



Innovation for the Future

Better delivery of Mega Projects

About Balfour Beatty VINCI

In 2008, Balfour Beatty and VINCI Construction set up a strategic alliance to deliver major infrastructure projects in the UK.

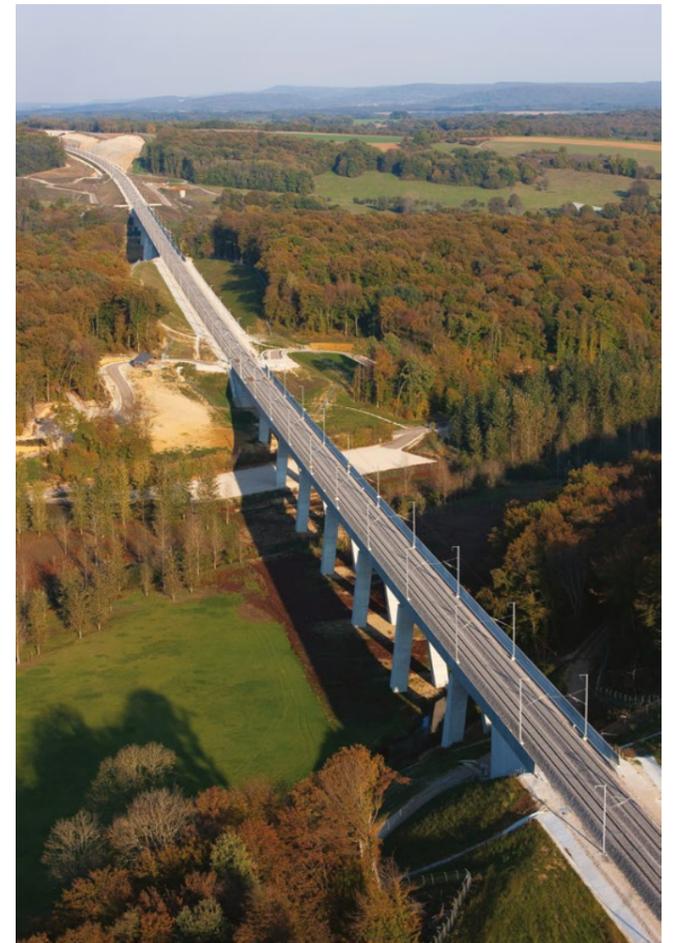
Balfour Beatty is the UK's largest infrastructure contractor and VINCI Construction is France's leading construction company and a major global player. Having successfully worked together on various Crossrail projects, we have recently been awarded the £45.4 million Smart Motorway Programme Package 1, which starts with the 18km stretch of the M5 between junctions 4a and 6 near the South West of Birmingham. Subject to statutory approval, we will then work with Highways England on the M6 between junctions 2 to 4 near Coventry and the M4 between junctions 3 to 12, Heathrow to Reading.

Balfour Beatty and VINCI have also joined forces to pursue work on High Speed 2, utilising the expertise acquired by both companies on High Speed 1 and VINCI's involvement in the €8 billion Tours-Bordeaux high speed rail project in France, and Balfour Beatty's extensive work on transport networks across the UK and overseas.



Executive summary

1. The UK has a number of mega projects in the pipeline, from the new runway in the south east, to the Thames Tideway Tunnel, a nuclear power station at Hinkley Point and new railways including High Speed 2 and Crossrail 2. Given the scale and importance of these mega projects to the UK, all the key players, including government, contractors and commissioners, need to play their part in ensuring that they are delivered as efficiently as possible.
2. Balfour Beatty VINCI believes that a key element must be to ensure that innovation is fully understood and exploited. However, all the evidence shows that this is not currently the case: the UK infrastructure industry is behind the curve compared to other sectors in key areas, for example, it is among the least digitised¹. As projects get increasingly larger and more complicated, improving the way we work in areas such as this will become more and more important.
3. As if the exciting mega projects in the pipeline alone were not a strong enough reason to innovate, we believe that with government and investors taking a measured approach to spending following the vote to leave the EU, the infrastructure industry must modernise in order to secure its own future.
4. Furthermore, in the light of the current skills shortage and uncertainty over Free Movement of People, it is equally important that we are able to attract new talent who currently perceive the industry as being old fashioned². We must be at the forefront of innovation to attract the multi-generational, skilled workforce we need.
5. To achieve this, we have to embrace technological advances and more collaborative ways of working. We therefore welcome the work Mark Farmer has undertaken under the aegis of the Construction Leadership Council, which considers many aspects of the construction business model: this paper is intended to complement that report.
6. Of course, industry cannot innovate in a silo. Change will only occur if it has client buy-in and if it has support and leadership from a government which leads by example and regulates where necessary.



