

INNOVATION: STEPPING UP THE INDUSTRY

OCTOBER 2015

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Foreword

We talk a lot about innovation in our industry. Most of the leading consultants include innovation as a key company attribute on their websites. Each year we celebrate innovation in the many awards ceremonies that take place around the world. And clearly there are plenty of examples of innovation in the projects we deliver. **Yet innovation is not routine. We struggle to build the processes that lead to innovation into our day to day work. Even though we know that we must innovate more if we are to secure the success of the industry, and our share of it, in the future.**

At the start of my presidential year I set my seven apprentices the task of understanding why we find innovation elusive and what we might do to address that – to make it part of our day to day business. I asked them to learn from the exemplar projects where innovation has delivered success for designers, contractors and clients. This is their report. I hope you find it informative and practically useful. By adopting its findings you will be able to drive innovation into your own organisation. And together we will reshape the future of our industry.



Professor David Balmforth
President
Institution of Civil Engineers
October 2015

Executive Summary

Business as usual will not drive our industry forward and as we step back to look at our shortfalls, we must step up to the innovation challenge. Investing time, money and resource into our efforts is a major part of this, but to truly foster innovation we must embrace it within our culture and create an environment where people are empowered to take forward their good ideas. This in turn will give rise to improvements in productivity and our reputation as an industry.

Businesses are tackling the innovation challenge in different ways; depending on their clients, their current capabilities and future aspirations, and their ability to invest. However, the common theme amongst innovators that are already winning is the creation of a culture that allows innovation to thrive, which centres on planning for innovation and allowing employees the time and headspace to deliver it.

Transforming construction is about more than just changing what we build. It is also about the way that we think about our problems and turn them into projects. Diverse teams, flexible project scopes and support from the top are all ways that we can encourage fresh, creative thinking and drive innovation. This report looks at the culture of our industry and from this, sets out the building blocks that will help individuals, teams, businesses, CEOs, government, clients and institutions to deliver value through innovation.

“
**WE MUST
STEP UP
TO THE
INNOVATION
CHALLENGE**”

Introduction

Manufacturing, pharmaceutical and technological organisations can all boast reputations as leaders of innovation, yet it is perceived that the construction industry lags behind. Have other sectors done something different, or has construction just not seen the same opportunities? These other industries have successfully systematised and invested in innovation and, crucially, accommodated and learnt from their failures.

With the UK's Construction 2025 strategy^[20] setting out an ambitious vision for the industry, there has never been a more inspiring time to innovate. Driven by a goal to achieve lower costs and emissions, faster project delivery and improvements in exports, we must become smarter, more sustainable and exploit our unique talents across the industry and beyond.

The civil engineering industry is often depicted as a risk averse business, where only small margins are to be made. As a result, innovation has not yet made it into the top priorities for most businesses, as organisations have been unable to find either the capacity, capital or capability to innovate. On top of this, the rise of the digital economy and smart construction technologies mean that the UK construction sector is at real risk of losing out on work to foreign competitors if it does not step up its drive and investment in innovation.

On behalf of the Institution of Civil Engineers (ICE), a year ago we set out to find what was hindering innovation and how we could facilitate and empower people to improve the industry. However, with a mixture of perceptions in the industry on what innovation is and what its value could be, there wasn't an obvious starting point. Interest in the role of innovation in driving the industry forward has picked up in recent years, such as in the Egan^[01] and Wolstenholme^[02] reports, but it has not yet gained the recognition and momentum required to convince every organisation to embed it into their business strategy.

“
THE UK CONSTRUCTION SECTOR IS AT REAL RISK OF LOSING OUT ON WORK TO FOREIGN COMPETITORS IF IT DOES NOT STEP UP ITS DRIVE AND INVESTMENT IN INNOVATION”

Over the course of the year, we sought out the leaders who have taken the plunge to embed innovation and are already reaping the benefits. This helped us to understand the key blockers and how they could be overcome to enable innovation. We studied ground breaking projects to see how innovation was being driven forward to achieve more than the status quo of keeping projects safe, on time and on budget. This has been realised through creating added value for teams and clients, improving productivity and facilitating a culture where innovation can thrive to exceed project expectations.

From understanding the what and the why of innovation, to how we can overcome the barriers, our work has enabled us to piece together the building blocks of innovation and identify tangible ways to set an innovation agenda for future construction projects. Our aim is to inspire, support and assist in the management of innovation and kick start a culture where innovation is embedded at every level. Innovation should be everyone's responsibility; and the time is now.

