools	Automated building services and vertical transportation planning and design tools for project teams to ensure financial efficiency and consistency for end users.	PD3
	Sustainable materials testing	Destruction testing of sustainable materials used in Buildings and Architecture renewals to review impact on design life and thus whole life cost estimates.	PD4
	Bridge design optimisation	Continuous improvement of designs and guidance for adaptable bridges and specialist footbridges.	PD5
	Research construction best practise	Research into best practice construction methods to improve safety and sustainability outcomes.	PD6
	Low-cost applications of design principles	Develop options to lower the cost to implement the design principles. Affordable sustainability improvements are developed. Business cases account for sustainability. Low-cost methods for achieving design principles are developed.	PD7
Crowd Insights	Digital wayfinding	Continued update of the wayfinding design manual to ensure our passenger facing wayfinding supports the digital technologies being rolled out at stations.	CI1
	Virtual wayfinding	Further develop the existing Network Rail wayfinding to include augmented reality accessible to passengers with impairments to enhance their travel experience.	CI2
	People movement insights	Harmonise and optimise the observation, analysis and interpretation of people movement providing real-time data on people movement to inform safety management, operational activities, customer satisfaction and commerciality.	CI3
	Digital services interacting with people	Review current people movement data analytics initiatives and promote the development of AI solutions to create a better understanding of asset and operational performance, and safety and sustainability trends. Contributes to enabling the provision of personalised digital service information across public spaces that facilitate integrated digital ticketing, journey flexibility and customisation, real-time information, station control lines and travel validation. Enabling digital services for customers, operations, maintenance and safety developed. Enabling business cases to account for social benefits. Carbon emission from operations is minimised. Building improvements increase biodiversity.	CI4
	Real-time data collection and surveys for building users	Establish real-time data collection and surveys for building users to evaluate how they value building ambience, personal security and accessibility. Enabling the monetization or quantification of building users experience metrics like building ambience, personal security and accessibility.	CI5
	Develop options for integrated, flexible barrier-free travel	Contributes to enabling the provision of personalised digital service information across public spaces that facilitate integrated digital ticketing, journey flexibility and customisation, real-time information, station control lines and travel validation.	CI6

Technology Initiatives

Category	Project Title	Description	Ref
Land Use	Rationalise station and lineside building use	Develop a harmonized cross-discipline strategy and tools to assess options for station and lineside building rationalisation. Enables processes to be established that assess options for building reuse, improving sustainability and revenue. With many underutilised buildings on our estate this work would review the estate and propose actions needed to achieve cost and carbon efficiencies by reducing the size of the estate.	LU1
Workflow Automation	Dashboards & MI	Providing users in the regions and routes with easily accessible information via PowerBI reports that integrate data from a range of enterprise systems.	WA1
	Budgeting & forecasting	Providing users in the regions and routes with easily accessible budget and forecasting reports that integrate data from a range of enterprise systems.	WA2
	Customer Relationship Management (CRM)	Standardise and integrate a number of existing processes and workflows into an enterprise level CRM.	WA3
	Inspection solution	Provide inspectors with web and mobile platform tools to standardise, integrate and centralise the auditing of building inspections.	WA4
	Process redesign & automation	Redesign and automate property management processes; investment valuations, rent deposits, service charges, rents payable, rents received, credit control and arrears management, insurance contributions.	WA5
	Case management	Pilot integrated tenant management applications.	WA6
	Document data extraction	Application using AI and natural language processing to extract and centralise structured data from lease documents to provide an easily accessible information source.	WA7
	Facilities management	Integrate data from IoT devices to inform facilities management activities.	WA8
	Digital employee & workplace	Improve the efficiency and effectiveness of Group Property employees by making the best use of available applications such as Microsoft 365.	WA9

