

◀ **CROSSRAIL** **INNOVATION** --- **STRATEGY** ▶

MOVING LONDON FORWARD

◀ FOREWORD

Innovation is the driving force of growth in firms, industries and economies. It guides the choices, strategies and behaviours of the world's leading businesses such as IBM, Google and Apple. But firms in construction are slow to benefit from innovation. Too often, they rely on tried and tested techniques and formulas found close to hand.

There are real signs that UK construction is aware of the possibilities generated by innovation. Leading firms – like Balfour Beatty, Laing O'Rourke and Arup – have developed systematic innovation programmes to harness the creative potential of their organisations and supply chains.

High-profile mega projects face the same issues. They can be a catalyst for innovation, but they can just as easily become innovation bottlenecks. Having a clear strategy can help tip the balance.

During the preparation for Heathrow Terminal 5 in the 1990s Sir John Egan, CEO of BAA, recognised the importance of learning and adopting best practices from other industries, the role of intelligent client, collaborative teams, and modularity adopted from oil and gas and lean production, just-in-time logistics, and concurrent engineering from the car industry. Since then UK construction has shown the way forward for managing mega projects as demonstrated by the world-class delivery of the London Olympics and Paralympics in 2012.

Crossrail is well-positioned to build on these successes. As this document explains, Crossrail has created a systematic process for generating, capturing and replicating innovative ideas. It aims to raise the bar for other construction projects by making those innovative ideas, technologies and practices available to the industry as a whole.

In this way, Crossrail will create a legacy the construction industry can build on in future.

What remains is the hard part. Just as an idea does not become an innovation until it is applied, strategy does not become reality until it is successfully executed. The success of this innovation programme depends on focused and committed leadership throughout Crossrail's supply chain. I can think of no better team to get us started on this exciting journey.



Professor David Gann
Head, Innovation and Entrepreneurship
Imperial College Business School and Civil & Environmental Engineering,
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PROFESSOR DAVID GANN CBE

David Gann CBE, CEng FICE is head of the Innovation and Entrepreneurship Group and Deputy Principal at Imperial College Business School.

He directs the EPSRC Innovation Studies Centre at Imperial College and is Partnership Executive of Imperial College's strategic relationship with IBM through which he leads the Digital City Lab cross-faculty research on smart city systems.

David is Chairman of Think Play Do Group. He was previously a board member of Rethinking Construction and Constructing Excellence, an advisor to Willmott Dixon, CSC, Group Innovation Executive at Laing O'Rourke, a member of the recent UK Government panel for the Independent Review of IP and Growth, and is a trustee and board member of the Institute for Sustainability. He was appointed CBE in the 2010 Queen's Birthday Honours for services to engineering.



STATEMENT FROM THE CEO ▶

I am delighted to present our innovation strategy for Crossrail. 'Inspiration' is one of our core values, and innovation is a key part of this value. Innovation is also a subject I am passionate about but is not one that is often associated with construction. I am confident that we can change this by developing a strategy on Crossrail where people are encouraged to think differently. If we get it right we will see a level of innovation that is unprecedented on a major programme like Crossrail.

On Crossrail, we are delivering much more than a railway project. We are developing the sites over our stations, creating new public spaces across the capital as well as providing skills and employment opportunities. We are all 'Moving London Forward'.

But we should also use this opportunity to raise the bar across the construction industry, one that for too long has been too focused on 'pushing' risk down the supply chain and giving too little thought to how we should be 'pulling' opportunities, and innovation up the supply chain.

If we all share in this view we can use Crossrail as a platform to generate new ways of working. But this can only happen if Crossrail first creates an environment where people feel they can safely exchange ideas across organisational boundaries, collectively build innovative solutions, gain the required support to develop the idea and receive recognition when they are successful.

The participation of you and your colleagues is critical to the success of our innovation programme. The first step is to recognise the innovative practices you or your team already employ, and then to share them with others.

I look forward to all of your contributions so that together we can make innovation an integral part of Crossrail.



Andrew Wolstenholme
Chief Executive Officer, Crossrail



ANDREW WOLSTENHOLME OBE

Andrew Wolstenholme graduated from Southampton University in 1981 with a 1st class honours degree in Civil Engineering.

He served in the British Army for 5 years, first in the Royal Engineers and later as an Irish Hussar. He resigned his commission in 1985 to pursue a career in engineering and joined Arup, the international engineering consultants, as a bridge designer.

He was later seconded to Schal Associates in Chicago where he worked with some of the great American architects on tall buildings. He moved to Hong Kong in 1992 and worked on a number of the major infrastructure projects in South East Asia, including Hong Kong Airport and the Western Harbour Tunnel Crossing.

Andrew joined BAA plc. in 1997 as Construction Director on the Heathrow Express Rail Link. He went on to be the Programme Director on Heathrow's £4.3bn Terminal 5 and later became BAA's Director of Capital Projects. He joined Balfour Beatty in 2009 and left, as Director of Innovation and Strategic Capability, in 2011 to take up the Chief Executive role at Crossrail.

He was awarded an OBE for services to the construction industry in June 2009.

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INTRODUCTION

Crossrail is delivering a world class railway that fast tracks the progress of London. It has developed an innovation strategy to improve the delivery of the project and create a legacy to improve the performance of the UK construction industry.

Much has been done over the past two decades to promote innovation in construction, through the adoption of lean design and production techniques, modular and pre-fabricated assemblies, integrated project teams and digital technologies. But there is

a great deal more to do. Raising the performance bar to the next level requires strategic efforts to promote innovation and learning from one project to the next. Innovation is surrounded by risk and uncertainty. The question is: How can we exploit the innovation capabilities of the Crossrail supply chain to create a high-performance railway without sacrificing affordability, safety or the environment? This document outlines Crossrail's strategy for meeting this challenge.