Beth Barnes, Peter Coppenhall, Takamborerwa Hove, Joanne Huett, Philippa Jefferis, Sophie McPhillips, Michelle Roche
ICE President's Apprentices
2014 – 2015

VISION

AN INDUSTRY WITH THE CAPACITY TO REPEATEDLY DELIVER UNCOMPROMISED QUALITY AND VALUE, AIDED BY A CULTURE THAT FOSTERS INNOVATION AND RECOGNISES THE TALENT WITHIN IT.

What is Innovation?

Innovation is the process of translating an idea into goods or services that meets a new or existing need and creates value. The idea could be, for example, a brand new product, the adaptation of an existing service, or a change to a management process.

Innovation is not necessarily invention and creativity may well lie within a different application of an existing approach or technology. Value may be seen in an improved company reputation or repeat work, time or cost efficiencies, improved safety, or an increase in paying customers, all of which ultimately result in increased profit.

Why Innovate?

- ◆ Deliver increased value and exceed client expectations
- ◆ Improve reputation and gain a market advantage by being a step ahead of the competition
- ◆ Reduce costs and maximise time efficiencies through increased productivity
- ◆ Drive improvements in safety
- ◆ Adapt to changing markets and diversify revenue streams by accessing new ones
- ◆ Reduce resource use, waste and carbon emissions
- ◆ Resist increased competition from other organisations
- ◆ Adapt to technological change and engage with the Digital Economy and the Internet of Things
- ◆ Develop and retain a skilled workforce
- ◆ Meet the targets of government strategies 'Digital Built Britain'^[30] and 'Construction 2025'^[28]



“
**ALL CONSTRUCTION
PROJECTS ARE UNIQUE,
SO IT IS TOO HARD
TO INNOVATE”**

Culture is at the Heart of Innovation

“All construction projects are unique, so it is too hard to innovate”. This is one of the perceptions of innovation that has developed in our industry. Sometimes it is that we are actually innovating as part of our day jobs, but just not recognising it and therefore not sharing ideas. Some of the biggest blockers to innovation can be ascribed to individual attitudes and industry culture.

We have grown used to a restrictive and risk-averse culture between different players in the supply chain. The client prescribes what they want. The consultant designs it. The contractor builds it. Then because of our traditional procurement processes, if something goes wrong, there is a scramble to make sure the right organisation stumps up the cash, rather than working together to find a solution.

Traditional procurement approaches push risk down the supply chain, yet any value gained from alternative solutions benefits the client or the end user, so there is no incentive for the supply chain to take on a risk and innovate. With early engagement, a collaborative approach, and a contract which reflects this by sharing the risks and gains of innovation, alternative solutions can be explored, with the potential to be cheaper, quicker or safer. The best results come when the value chain is aligned to the risk chain.

Within our teams and companies, we often work in silos, not sharing our ideas. Without a structured process or the tenacity of champions, ideas are not developed and progressed. With the uncertainty of innovation, and with positive results not always guaranteed, it can be difficult to accommodate new ideas amongst the pressure to complete on time and increase margins. We can start to empower people to innovate by giving them the space, time and an approval process. This needs to include clear feedback mechanisms, whether ideas are progressed or not, to not discourage the innovators. When someone voices an idea, can we all make the effort to pause for thought before passing judgement? Are we sharing valuable ideas with colleagues? Are there particular attitudes in our team which might prevent us putting forward our own ideas? What can we do to change them?

The nature of culture is that it is embedded in people and organisations so is difficult to change. We tend to continue with the same concepts and solutions unless we have leaders driving change at industry level and empowering our workforce. By recognising the value of innovation at all scales, building confidence in our talented individuals, and championing contracts which share risk and value, we can advance a new culture of innovation.

Building Blocks of Innovation

There is no single way to create an innovation culture, but rather a collection of changes that when addressed together, can influence organisations and our ability to innovate.

Presented here are the eight building blocks that can make this transformation happen, turn barriers into drivers and, most importantly, unlock innovation across the UK Construction Industry.



People

A successful project is often marked out as one with a highly skilled workforce, where there is diversity of thought and the project is driven by a strong leader or leadership team.