7. There must be change in the way we work at all stages of the process: a move towards a more collaborative approach, where all parties work together to achieve the desired outcome. Innovation has to replace business as usual and become the new normal. To this end, this paper briefly considers how the following areas might evolve in order to deliver this change:

- Enabling contractors to innovate
- Skills
- Technological innovation
- Supply chain engagement

¹ McKinsey Global Institute Industry Digitization Index, June 2016

² CITB Construction Skills

Summary of recommendations

1. All mega projects should follow the example of Crossrail and develop and implement an innovation strategy.
2. The Government should maintain funding in R&D ensuring that it is accessible and operating within a long-term strategy to support innovation, whilst also setting an overall framework which effectively manages the risk that comes with these innovations and establishing a firm pipeline for infrastructure projects which builds and maintains investor confidence.
3. The Government should also consider establishing a mechanism to boost R&D in construction, such as France's R&D tax credit, in order to redress the decline in public funding of R&D in construction and bring the UK into line with other advanced countries which have dedicated construction R&D funding streams.
4. Contractors must be encouraged to suggest new ideas, implement them and share rewards even once contracts have been awarded and the supply chain established.
5. Contractors should be treated as partners in the delivery of mega projects: this is more likely to drive the delivery of high quality projects to time. Contracts should therefore be based on a set of common interests with well-defined payment structures and a balanced mix of incentives and penalties, rather than a position where fixed-price contracts, risk transfer, lowest-cost tendering and adversarial relationships are the norm.
6. Outcomes-based specification in contracts as opposed to overly-detailed specification should be considered where it allows for greater innovation and allows suppliers to adapt to unexpected challenges which emerge once contracts have been signed.
7. Those commissioning mega projects should consider a longer, more detailed planning cycle before construction begins, in order to save time and cost later in the process.
8. The incentives, both regulated and non-regulated, that govern infrastructure networks, should be examined in order to address the fact that they often promote low-risk behaviour and impact on procurement processes.
9. Barriers to developing and accepting innovative ideas must be challenged and regulators and other key players should be encouraged to facilitate innovation.
10. Those companies which pioneer innovative new ways to drive efficiency while maintaining quality should be drawn out for praise.



Innovation in the infrastructure industry

It is well documented that infrastructure is crucial to strong, sustainable, long-term economic growth³. In recent decades, governments around the world have recognised that by investing public money in mega projects they can better underpin and drive regeneration. In the UK, investment in infrastructure is a key component of the Government's strategy to rebuild and rebalance the economy, with unprecedented levels of public money going into new projects.

Mega projects are large-scale, high-risk and high-cost (typically over \$1 billion dollars) infrastructure assets, such as airports, tunnels, bridges, power plants or transport systems. They are complex systems that usually involve a coalition of clients and contractors, and are vulnerable to delays and over-spend; according to recent research⁴, 90% of mega projects over-spend their original budget. Failures in delivery can have serious long-term economic consequences and risk damaging public and private sector reputations. In the current financial climate, with the UK still emerging from the financial crisis and an uncertain economic outlook following the UK's vote to leave the EU, the public needs and expects the projects

being brought forward to be delivered on time and on budget. Furthermore, the Government has a duty to the taxpayer to ensure that major infrastructure projects deliver value for money.

To help government deliver and to improve what we do as an industry, we need better planning to allow time for crucial innovations. In order to be delivered on time and on budget, mega projects have to be innovative and flexible so that owners and contractors are able to deal with unforeseen events and embrace new opportunities that could not have been anticipated when the project goals were first defined. If we are to make significant and swift improvements to the delivery of mega projects on time and on budget, we need bold thinking.