BEST PRACTICE

Crossrail is learning from organisations outside the construction industry that have world-class innovation programmes. These organisations – such as Procter and Gamble, Rolls Royce, Siemens and IBM – have created programmes to support rapid and systematic innovation. Many are moving away from traditional 'closed innovation models' based on in-house R&D, production and marketing processes to take their new discoveries and intellectual property (IP) to the market themselves. They are now establishing 'open innovation models' to search for the best external ideas, discoveries and technologies and

connect these with internal capabilities. Open models are being introduced in industries as diverse as design (e.g. OpenIDEO), hardware development (e.g. Arduino), consumer products (e.g. P&G), documentation (e.g. Xerox) and mining (e.g. AMIRA International). What unites these innovating organisations is their ability to excel at creating and capturing value from innovation. The construction industry has long avoided investing in processes for managing innovation. There are signs that this is changing. Leading firms are recognising the value of formal innovation management processes and

investing accordingly. It is time for the organisations managing mega projects to start running with this baton, but this journey will not be without difficulties.

The world's leading innovators such as Google, Apple, GlaxoSmithKline and Toyota are permanent organisations. They develop corporate strategies to support innovation over many years. Mega projects like Crossrail, in contrast, are temporary coalition of firms. The firms involved are both collaborators and competitors and this creates new challenges.

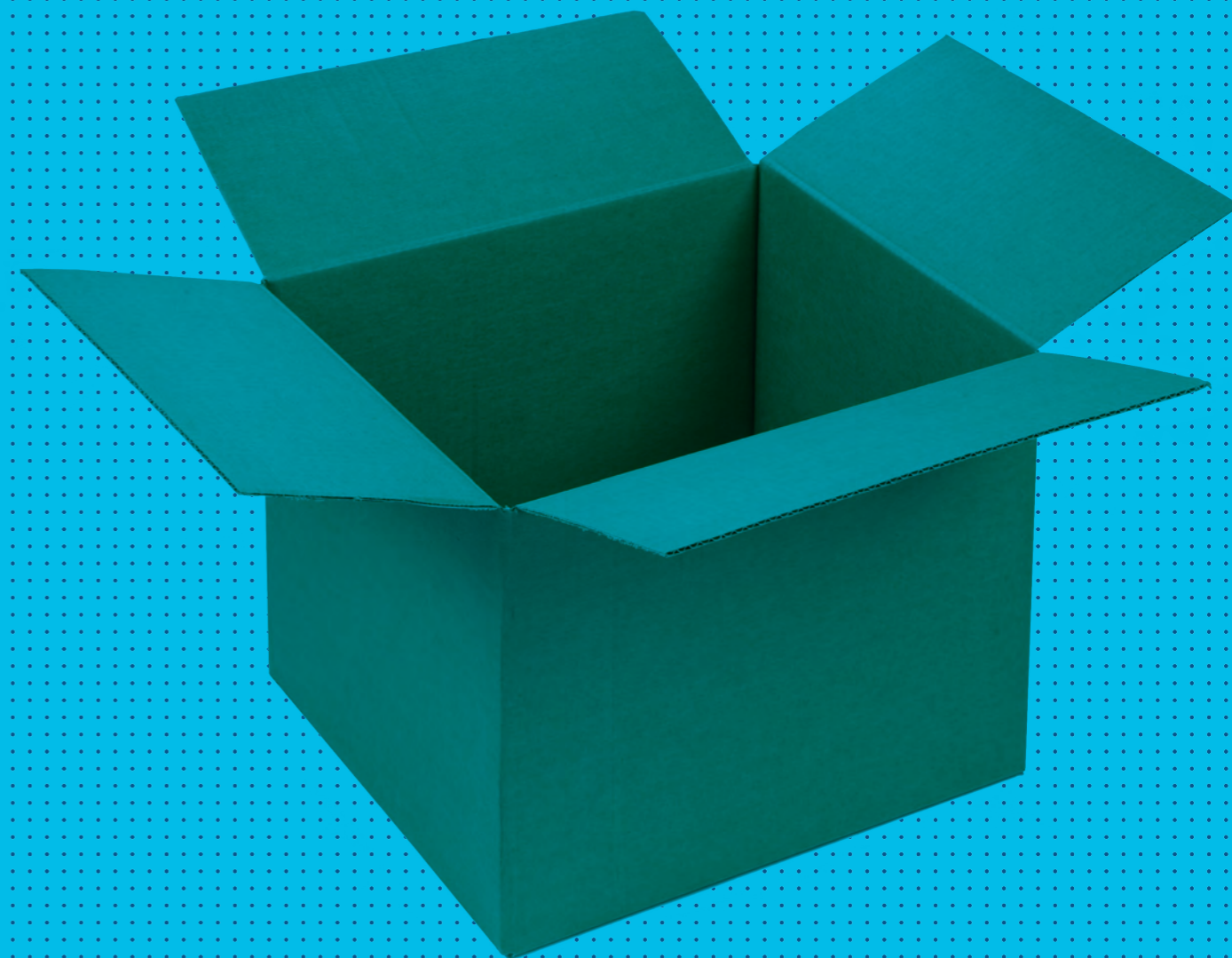
WHAT IS INNOVATION?

Developing this strategy requires a clear definition of what we mean by 'innovation'. Innovation is the successful commercial exploitation of new ideas. It refers to the scientific, technological, organisational, financial, and business activities leading to the commercial introduction of new or substantially improved products, processes, services or entire business models.

Innovation can be incremental or radical. It ranges from incremental improvements in existing products, processes and services

at one end of the spectrum to radical changes associated with breakthrough products, disruptive change and new-to-the-world ideas at the other end. A great deal of innovation takes place in the middle of the spectrum where organisations develop and produce new products, process and services for existing markets and customers. Innovation does not depend on new technology. An organisation can develop radically new products – such as Apple's iTunes and iPod platform – using established technologies.

Innovation involves varying degrees of risk and requires different resources and processes for its successful execution. In contrast to the highly uncertain process surrounding the introduction of a breakthrough concept, incremental innovation encourages less risky improvements by extending existing processes, products or services. Innovation always involves change.