Teams need to be capable of delivering not just the “everyday” engineering solutions but effective alternatives also. This means teams made up of the right people with the right skills, providing a collaborative environment and facilitating innovative thinking – a diverse team. Above all else, people will be the driving force behind successful innovation. To allow for success, there is a need to attain the best from people by providing them with the necessary incentives to achieve.

Leaders

Leadership must be effective in order to drive innovation forward. Leaders need not necessarily provide the innovative ideas or solutions, but offer high level support in a clear and consistent manner, as well as setting out a vision for how their organisations should address the challenge. Organisations should therefore, provide their leaders with the necessary skills to support this, and allow an innovation culture to flourish.

Governance

Innovation can be systematised. An aligned governance structure ensures that from top to bottom, a company values innovation and sets it in the heart of their business. This should also set out feedback mechanisms to encourage innovators to keep producing ideas even if they are not all followed through.

Communication

Clear communication at all levels is key to embedding innovation within organisations. Innovation needs to become a core value which encourages, and is accepting of behavioural change, including sharing best practice and learning from failure. Communication skills should be greatly valued and training should not focus solely on technical skills.

Skills

The industry recognises that engineering faces a skills shortage. It has been reported that to deliver the expected programme of work, the UK will still need to recruit around 87,000 graduate engineers per year, in the next decade^[03]. In 2013 the industry was 36,000 short of this^[04]. This needs to be addressed, but can also be aided by building skills and capability into the existing industry professionals, to help enhance their current abilities.

Training and development

The skills shortage is further exacerbated by the decrease in training for workers, as the number of training days per worker per year fell by around a third (32%) between 2006 and 2012^[05]. A drop in training will further hinder companies' capabilities to meet the innovation challenge. Providing the workforce with the necessary training and development will help workers support their own success. It is certain that there is a need to invest today in the engineers of tomorrow.

“FOR CIVIL ENGINEERS I SUGGEST THAT INNOVATION IS BEST ENCOURAGED BY A STATE OF MIND WHICH TREATS EVERY PROJECT AS A PROBLEM TO BE SOLVED”

John Bartlett CBE – ICE President 1982-83
Inventor of the Bentonite-Slurry Shield Tunnel Boring Machine

Diversity

Engineers need to engage with and promote a diversity of thought, where ideas are challenged to provide the optimum solution. This can be accommodated with additional training for workers, but on the whole, diversity across the industry needs to be addressed. This is supported by a recent NCE survey, which reported that “although 85% of the heterosexual engineers surveyed said they would be comfortable with gay colleagues, one in ten said that gay employees should keep their orientations private so as not to make other colleagues feel uncomfortable”^[06]. A diverse workforce from a range of backgrounds, can draw on their varied experience, to create a wider idea pool and produce more innovative solutions.

“Not Invented Here” Syndrome

The ‘not invented here’ syndrome is the principle of not using a solution due to the origin of the idea i.e. it has come from outside of the team. This can cause problems when a less than optimum solution is adopted instead. There is not a single reason for this syndrome but many, including; lack of involvement from the offset, fear of infringement, lack of clear understanding of others work or jealousy. Businesses need to implement an approach that encourages sharing of ideas, not just internally, but from external sources too, ensuring the best solutions are supported and buy-in is achieved. Managers need to reinforce decisions to adopt innovative ideas, in particular when the decisions are questioned.