Balfour Beatty VINCI believes that innovation⁵ is the key to improving performance, efficiency and delivery. In our experience, however, where mega projects are concerned there is often a reluctance to embrace new ideas or approaches, favouring instead the 'tried and tested' methods. As a result, designs can be finalised



³ Égert et al, Infrastructure and Growth: Empirical Evidence, OECD, 2009

⁴ Flyvbjerg, 2014

⁵ Balfour Beatty VINCI defines innovation as a new product, process, service or technology, or system of organisation that improves how a project is delivered. This can encompass both radically new ideas and incremental improvements to existing products, processes, and services.



too early and opportunities to improve performance can be missed: mega projects often have elaborate systems for managing downside risks, but are less sophisticated about managing upsides.

In part this may be because innovation itself is often associated with risk and cost overruns⁶. Suggestions to adopt an innovative new process or technology are therefore often met with reticence rather than enthusiasm. As Andy Mitchell, former Crossrail Programme Director and currently Tideway Ltd CEO said:

“When it comes to innovative ideas...on major projects the natural state of mind is to control risk by using the tried and tested”⁷.

Balfour Beatty VINCI believes that considering innovation in terms only of the downside risk associated with it, results in missing the opportunities that it can trigger.

The importance of innovation in mega projects was recognised in the UK in the 1990s, when the Latham Report⁸ and the Egan Report⁹ were commissioned to examine the reasons for the industry’s poor performance record and how to overcome it by developing new ideas. In response, clients for the construction of Heathrow’s Terminal 5 in 2008 and London’s 2012 Olympic infrastructure, promoted the use of a more systematic

approach to innovation and the construction industry engaged with new methods. Crossrail went on to develop the first innovation strategy for a mega project, which it is hoped will feed through to new projects in the pipeline. We welcome the fact that lessons have already been applied and shared with the Thames Tideway Tunnel and High Speed 2 schemes.

In summary, innovation does exist in the infrastructure industry, but industry often finds it difficult to innovate as quickly as it could and should: the industry still builds by pouring concrete and using other traditional materials and methods. Industry remains fractured, with procurement processes failing to incentivise innovation or research and design, in part due to slender profit margins. Furthermore, companies often view projects in isolation, a mind-set that works against the transfer of innovation from one scheme to another. It was in response to this challenge that VINCI introduced its bi-annual internal Innovation Awards allowing the sharing and dissemination of the best ideas across the company and ensuring that innovation is embedded across the organisation.

It is Balfour Beatty VINCI’s view that with billions of pounds being invested in infrastructure, a more strategic approach to managing innovation will release huge potential.

Enabling contractors to innovate

In our experience, the tendering process sets the scene for a project and offers the opportunity to create incentives and rewards thus encouraging innovation. We believe, however, that innovation should not come to an end once contracts have been awarded and the supply chain established. Even at this stage, contractors should be able to suggest new ideas put them into practice and share the benefits. This openness should continue throughout the process.

Too often though, the temptation for those running the bidding process is to control risk by using tried and tested methods. The exception to this has been Crossrail, where a novel approach, known as ‘Optimised Contractor Involvement’ was developed and introduced. This was one of the processes introduced by the Crossrail Innovation Forum, a dedicated team set up to drive and oversee innovation.