OUR VISION

Crossrail has broken the mould in UK construction by being the first organisation to develop a strategy and process for managing innovation in mega projects. Some of the UK's previous mega projects (e.g. High Speed 1, Heathrow Terminal 5 (T5) and the London Olympics 2012 construction) have taken important steps to institutionalise innovation in mega projects. However, efforts have often been informal and lessons have not been fully captured. Previous projects focused on creating novel approaches to project delivery (e.g. BAA's T5 Agreement) rather than establishing a process to promote innovation within and beyond the life of the project.

Open models of innovation provide a toolbox better suited to tackling the challenges which have historically made the management of innovation so difficult in mega projects. Our open approach views the mega project as an 'ecosystem' of many diverse and interconnected

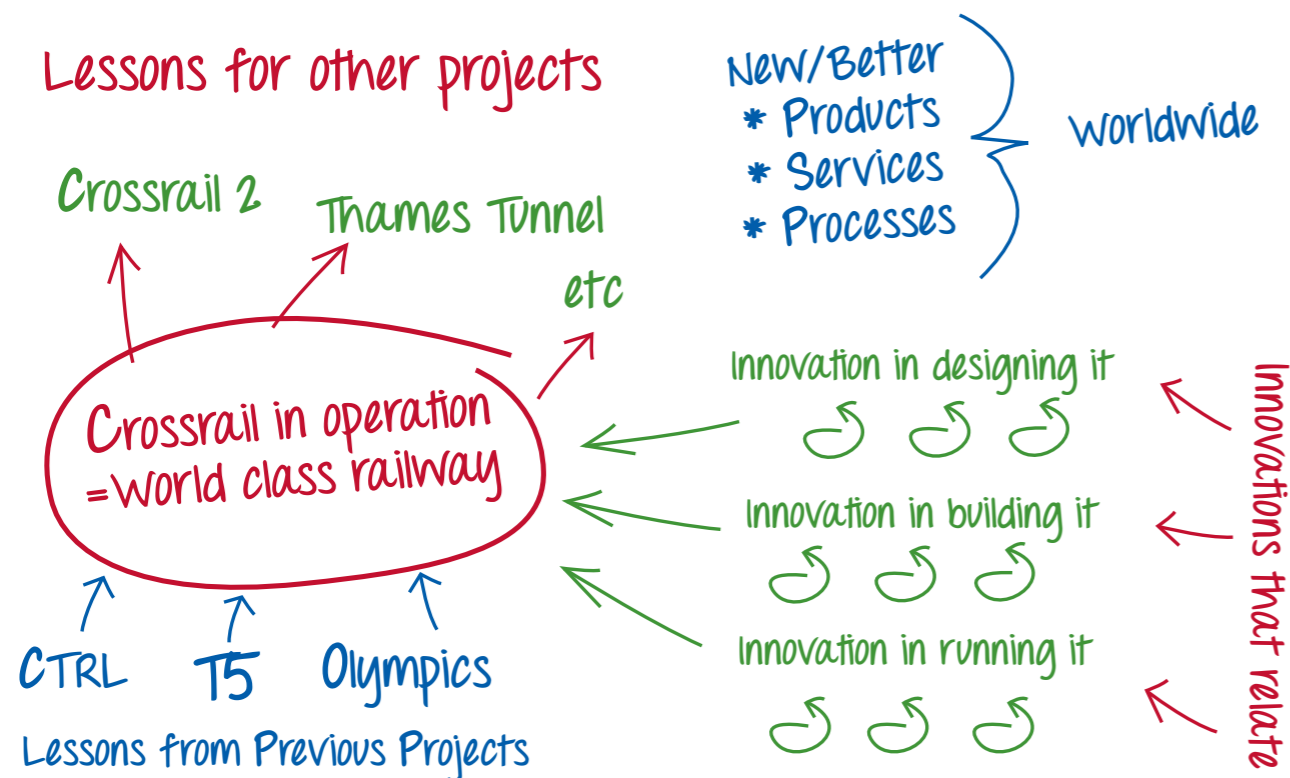
organisations. It focuses on building the organisational mechanisms and culture required to broker innovation between the different parts of this ecosystem.

Figure 1 shows our vision for an innovation strategy at Crossrail including processes that:

- ▶ **Generate, develop, codify and formalise innovation in Crossrail's design, construction and handover to operations**
- ▶ **Benchmark and measure innovative improvements**
- ▶ **Capture and transfer lessons to future projects**



Figure 1. Crossrail's innovation vision



OUR STRATEGY

Crossrail's strategy is to deliver a world-class railway where innovation goals are clearly targeted as everyone's responsibility, and collaboration across the programme's boundaries is used to create a legacy that moves London forward.

Crossrail's innovative activities have been systematically aligned with the programme's overall vision and goals. Achieving and maintaining alignment will require determined leadership throughout the project.

While some ideas can be generated locally by individuals and teams, many novel solutions require people to look beyond established boundaries. Members of the Crossrail programme will be encouraged to break with traditional 'business as usual' practices and participate in an open minded, creative exploration of new possibilities.

To become effective innovators, people must believe that their organisation welcomes and encourages the generation of ideas 'from everyone and

everywhere.' Smart risk taking will be encouraged and embedded in corporate values. Ultimately, innovation needs to become an essential part of the mind-sets, routines and behaviour of people from different collaborating firms working as part of the same organisation.