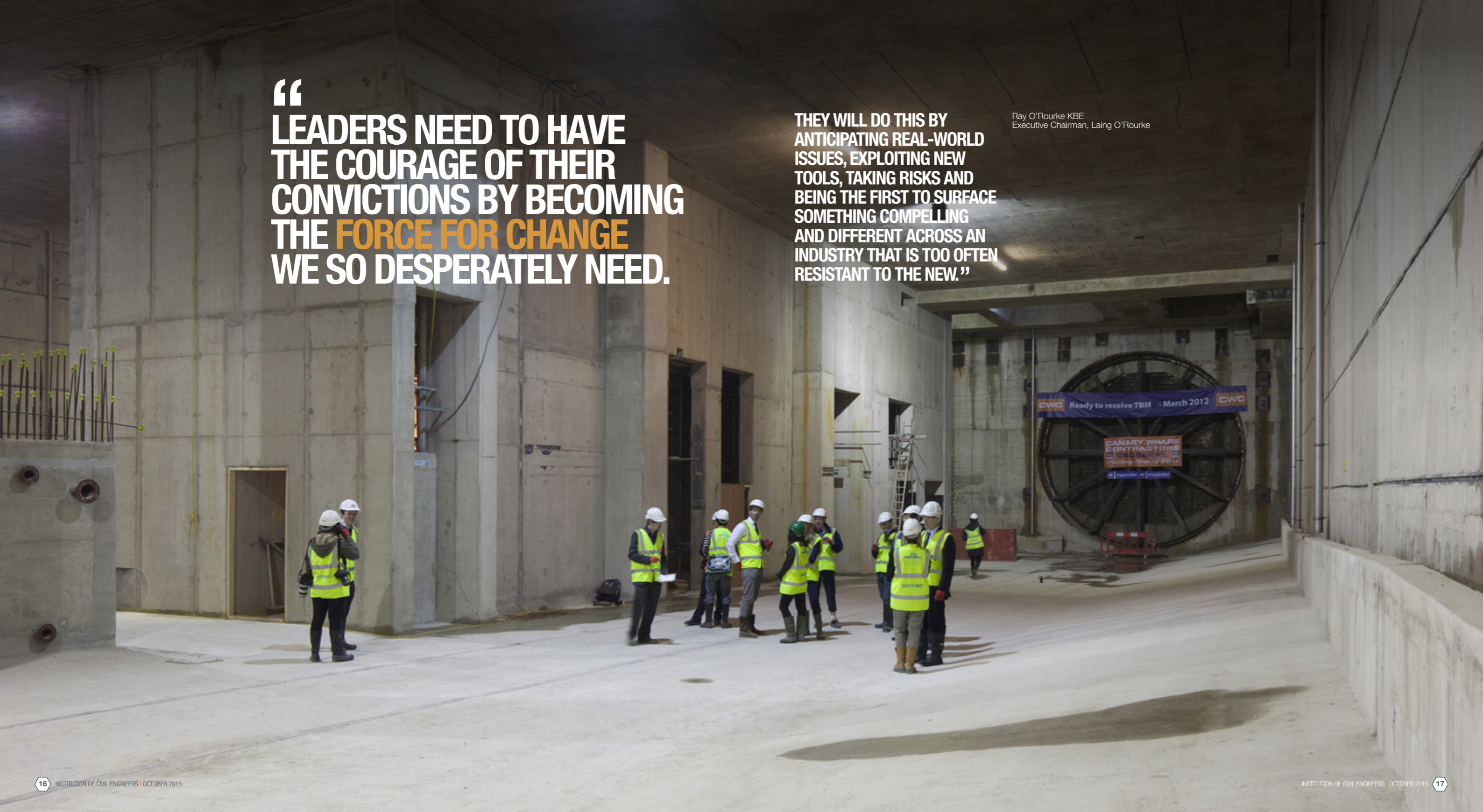
“Ugly Baby” Syndrome

Nobody wants to believe they have an ugly baby, and this can be described in the business context too, in that nobody wishes to believe their idea is a bad idea, especially when they have invested time and effort in the original concept. Business decisions need to be objective in order to choose the most successful solution. To accommodate success, ideas must be backed up with an evidence base, then shared so that a selection process can occur. This selection process ensures that there is a business case to take forward and the correct “baby” is supported. The ugly baby syndrome is pervasive and subtle and if not dealt with can destroy a specific innovation. It must be dealt with sympathetically but thoroughly and may require senior management reinforcement.

“
**LEADERS NEED TO HAVE
THE COURAGE OF THEIR
CONVICTIONS BY BECOMING
THE **FORCE FOR CHANGE**
WE SO DESPERATELY NEED.**

THEY WILL DO THIS BY
ANTICIPATING REAL-WORLD
ISSUES, EXPLOITING NEW
TOOLS, TAKING RISKS AND
BEING THE FIRST TO SURFACE
SOMETHING COMPELLING
AND DIFFERENT ACROSS AN
INDUSTRY THAT IS TOO OFTEN
RESISTANT TO THE NEW.”

Ray O'Rourke KBE
Executive Chairman, Laing O'Rourke



Strategy & Delivery

Innovation is not simply about generating ideas but also about demonstrating the business case and delivering an output. For the best results the process can be systematised.



This is observed more widely outside of the industry, where companies in the pharmaceuticals and agriculture industries have successfully implemented stage-gate processes to evaluate their ideas, produce prototypes and bring new products to market.