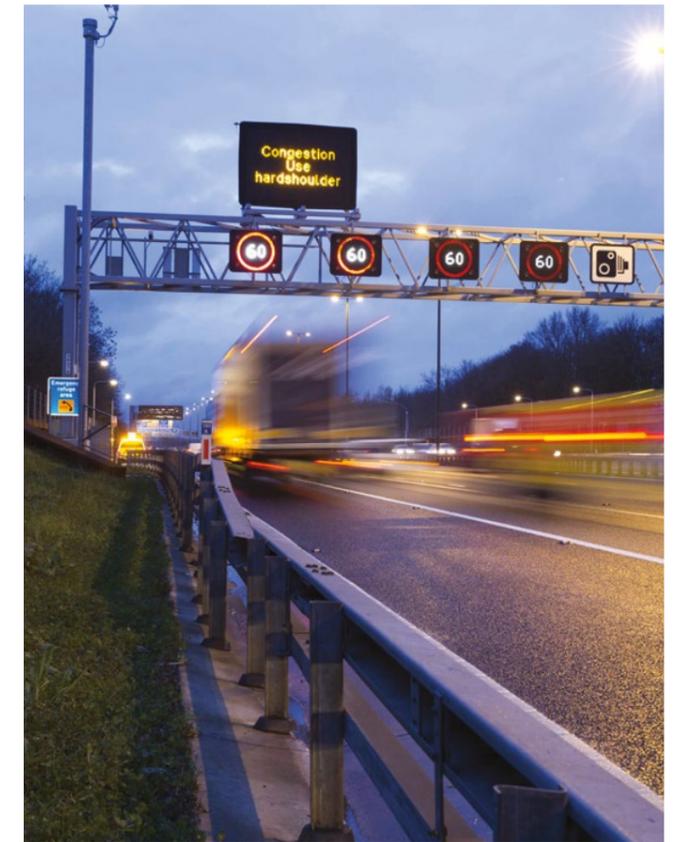
The aim of this new approach has been to incentivise contractors to innovate and find new ways to reduce risks and costs. It has meant that each contractor could input new ideas, while at the same time sharing the risk and rewards of doing so. In one example, joint venture partners found a new and more cost effective way to construct tunnels by boring them in advance of constructing the stations, rather than at the same time, as had been done previously.

We believe that contractors should be treated as partners when completing mega projects and that there is, in some cases, more that clients can do to drive innovation in key schemes. In our experience, rather than draconian contracts which penalise contractors for delays, it would be better to base contracts on a set of common interests, with a well-defined payment structure and a balanced mix of incentives and penalties. This would be a better basis on which to build an equal relationship and drive the delivery of high-quality projects to time. For example, incentives for early completion, or for benefit sharing (where the contractor suggests ways in which the project delivery could be improved), can help ensure that the owner and contractor are working together effectively. In some cases, bonuses are paid if projects are delivered on time and on budget. The design of the payment structure can also help to align incentives. For instance, rather than

the more traditional approach of paying when contracts are signed, mobilisation fees can be paid after key milestones, such as when contracts are in place for key equipment or the workforce is ready. A payment system based on completing milestones rather than end-of-month payments also motivates teams to achieve milestones and increase the chances of finishing early.

Balfour Beatty VINCI believes that rather than this concept being used with build-only contracts, this approach should be mainstreamed across the industry, coupled with Early Contractor Involvement (ECI) / Optimised Contractor Involvement (OCI) Design and Build.

Contractors should be empowered to innovate: we need to move away from the position where fixed-price contracts, risk transfer, lowest-cost tendering and adversarial relationships are the norm.



⁶ Van Marrewijk, 2008

⁸ Latham, 1994

⁷ Andy Mitchell, New Civil Engineer, 2012

⁹ Egan, 1998

Case study: SEA Tours-Bordeaux

Balfour Beatty VINCI believes that, even if the UK were to implement the changes recommended in this paper, it would still lag behind other countries in terms of innovation in the delivery of mega projects. Consider the example of high speed rail. One of the most significant projects in France in recent years is a 302km line, built by VINCI, which runs from Tours as far as Bordeaux in the south-west, and 38km of connecting lines to the existing rail network along the corridor. Tours-Bordeaux is one and

a half times as long as HS2's London-Birmingham route, but has been delivered more efficiently, both in terms of time and cost. Even taking into account the differences such as the extensive tunnelling and the significant cost and complexities involved in building new stations for HS2 (of which there were none with Tours-Bordeaux) and getting HS2 into London, the differences between the cost and time taken to deliver Tours-Bordeaux and the projected delivery of HS2 is significant.



We believe that there are three key reasons for the difference in the time and cost of delivery between the two schemes:

Consistent investment in research and development (R&D)

In the UK, the level of investment in R&D in construction and infrastructure by both industry and the Government has been steadily declining. On the industry side, this is largely explained by the tight profit margins the industry operates at – generally around just 2%, which does not provide sufficient funding for contractors to invest enough in innovation.