OUR MODEL

Figure 2 presents the Crossrail innovation model and identifies the key building blocks required to achieve Crossrail's innovation strategy including:

- ▶ Innovation policy – a statement of intent and strategic commitment
- ▶ 3Cs of innovation – collaboration, culture and capability

- ▶ Innovation readiness levels – guidance on how ideas are selected and developed based on their readiness levels
- ▶ Methods – logical and systematic process for facilitating innovation from idea generation through to development, implementation and legacy

- ▶ Themes – all innovation activities fall under a theme associated with Crossrail's priorities and opportunities
- ▶ Roadmap – a visual tool that enables innovation to be managed as a portfolio

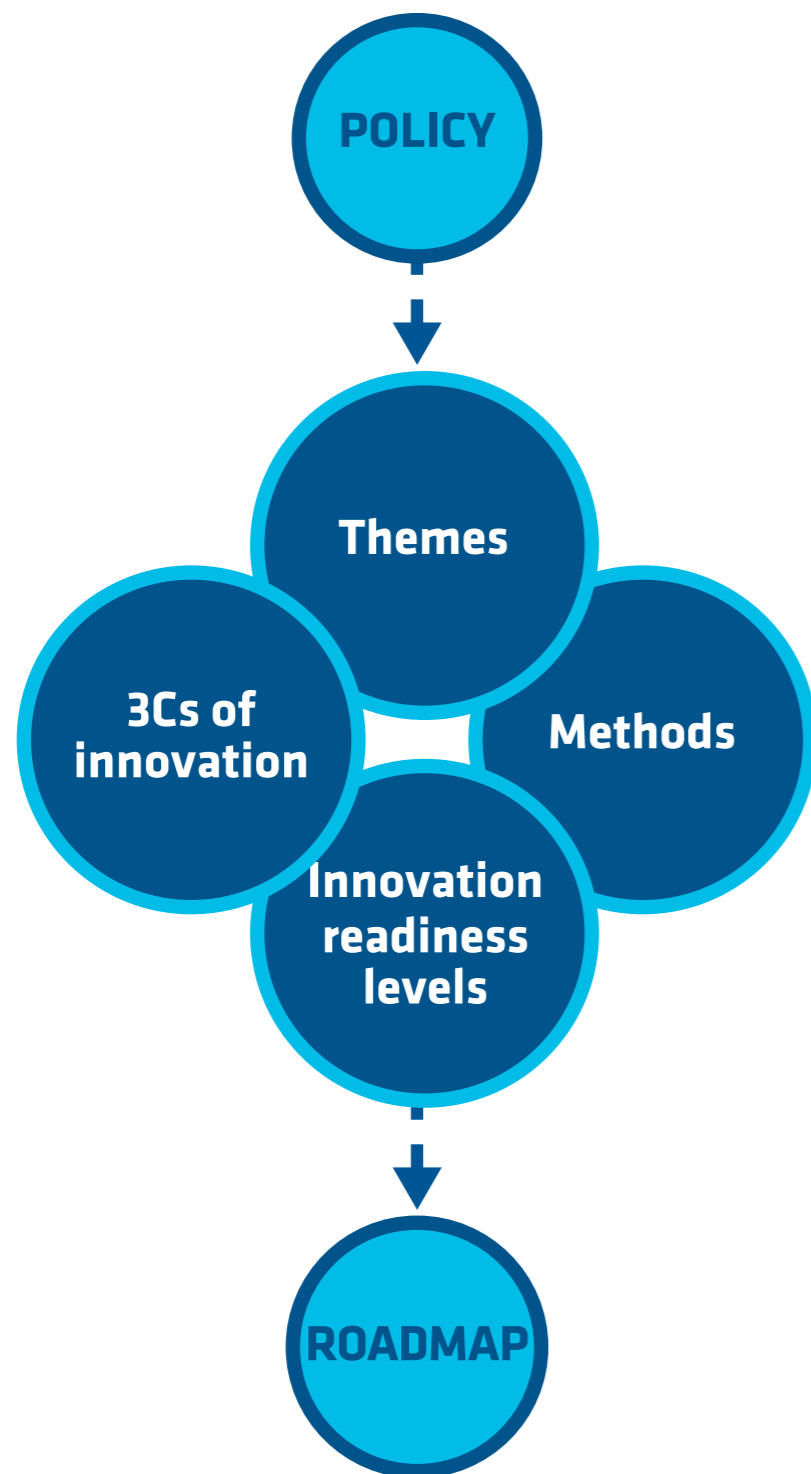


Figure 2. Crossrail's innovation model

OUR POLICY

Crossrail's innovation policy is a statement of intent and commitment to fostering, nurturing and incentivising innovation across the programme.

It consists of a statement of purpose, the policy's applicability and scope, the responsibility for delivering it, and clear principles to guide innovation investment

decisions. The policy has been tightly aligned with Crossrail's values of safety, inspiration, collaboration, respect and integrity.

THE 3Cs

Collaboration, Culture and Capability (shown in Figure 3) are the three key enablers fostering, nurturing and incentivising innovation across the Crossrail programme.

COLLABORATION

Crossrail is driving innovation by building effective collaboration among partners in the supply-chain, including universities, railway operators, users and other stakeholders. Collaboration among

partners varies depending on whether participation is open or closed, and whether governance is hierarchical or flat.

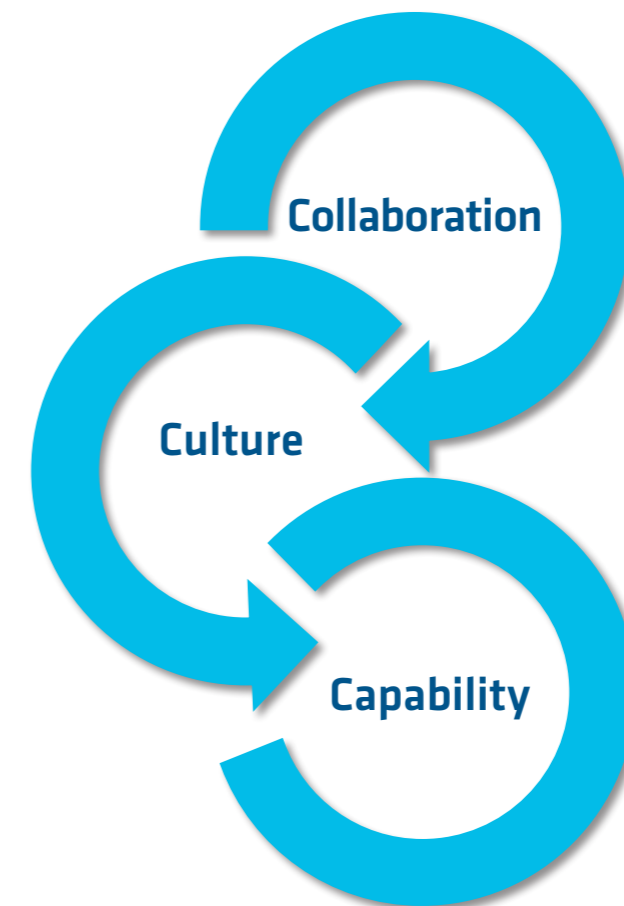
Crossrail has established a new governance structure, the Crossrail Innovation Forum, to help drive the collaboration required to execute its strategy. Collaboration consumes resources and budgets. Developing a funding model in collaboration with Crossrail's partners is essential. This funding

model is not limited to current stakeholders but can open up to access resources through R&D funding mechanisms supported by government bodies such as Engineering and Physical Sciences Research Council, Technology Strategy Board and EU.