Innovation needs to be well managed and a defined strategy is a proven way of achieving this. There is a need for a process to determine whether an idea should be progressed or whether it should be parked for a more appropriate time. Defining periods for idea generation and for delivering innovation also allows companies to utilise their resources effectively and focus on implementation.

Equally, failure is part of the process too. Not all innovations will be successful and where appropriate feedback should be provided to encourage future engagement. Providing an incentivisation scheme can also help encourage participation. There are already a number of early adopters in the civil engineering industry who are realising the rewards of systematising their innovation into formalised innovation strategies and processes.

CASE STUDY Crossrail Limited [07] [08] [09]

Crossrail Limited is responsible for delivering Europe's largest infrastructure project, the new east to west route across London which will increase central London's rail capacity by 10%. The project involves constructing 42km of new rail tunnels and 10 new stations. The total funding envelope to deliver Crossrail is £14.8bn.

Crossrail quickly realised that innovation was central to completing the project successfully as well as achieving their drivers regarding; time, cost and safety.

Crossrail's Innovate18 programme has actively set out to establish "a process to promote innovation within and beyond the life of the project" and as part of this has developed and implemented a formalised innovation strategy based on an open model which

shares successful ideas across the different projects. Crossrail's innovation strategy, including team structure and a stage gate process for ideas, has set out a structured process for innovation.

Their five staged process starts with an idea, which is then expanded with further detail, challenged and then if successful, implemented. Crossrail also provides the opportunity for funding.

To be successful, innovation and collaboration has had to be well supported and embedded within their culture. Within the project there is good evidence of success, particularly in terms of embracing change, with a strong uptake of new technologies and processes. Supporting this, the Innovate18 portal, has published over 700 ideas implemented across the project.



“
IN DELIVERING LONDON’S NEW
EAST TO WEST RAILWAY
**CROSSRAIL HAS SOUGHT TO
RAISE THE BAR** IN HOW WE BUILD
SMART INFRASTRUCTURE IN
THE UK, LOOKING AT THE WHOLE
LIFECYCLE OF THE RAILWAY FROM
PLANNING AND CONSTRUCT
TO ITS LONG TERM OPERATION.

By thinking differently about how we share ideas and implement them, we have created a culture that has already brought improvements in safety, increased efficiency and delivered more sustainable solutions; we have proven that there is a direct link between innovation and world class performance.”

Andrew Wolstenholme OBE
Crossrail Chief Executive

Procurement

Procurement strategy can greatly influence the scope and capacity for innovation within a project. Often the greatest opportunities for innovation to occur are during the initial concept phase. Critically, this can either foster or stifle innovation. Several elements in particular play an important role:

01

The Role of the Client:

The client's ability to steer project direction is a key facilitator in allowing innovation to take place. Over the last few years, the concept of the "Intelligent Client" has been born with a growing desire for clients to be more collaborative in their approach, working together with designers and contractors and remaining open-minded when it comes to alternative solutions^[10]. In defining the scope, emphasising the required outcome and needs, rather than being overly prescriptive with a required solution, provides an opportunity for the supply chain to be creative in their delivery. Targets such as low carbon requirements within project scopes have been a proven driver for innovation in projects set out by Olympic Delivery Authority and Anglian Water^[11]. Clear objectives and requirements within the project scope also allow the supply chain to better align their goals with those of the client.

02

Contract Types

Traditional construction contracts push risk further down the supply chain rather than sharing it. Under these contracts when a consultant or contractor innovates, the client and the end user receive the reward and value, but the contractor carries the risk associated with the uncertainty of innovation. There is therefore a disincentive to innovate. For innovation to thrive incentivisation has a role to play. Contracts with pain-gain mechanisms can and have been used as motivators for all stakeholders to innovate by sharing both successes and failures as well as spreading the risk and opportunity. Thames Water has set up the Eight20 alliance, in which any savings made against the business plan will be distributed between the parties in the alliance. Contracts can also be used to inspire desired behaviours during their execution especially when innovation is a goal. Collaboration is an example of a behaviour that can be engendered through the contract^[12]. NEC3 contracts provide an example of a contract type that seeks to enhance collaboration when effectively applied.

03

Integrated Supply Chain

The construction industry is fragmented with many small and medium enterprises^[13]. Smaller companies may not have the margins to invest in innovation themselves, but may have the insight, expertise and agility to see opportunities and put forward ideas. Early Contractor Involvement (ECI) allows diverse viewpoints to be shared at an early stage when there is the greatest opportunity to look for alternative solutions. Matched funding initiatives from larger contractors or clients can harness these ideas and encourage the successful delivery of shared benefits.