On the Government side, there has been a decline in public funding of R&D in construction over the past two decades and in 2003 the Government also stopped funding sector-specific R&D, making the UK the only advanced country in the world not to have a dedicated construction R&D funding stream. Up until this point it had invested £23 million a year in the construction industry, money that now goes into the Technology Programme, where construction competes with other industries. According to the Building Research Establishment (BRE), the UK spends just £43 million on construction R&D, compared to £206 million in France, and £750 million in Japan.

In comparison, France actively supports business investment in R&D activities, mainly through the R&D tax credit, which significantly decreases the cost of R&D activities in France. This is a key reason for the increasing importance of international collaboration to UK businesses and the ability to draw on resources around the world.

A longer planning cycle

Construction practice in France typically has a longer, more detailed planning cycle than major projects in the UK. On Tours-Bordeaux, for example, over three years were spent on the planning stage alone before construction began in 2012. Although many in the UK would balk at taking such a long time over planning without anything to physically show for it, our experience is that this approach can deliver substantial savings in construction, both in terms of time and cost where all the parties involved in the project are involved at an early stage. Instead, where the design of some projects in the UK is finalised too early, others are characterised by incomplete design and a lack of clear scope, which adds



significant cost and time delay later in the process. There are also many instances of costly over-specification, one of the reasons identified by Infrastructure UK as a cause of additional cost¹⁰ in the delivery of mega projects. Over-specification also, in our view, stifles innovation.

This is a key area where many mega projects could innovate to save time and cost later in the process.

Public buy-in

The Tours-Bordeaux scheme achieved significant public buy-in, due both to the visibility of the employment opportunities that were created (8,500 people were employed on Tours-Bordeaux at its peak), and to the seriousness with which VINCI took environmental concerns. Protecting the environment is a headline issue in France and any controversy could have posed serious risks. Intensive planning ensured, however, that Tours-Bordeaux had minimal impact on the environment, including all 220 protected species identified along the route. The project was the first to collaborate with and enlist the support of local environmental groups, a strategy which won widespread public support.

France, of course, also has a 30 year history of high speed rail, which means that the public has already seen the economic boost to cities such as Lille, Lyon, Marseille, Nantes and Bordeaux from being connected to high speed rail and so public awareness on the benefits to Tours-Bordeaux were already understood.

¹⁰ Stephen Dance, presentation to the All Party Parliamentary Group for Excellence in the Build Environment

Skills



Balfour Beatty VINCI believes that the UK's pipeline of mega projects represents a once in a lifetime opportunity to change the face of the infrastructure workforce. They will create opportunities across a range of sectors to train, upskill and inspire a generation, providing existing workers and younger people with the technical skills and employment opportunities to create fulfilling careers for those of all backgrounds. These projects have the potential to drive change in the infrastructure industry, bringing in the diversity currently lacking and ensuring that the infrastructure workforce better reflects the makeup of the country. That means more women, more minorities and more young people.

To attract these people, we need to innovate and we need to be more ambitious in how we go about sourcing talented individuals. To this end, we welcome moves such as the publication of the *Transport Infrastructure Skills Strategy*¹¹, which sets stretching targets to attract and retain a more diverse workforce. It also sets out how the Government aims to create 30,000 apprenticeships in the road and rail sectors by 2020 as well as how it will attract

more women and people from diverse backgrounds. Both VINCI and Balfour Beatty made a corporate commitment in 2010 to reach a target of an employee base made up of 20% women by 2015. Both companies exceeded the targets, achieving over 24% of female staff in April 2016. We recognise, however, that this is not enough and have committed to maintaining momentum and building on this progress. Balfour Beatty VINCI's own targets are to reach 30% female employees; 15% from diverse backgrounds; 5% from lesbian, gay, bisexual, and transgender backgrounds; and 4% disabled employees.

Balfour Beatty VINCI is determined to play its part in upskilling the industry and the next generation in particular. To this end, it has joined The 5% Club¹² – an industry-led campaign which aims to tackle the dual issue of skills shortages and youth unemployment by committing to meet a 5% figure of apprentices, graduate recruits and sponsored students within our workforce. We believe that developing home-grown skills is not only vital to the future of the infrastructure industry, but to the economy as a whole.