The key elements of collaboration and organisation are:

- ▶ Partnering
- ▶ Funding
- ▶ Intellectual Property
- ▶ Governance

'Nurtured from the top-down, grown from the bottom up'



'We can't tender innovation, it requires partnership'

'Building internally, accessing external talent and complementary assets'

Figure 3. The 3Cs of innovation

CULTURE

Culture refers to the shared beliefs, values and attitudes that contribute greatly to successful innovation. It starts with top management support and cascades throughout the organisation. It requires the right resources, incentives and performance metrics. Key elements of developing innovation culture and environment are:

- ▶ Vision
- ▶ Leadership
- ▶ Strategic planning

The vision identifies the purpose and values of the organisation. For Crossrail, this means focusing our innovation efforts on delivering a world-class railway that fast tracks the progress of London. And in doing so, reflect this through our values of safety, inspiration, collaboration, integrity and respect. Leadership and strategic planning must encourage smart risk-taking, reward collaborative efforts and create the resources to support the generation and transfer of novel ideas and practices.

Innovation in Crossrail is the responsibility of everyone. The leadership team is creating a culture and environment conducive to innovation. Mark Thurston is responsible for leading the innovation programme and providing the resources to support the brokering of innovative ideas among organisations in the supply chain. Strategic planning will ensure that innovation efforts are connected to Crossrail's strategic priorities. An innovation roadmap is an important strategic tool for this purpose. Portfolio management tools are used to manage the innovation programme that flows from this roadmap.

The on-line Innovation portal www.crossrail.co.uk/innovation acts as a single point of access for managing innovation in Crossrail. It incorporates tools to capture and promote innovation including an idea management system, a stage gate development process and reward system. Key performance metrics are being developed to measure the success of the innovation programme and reward efforts.

Crossrail's innovation culture will:

- ▶ Involve people and organisations, helping them understand our innovation objectives and support leaders that take the right steps to support an innovative culture
- ▶ Inspire people through Crossrail's values, celebrating success and rewarding high-performance

CAPABILITY

Crossrail has assembled high-performance project capability through a rigorous procurement process. We have engaged world-class organisations as our contractors, designers, technology providers and supply-chain partners. To build our innovation capability, we will invest in:

- ▶ People & technical expertise
- ▶ Tools and techniques
- ▶ Data and information systems
- ▶ Training
- ▶ Facilities

People with technical expertise and experience are fundamental to the successful delivery of the strategy. They are the source of novel ideas and are central to turning these ideas into innovations. Crossrail is developing and honing our capability during the life of the programme. We are working with our suppliers and academic partners to bring in people with the appropriate capabilities to broker ideas and solve problems when they are encountered.

The innovation portal is now being piloted at our Liverpool St, Paddington and Connaught Tunnel sites. This new tool aims to provide a more direct route to implementation for innovative ideas across the Crossrail programme. We are working with our industry and academic partners to share and use technical data required for innovation project teams, while respecting each organisation's intellectual property rights.

We are collaborating with our partners in the education sector to provide targeted training in areas of need. Our Tunnelling and Underground Construction Academy (TUCA) provides an important example of an area where this sort of thinking has already been implemented.

INNOVATION READINESS LEVELS

Novel ideas, practices and technologies generated during the Crossrail programme are associated with varying degrees of innovation readiness. As shown in Figure 4, we have developed a classification based on five innovation readiness levels (IRLs)

The maturity of any potential innovation at Crossrail, and the resulting readiness, can be assessed using Crossrail's 3Cs of innovation (see Figure 5). For example, innovation in 'lorry drivers' safety training' is now an industry norm and has achieved its highest readiness level. Progress from one level to the next is a clear indication of Crossrail's maturity in:

- ▶ Collaboration: development of innovative ideas
- ▶ Culture: acceptance and adoption of innovation
- ▶ Capability: implementation of innovation

Innovations such as 'geothermal tunnel segments' fall into the 'radical' level of innovation readiness and require significant efforts in development

to implement in Crossrail. As maturity of the 3Cs increases and innovations progress to implementation, they may become an industry norm and leave a legacy for future projects. BIM for operations is a standard practice in adjacent industries such as automobile and aerospace but relatively new for the rail industry. These reapplied innovations are characterised by a medium level of maturity. Their reapplied nature means that organisations in adjacent industries have valuable experience that can benefit Crossrail. Rather than 'reinventing the wheel', learning from other innovators is the most effective way of moving to the next level of maturity.