“**THE APPROPRIATE TERMS AND CONDITIONS FOR EACH PROJECT WILL NEED TO BE DETERMINED BY THE CLIENT. MATCHING THE WAY IN WHICH CLIENTS EXPECT THEIR SUPPLY CHAIN TO BEHAVE WITH THE CHOSEN TERMS AND CONDITIONS IS IMPORTANT AND WILL CEMENT PARTIES' EXPECTATIONS AT AN EARLY STAGE.**”

Those conditions will in turn need to allow for things this report touches on – for example incentivisation, promoting collaboration, encouraging dialogue, allowing for the sharing of required outcomes and needs, sensibly dealing with risk distribution, allowing for alternative payment mechanisms including target cost and so on.

The NEC3 family of contracts allow for all of these and more. Recommended in the Latham Report, endorsed by the UK Government and more recently to be adopted across the board by the Hong Kong Government, this flexible set of contracts for buying goods, works or services is rapidly becoming the contract of choice for intelligent clients and their supply chain.”

Robert Gerrard
NEC Users' Group Secretary



CASE STUDY London 2012 Olympic Velodrome ^[14]^[15]

The successful delivery of the London 2012 Olympics highlighted the influential role that clients play in project delivery. A great example of this success was demonstrated during the construction of the Olympic Velodrome. Through the Olympic Delivery Authority (ODA) setting out a clear project scope, creating a collaborative environment and encouraging contractor involvement, significant savings were achieved ^[14].

By challenging aspects of the schematic design, the Contractor convinced the ODA to look at alternative roof solutions advocating the use of cable net roof over a

conventional steel truss ^[15]. This led not only to considerable savings in the embodied carbon of the structure, but also to a reduction in construction time. Emphasising performance criteria in the project scope meant the designer, contractor and the supply chain were given the opportunity to be creative with their proposal for the Velodrome.

The NEC3 Option C contract was specifically chosen for the project as it required the client and the supply chain to collaborate and targets to be established for project delivery within the contract, incentivising value creation.

Investing in Innovation

Investment is a crucial input in innovation. Investing in people and platforms, as well as traditional Research and Development initiatives, will create an environment where innovation can thrive:



01

People: Innovation is driven by people having good ideas. Good ideas occur when there is a focus on outcomes, there is a culture of challenge of concepts, and there is space in the delivery programme for people to think and test new ideas.

02

Incentivisation: Individuals, teams and organisations should be recognised and rewarded for good ideas. Providing worthwhile incentives is a good motivator to ensure ideas are continually generated. These do not have to be financial incentives. Company awards can be a great motivator. Encouraging and supporting submissions for external awards is also good.

03

Acquisition of new technologies, materials and processes: Upfront investment in new technologies and software will facilitate innovation, drive efficiencies and generate value for businesses.

04

Acquisition of Data : Good data enables projects to set off on the right foot. It is vital that there is investment in good data acquisition from the offset, as well as in an adequate capability to correctly interpret data. This ensures there is an application of sound science in the problem understanding process.

05

Marketing : From identifying gaps in the market, to celebrating success, the promotion of innovation both internally and externally is a key component in the innovation cycle to ensure it becomes embedded.

06

Innovation and Knowledge platforms: The ability to capture ideas for application in future projects or learning through forums should be considered for investment. Providing platforms that allow for knowledge sharing and feedback can help ensure good ideas are not lost.

07

Research & Development (R&D): Research and Development provides an opportunity for ideas to be tested and prototyped to ensure suitability for mass application. The opportunity provided by R&D to trial ideas or carry out a pilot project makes it an integral part of the innovation process.

Knowledge Sharing

Traditionally, the construction industry has not been particularly proactive in sharing and learning from its successes and failures. The lack of knowledge capture from previous projects results in 'reinventing the wheel' and repeated mistakes.

While many companies have started to tackle knowledge management within their own teams and organisations, there is little shared with the rest of the industry due to valid concerns over market competition and intellectual property. The 'not invented here' syndrome means companies can be reluctant to accept new approaches developed elsewhere. Knowledge sharing leads to better-quality information, available to the right people at the right time, enabling the industry to effectively harness ideas and promote innovations at all levels.