¹¹ Transport Infrastructure Skills Strategy, Department for Transport, 2016

¹² www.5percentclub.org.uk

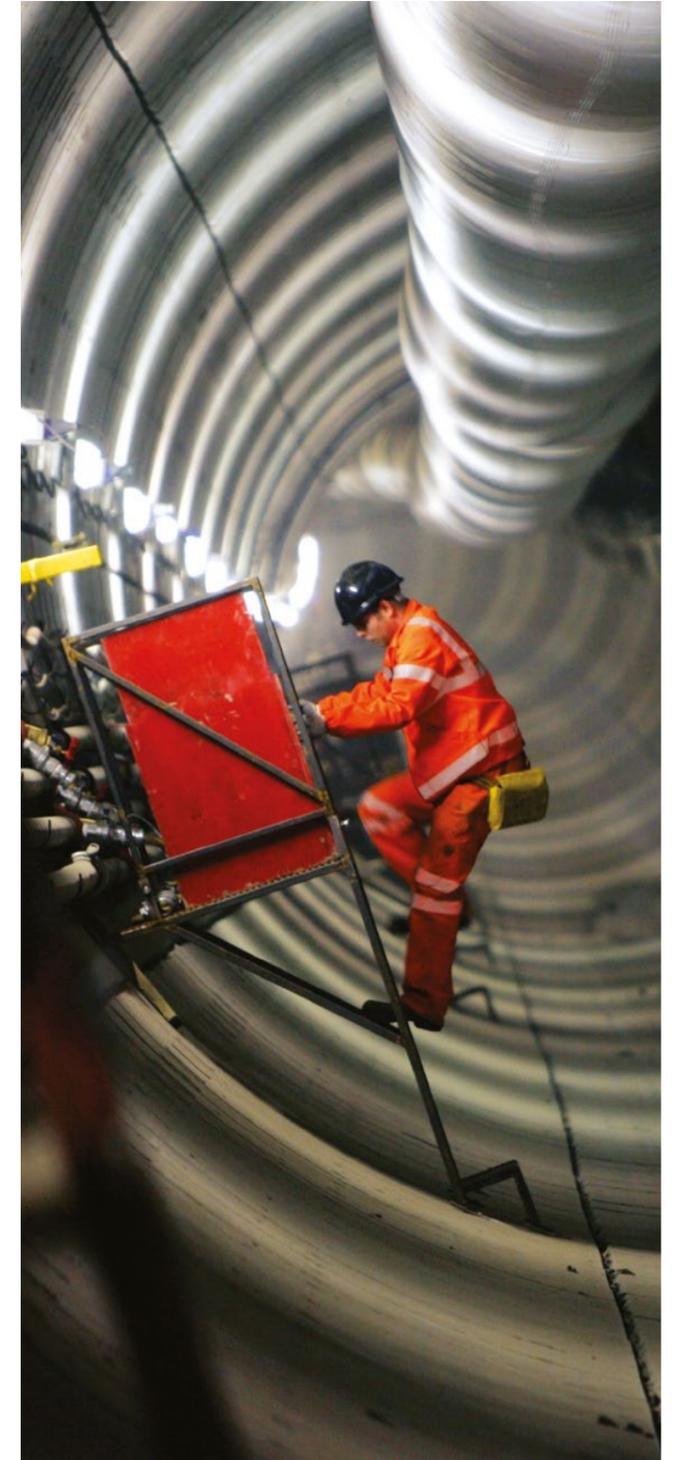
Technological innovation

Over the last decade, the world has seen a surge in new technologies that has transformed many industries. Although innovation has been slower in the infrastructure industry than elsewhere, there have been some significant changes which are changing the way mega projects are delivered. These changes span the whole process, beginning, for example, with technologies that impact infrastructure development at the design and planning stage, such as modelling software which allows for better visualisation, planning and forecasting. Over time, better software and modelling have been and will continue to be developed to make improved forecasts of costs and time required for infrastructure development. All these will lead to better designs and hopefully, faster approvals.