Figure 4. Innovation readiness levels

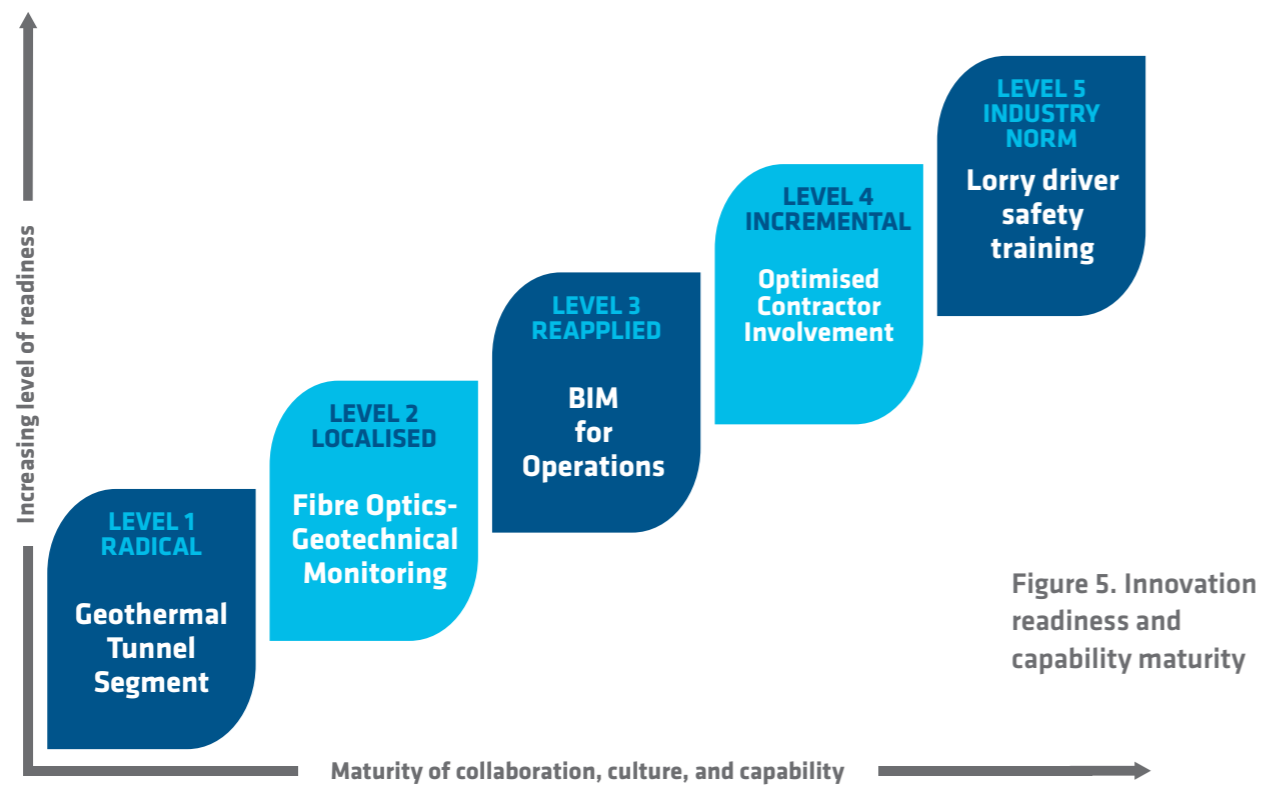


Figure 5. Innovation readiness and capability maturity

INNOVATION PATHWAY

IRLs provide a simple way of assessing how innovation is progressing on the path of maturity. Each may have a different starting point and follow its own distinct path. Some will become widely adopted as an industry norm, while others may be abandoned

after only passing through one or two stages. Innovation pathways identify and measure the progress of maturity. These pathways, as illustrated in Figure 6, are a result of an organisation's efforts (or investment) to turn a novel idea into an industry norm (or a legacy).

The Crossrail approach will assess the readiness level of an innovation and then track progress along these pathways using the 3Cs maturity model. Clear management guidelines help to identify the efforts needed to move forward.

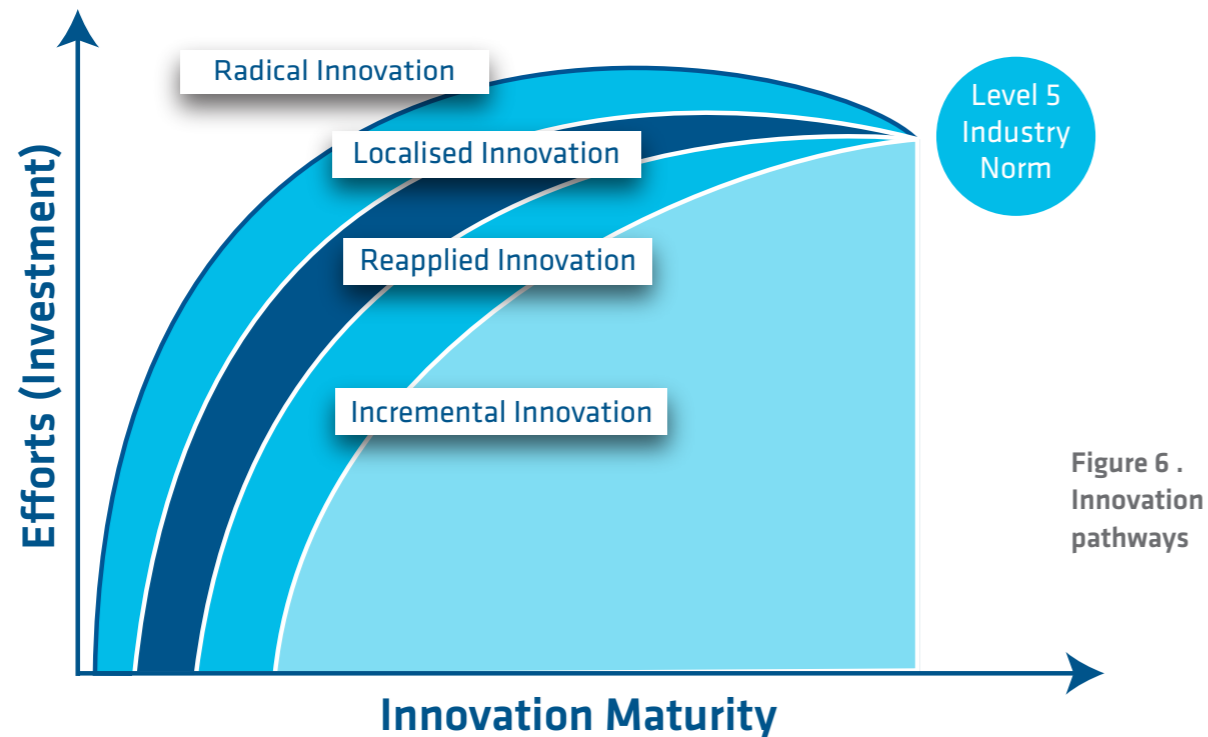


Figure 6 . Innovation pathways

METHODS

Figure 7 shows three connected and mutually reinforcing methods or processes to promote innovation in the Crossrail programme. The three methods are sequential:

- ▶ 1. **Open Innovation:** to connect and develop novel ideas with external communities
- ▶ 2. **Brokering Innovation:** to capture, coordinate and replicate innovation within and across the programme
- ▶ 3. **Innovation legacy:** to articulate and codify lessons for future projects

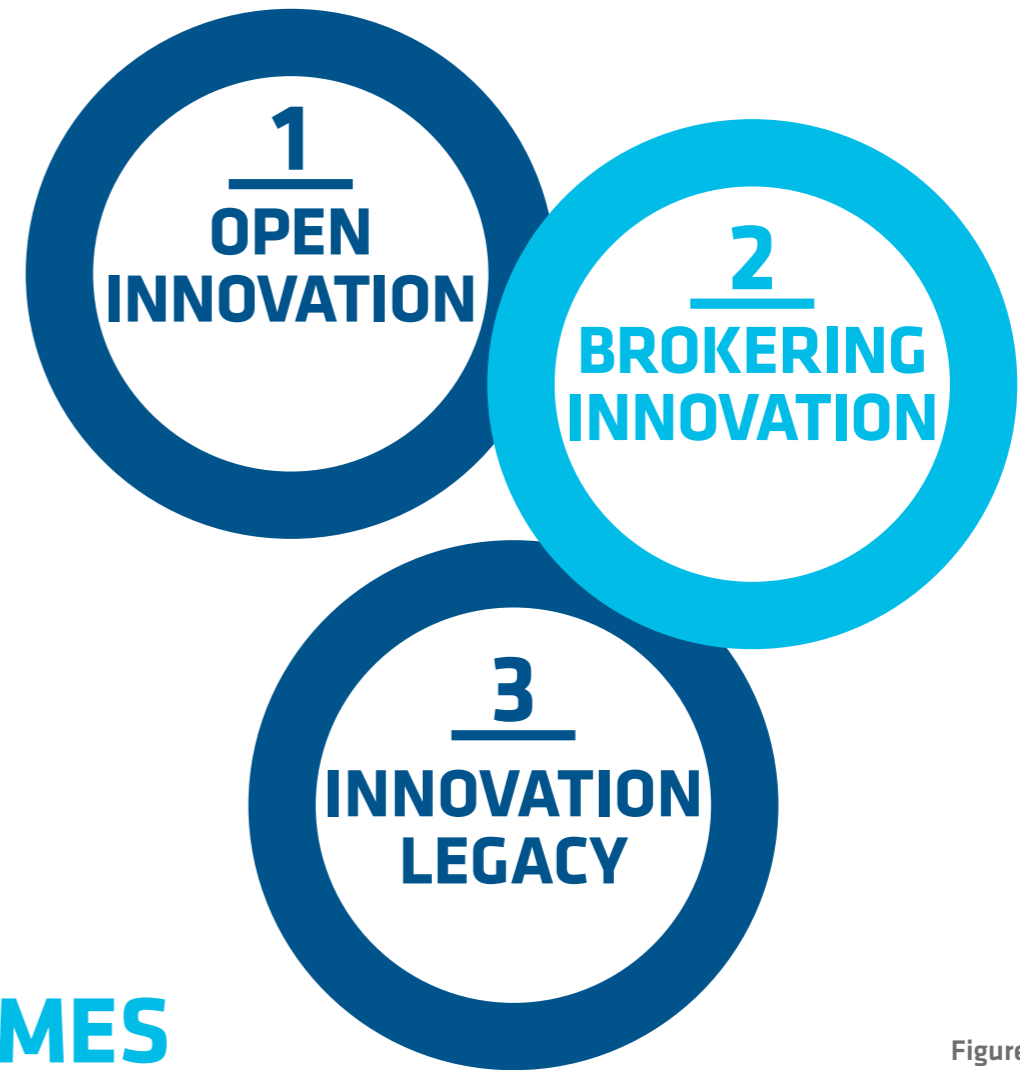


Figure 7. Methods of innovation

THEMES

Crossrail has identified three fundamental themes to provide direction.

These are:

Delivering efficiencies through the life cycle

- ▶ Safety
- ▶ Design for manufacturing, assembly and operations
- ▶ Integrated systems
- ▶ Asset management