Technology Initiatives

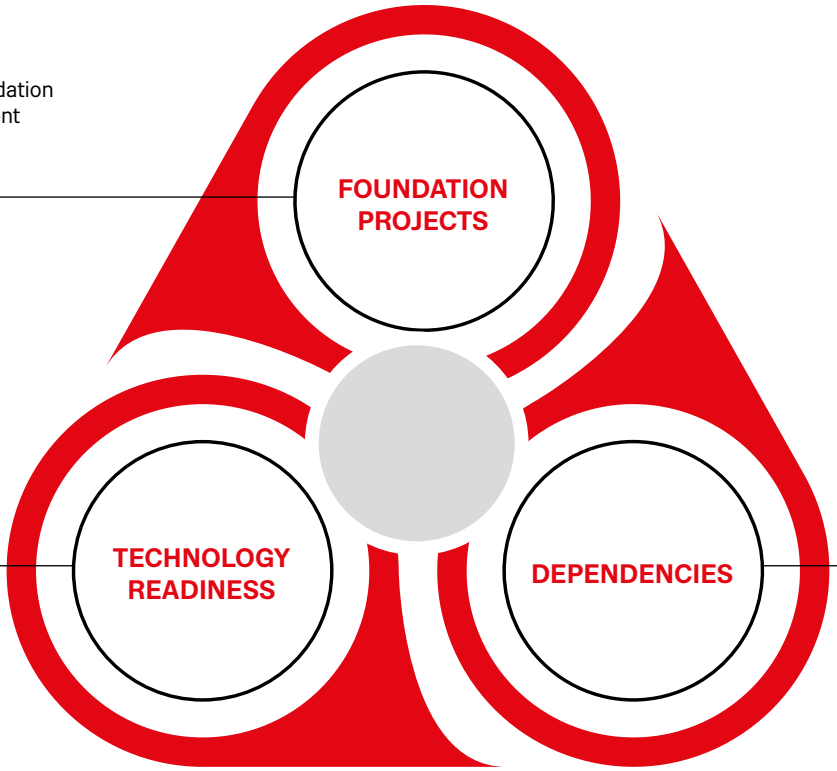
3.1

3.1 Mapping

The mapping of technology initiatives into phases and the grouping or linking of technology initiatives is guided by the following principles.

These projects form a foundation that supports the subsequent research, development and implementation projects.

This refers to the need for the project to evolve through a research and development phase before implementation and operationalisation. Some initiatives will arrive ready for operationalisation and others need to start from the research stage.



Some technology initiatives will be dependent on other initiatives being established first.

Technology Initiatives

3.1

Key

Concept | Feasibility | Development | Implementation | Market Scanning | Continuous Improvement

Foundation

Project Title	First	Early	Next	Later
1. Joint working group				
2. Minimise innovation blockers				
3. Support predict and prevent maintenance				
4. Quantum computing strategy				

Digital Asset Management

Project Title	First	Early	Next	Later
1. Harmonization of Asset Management systems				
2. Harmonization of Data Analytics & Exploitation				
3. Consolidate and augment building information				
4. Automatic recognition of assets and faults				

Condition Monitoring

Project Title	First	Early	Next	Later
1. Harmonise strategy for Smart Buildings				
2. Smart Buildings implementation *(CM1. must be completed first)*				
3. Remote building condition monitoring				
4. Remote inspections development				
5. Crack IT 2 continuous development				
6. NDT technologies market scanning				

Technology Initiatives

3.1

Key

Concept | Feasibility | Development | Implementation | Market Scanning | Continuous Improvement

Net-Zero & Climate

Project Title	First	Early	Next	Later
1. Minimise embodied carbon				
2. Minimise carbon emissions				
3. Carbon assessment tool				
4. Whole-life carbon analysis				
5. Built environment carbon benchmarking				
6. Prosumer energy solutions				
7. Lighting of the future				
8. Increase Biodiversity				
9. Quantify social and sustainability benefits				

Progressive Design

Project Title	First	Early	Next	Later
1. Level boarding platform system				
2. Automated generative design				
3. Building services planning and design tools				
4. Sustainable materials testing				
5. Bridge design optimisation				
6. Research construction best practise				
7. Low-cost applications of design principles *(PD6. must be completed first)*				

Technology Initiatives

3.1

Key

Concept | Feasibility | Development | Implementation | Market Scanning | Continuous Improvement

Crowd Insights

Project Title	First	Early	Next	Later
1. Digital Wayfinding				
2. Virtual Wayfinding *(CI1. must be completed first)*				
3. People movement insights				
4. Digital services interacting with people *(CI3. must be completed first)*				
5. Real-time data collection and surveys for building users *(CI4. must be completed first)*				
6. Develop options for integrated, flexible barrier-free travel *(CI4. must be completed first)*				

Land Use

Project Title	First	Early	Next	Later
1. Rationalise station and lineside building use				

Workflow Automation

Project Title	First	Early	Next	Later
1. Dashboards & MI				
2. Budgeting & Forecasting				
3. Customer Relationship Management (CRM)				
4. Inspection Solution				
5. Process redesign & automation				
6. Case Management				
7. Document data extraction				
8. Facilities Management				
9. Digital Employee & Workplace				