Technological developments have also impacted the actual construction of the infrastructure assets. This includes the use of different building materials and new and more efficient methods of construction, such as pre-fabrication.

Finally, there has been innovation in terms of data analytics which should make the operation and maintenance of infrastructure much more efficient. Through a network of drones and other sensory equipment, it is now possible to collect a lot more data than used to be the case. This in turn means better monitoring, better forecast of demand and supply and therefore, better solutions to match supply and demand. The improved data also means the earlier detection of defects to prevent wastage and downtime. For example:

- The use of Building Information Modeling (BIM) helps improve productivity as projects progress because all information is contained in a single location. BIM tools are based on 3D models. They help planners avoid design clashes, enabling them to sequence work on screen and allowing all possible solutions to be fully modeled, analysed and compared at an early stage. Some companies are exploring adding dimensions, such as cost, time, and resources, in order to smooth project management in the execution phase and facilitate maintenance during operations. Balfour Beatty VINCI has already been engaged in 4D planning at the complex Crossrail Whitechapel project. Modelling allowed us to maximise opportunities such as increasing the work area



¹² Transport Infrastructure Skills Strategy, Department for Transport, 2016

length by five metres, improving safety. We use BIM / 4D planning to recreate complex works in a virtual environment, showing points / times of interface between different suppliers or work packages and allowing us to pre-empt and resolve issues before going out on to site.

Since April 2016, BIM Level 2 has been a requirement for all government construction projects in the UK. The aim is to modernise the industry and ensure more collaborative behaviour, something which Balfour Beatty VINCI supports, just as we support the commitment to BIM Level 3 in the 2016 Budget. The adoption of BIM Level 2 means that firms that are not using it should no longer be considered for public sector work, a move which has made the UK one of the first to use legislation to ensure the use of BIM. However, in spite of this, BIM uptake remains low. According to the 2016 NBS National BIM Survey, just 10% of the construction industry was ready for the April deadline. Enforcing the requirement to operate at BIM Level 2 for those delivering public sector contracts will therefore be key to ensuring that the industry as a whole modernises, rather than just individual companies such as Balfour Beatty VINCI and its parent companies.

- The use of aerial, laser, and radar technology can rapidly improve surveying productivity. In the design of transmission lines, for example, the ground survey can be conducted with helicopter-mounted radars rather than having ground crews do manual surveys. Such non-invasive methods are ideal at sites of historic importance. For example, on Balfour Beatty's A63 improvement project, we utilised non-intrusive laser surveying for highly sensitive exhumation works, reducing the time and cost usually associated with surveys of this nature.
- Although it is very early, universities and companies are exploring the use of additive manufacturing techniques, such as 3D printing, as a next stage of innovation in building. The use of select design elements and fixtures could pick up rapidly, as 3D technology allows for new shapes and forms to be constructed efficiently.
- Challenging the status quo of existing technology should also be promoted where possible, as it can lead to important savings. The award winning introduction of the uphill excavator on the Crossrail C510 project is one example. The on-site team realised that the ability to excavate upwards from



existing tunnels at the base of the escalator shaft would generate significant time and cost savings over the normal process. In response, the Balfour Beatty VINCI and Morgan Sindall joint venture, BBMV, introduced a bespoke uphill excavator that is suspended from the ceiling of the construction tunnel and advances in line with the tunnel progression.

Balfour Beatty VINCI's parent companies both invest in innovation, and both have dedicated locations in the UK where we design, build and test new products:

- Balfour Beatty has a Rail Technologies office in Derby, where it employs around 100 people who carry out testing on innovative new approaches to ways of working on the rail network, for example, laser scanning. It is a dedicated Research and Development area where engineering teams work on developing the "next" innovation to support Railway Asset Management solutions. Also based at the innovation centre are Track Measurement Services, Signalling Monitoring and Software Development teams, who all underpin the Railway Asset Management Solutions. These teams deliver existing works on numerous projects both within the UK and abroad in Singapore and Hong Kong. Current projects include:
 - Specialist engineers, working with Bombardier, who will provide three new trains to Crossrail equipped with our unattended Infrastructure Measurement Systems (IMS). The systems include non-contacting monitoring systems for the overhead line system to undertake Height and Stagger measurements and the very latest Unattended Track Geometry System (UTGMS). They are also providing DataMAP visualisation software that allows run on run comparisons and correlation of multiple parameters at a given location that allow predictive maintenance to take place at the best time and overall maintenance costs to be minimised. This allows Crossrail's maintenance teams to record data that will identify possible issues before they actually take place. They are also engaged on major asset management programmes in the UK for NWR, Hitachi Trains (IEP).