Digital-physical integration

- ▶ BIM
- ▶ Smart Technologies

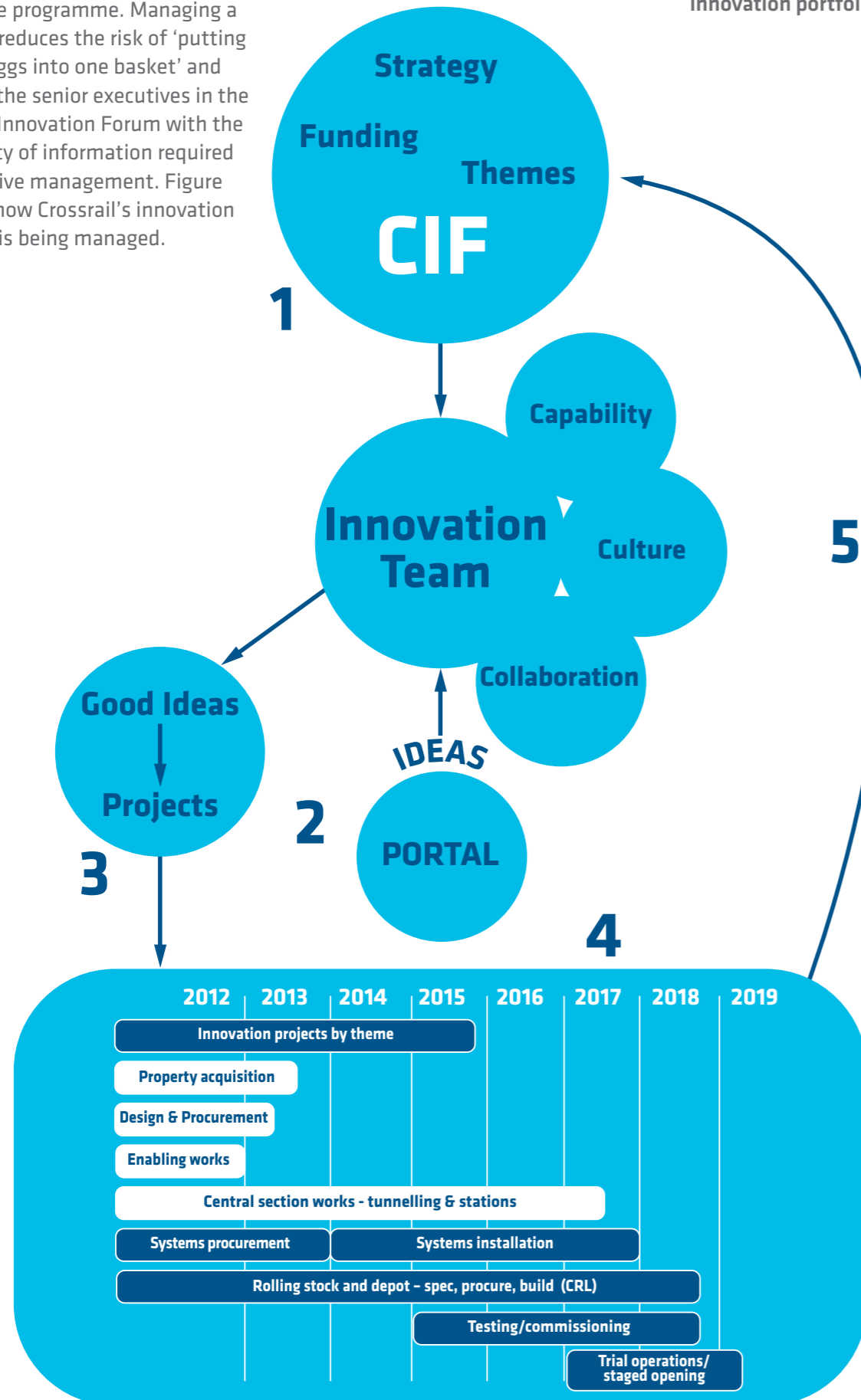
Sustainable solutions

- ▶ Economic
- ▶ Social
- ▶ Environment

PORTFOLIO

Crossrail manages innovation as a coherent portfolio of projects across the programme. Managing a portfolio reduces the risk of 'putting all your eggs into one basket' and provides the senior executives in the Crossrail Innovation Forum with the granularity of information required for effective management. Figure 8 shows how Crossrail's innovation portfolio is being managed.

Figure 8. Crossrail's innovation portfolio



1. The Crossrail Innovation Forum (CIF) is the executive body charged with providing governance and direction to Crossrail's innovation programme. It draws on Crossrail's corporate strategy to develop a core set of themes that the innovation programme will target. These themes organise Crossrail's innovation projects into a coherent portfolio and link these activities back to the overall strategy.
2. The innovation portal provides a platform to capture, track, and develop innovation across the Crossrail supply chain. The innovation team mobilises the Crossrail supply chain by using all internal communication channels to encourage stakeholders to submit their ideas for innovation into the portal.
3. The best innovations submitted to the portal are selected by the innovation team for

4. Once projects are selected, they are added to the innovation roadmap. The roadmap acts as a visual strategy tool. Clusters of projects are classified by theme and their schedule plotted by time. The initial innovation readiness level of the project is assessed and the target innovation readiness level is reported.
5. The roadmap is used to report information about the Crossrail innovation portfolio to the CIF. All projects are colour coded and clustered by theme, this enables the CIF to monitor and manage the distribution of the portfolio across the programme. Each theme has an information tag that reports key performance metrics (e.g. size of investment, number of projects, % of projects across maturity and IRLs). The roadmap is summarised by an information table that

development as projects. reports performance data across the whole portfolio. This combination of data enables the CIF to decide whether there is an appropriate balance between the innovation themes and determine whether the projects within these themes are aligned with Crossrail's organisational strategy. The quarterly CIF meetings provide the forum for making these judgements and for any re-alignment required in either the themes or the projects.

Crossrail's Innovation Team is currently collaborating with Imperial College London and University College London to pilot these processes across three of our sites: Paddington, Liverpool St and Connaught Tunnel. These pilots will provide data on how we can improve our innovation strategy before it is rolled out across the programme.



RESEARCH

Method

The core input to this strategy's development has been research conducted by Prof. Andrew Davies from the Bartlett Faculty of the Built Environment at University College London, Dr. Sam MacAulay and Dr. Dheeraj Bhardwaj from the Innovation and Entrepreneurship Group at Imperial College Business School, and the input of people at Crossrail, especially Mark Thurston and Tim DeBarro.

The research programme consisted of two components: 1) The Innovation Status Report; and 2) The External Scan.

Innovation Status Report

The internal scan carried out for the Innovation Status Report was designed to provide insight into what innovation existed within the Crossrail programme and how it was currently managed.

Relevant Crossrail documents, including the Delivery Strategy, Systems Integration Strategy and Lessons Learned Procedure, were reviewed.

In-depth interviews with 15 key informants were used to gather detailed information about innovation across key areas of the programme.

External Scan

The external scan was designed to gather evidence on how world-class organisations manage innovation.

Analysis was focused on organisations in the design, engineering and construction industries, asset owners (e.g. Network Rail, Infrastructure Ontario), professional institutions and forums, mega projects (e.g. T5, London 2012), as well as organisations in adjacent industries (e.g. Oil & Gas, Aerospace and ICT).

Detailed analysis was conducted of annual reports and corporate strategies, interviews with innovation leaders, academic literature, practitioner literature and personal experience.





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