- In South East Asia the team are working with SMRT Corporation to provide points condition monitoring that has helped capture system failures before they happen, helping the railway to remain operational.
- A comprehensive set of track recording and rail flaw defect inspection systems for MTRC in Hong Kong.
- VINCI has a Technology Centre, based in Leighton Buzzard. The Technology Centre's history of achievement includes:
 - VINCI was one of the first firms to offer cladding testing;
 - They were early adopters of Building Information Modelling;
 - Thanks to the work of the Technology Centre, VINCI are leader in materials technology;
 - VINCI became one of the earliest to achieve certification for Energy Management systems.

VINCI has a team of experts who can deliver solutions however complex, with a clear understanding of the regulatory, deliverability and cost parameters around which that solution is being created.

Supply chain engagement



Mega infrastructure projects are never delivered by just one organisation. Most have long and complex supply chains, which are critical to success. However, this can equally result in a lack of integration, which must be challenged. In our view, to deliver real innovation, change must extend to the way the whole supply chain operates. The planned mega projects present the perfect opportunity to encourage new thinking and to tackle the historically often isolationist approach that permeated the infrastructure industry in the past. In our view, this approach led to a focus on cost and individual company profits rather than overall outcomes and firms which were so focused on individual projects that they failed to listen to innovative ideas from their supply chain and to apply lessons learned from their own previous projects.

In our experience, however, part of the reason that ideas and technologies generated by the supply chain have not always been developed and integrated into projects relates in part to the incentives (regulated and non-regulated) that govern infrastructure networks. These can often promote low-risk behaviour and impact on procurement practices and interaction within the supply chain. This needs to be addressed, especially given that in the coming decades the UK will increasingly come to rely on innovation for schemes in areas requiring new and emerging technology, such as low-carbon, and in order to safely drive down costs.

Mega projects could and should act as a catalyst for change across the transport and engineering sector. Barriers to developing and accepting innovative ideas must be challenged and regulators and other key players should be encouraged to facilitate them. For example, Ofcom has a statutory duty to promote innovation which requires it to take a long term perspective on developments in its sector, resulting in solid and swift innovation in digital communications.

Balfour Beatty VINCI believes that those companies which pioneer innovative new ways to drive efficiency while maintaining quality should be drawn out as positive industry examples and that incentives should be created to encourage innovation.

A further barrier to the facilitation of innovation in the supply chain relates to the way in which some contracts are structured, for example, where they include overly detailed specification. We believe that greater flexibility through the use of outcome-based specification in contracts could allow for more innovation and allow suppliers to adapt to unexpected challenges which emerge once the contracts have been signed.

Finally, smaller suppliers face a particular challenge in successfully bringing forward innovative ideas or solutions, due to investors' inherent risk aversion. This makes it difficult to secure finance for novel infrastructure or for more innovative and inherently more risky technologies. We believe that part of the solution to this lies with the Government: it must maintain funding in R&D, ensuring that it is accessible and operating within a long term strategy to support innovation, whilst also setting an overall framework which effectively manages the risk that comes with these innovations and establishing a firm pipeline for infrastructure projects that builds and maintains investor confidence.

Conclusion

In conclusion, the Government's investment in forthcoming mega projects has the potential to be genuinely transformative to the country, industry and the economy. However, we believe that there are a number of changes that are needed to ensure the right environment for delivery could be created, for example, learning the lessons from the successful completion of previous mega projects, and planning for the long-term by ensuring investment in R&D and innovation.

All the key players must step up to the plate and play their part in modernising the industry and prioritising innovation. Crucially, we believe, they all need to work together to do so.



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