Knowledge sharing also promotes creative thinking and knowing what your competitors are doing pushes others to think outside the box and come up with better ideas, thus, moving our industry forward. Collaboration between companies and different groups including academia, consultants, contractors and institutions results in a wider ideas pool to draw from, faster development of ideas and shared benefits, with the industry moving forward together.

A known inhibitor for knowledge sharing is the "knowledge is power" mentality. While some may think this affects companies externally, it is also a huge blocker internally. Cultivating strong lines of communication within companies and encouraging knowledge sharing externally, can lead to greater collaboration and innovation.

“**KNOWLEDGE SHARING LEADS TO BETTER QUALITY INFORMATION, AVAILABLE TO THE RIGHT PEOPLE AT THE RIGHT TIME, ENABLING THE INDUSTRY TO EFFECTIVELY HARNESS IDEAS AND PROMOTE INNOVATIONS AT ALL LEVELS**”

Research & Development

Currently, the UK construction industry does not invest heavily in Research & Development (R&D). This is proven at both a national level where construction lags behind other industries and internationally where, despite increased investment, the UK as a whole “ranks only 13th within the EU member states and has not currently set a target for 2020”^[16] for the level of R&D intensity as a measure of GDP, for all industries”.

The Europe 2020 strategy has set a target for all EU members to achieve 3% of GDP being invested in R&D activities^[17], but in 2011 this figure for the UK was recorded at only 1.77%^[18]. On top of the UK’s European competitors, China is aiming to invest 2.5% of their GDP in R&D by 2020, South Korea is aiming for 5% by 2022 and Brazil a target of 2.5% by 2022^[19].

As such, there is a clear need for the UK construction industry to step up its R&D activities to be able to compete in the innovation challenge. R&D does not however have to be kept in-house by companies. An effective way to manage the long term resource requirements can be through setting up partnerships with academia, where R&D skills are more commonly available and where help can be provided to successfully achieve a marketable output. Commercial success arising from R&D could help to encourage further and future buy-in as well as additional investment for research activities.

There are a number of existing partnerships emerging between industries and academia. This can also provide a secondary benefit by allowing companies to influence the talent and skills being developed through higher education. For these partnerships to succeed there needs to be a clear strategy and effective communication process in order to ensure advances are translated into the industry.

R&D targets:

Europe 2020

3.0%
GDP

China 2020

2.5%
GDP

South Korea 2022

5.0%
GDP

Brazil 2022

2.5%
GDP

CASE STUDY

University of Cambridge Innovation and Knowledge Centre^[20]^[21]

Cambridge University’s Innovation and Knowledge Centre (IKC), named as the Cambridge Centre for Smart Infrastructure and Construction (CSIC), is an initiative from the UK government, jointly funded between the Engineering and Physical Sciences Research Council (EPSRC) and Innovate UK. The centre has also attracted £13.8 million of funding from non-IKC research grant funding, some of which has come directly from the civil engineering industry, challenging the perception that the industry does not have the capital to invest in R&D^[20].

The main focus of the centre’s research is on transforming infrastructure through smarter information. This is based on the desire for the sector to track their assets in real-time. Although the civil engineering industry is aware that it is constructing long life assets, the opportunity to monitor

these assets over their lifecycle to gain an understanding or knowledge on their long term performance and management is currently not being exploited to its full potential.

One successful example of the CSIC’s work is their use of fibre optics within piles. Fibre optics due to their low cost and ease of attachment can be used as a tool to provide real time data on the performance of an asset. The CSIC’s use of fibre optics within bored piles allows for greater quality assurance and control during piling. It also provides the ability to monitor pile performance during loading. Hence, the data collected from the fibre optics can be used to produce more efficient designs. In particular, to prevent piles from being over designed and conversely to allow for immediate action to be taken if they appear to be under designed^[21].



“**INVESTMENT IN RESEARCH AND DEVELOPMENT** BY THE CONSTRUCTION INDUSTRY HAS BEEN VERY LOW IN COMPARISON TO OTHER ENGINEERING SECTORS. MODERN INFRASTRUCTURE AND CONSTRUCTION CAN BENEFIT ENORMOUSLY BY INCREASING R&D INVESTMENT TO EXPLOIT THE USE OF NEW TECHNOLOGIES IN SENSOR AND DATA MANAGEMENT TO PROVIDE INNOVATIVE NEW SOLUTIONS, THEREBY MAKING RADICAL CHANGES TO THE CONSTRUCTION AND MANAGEMENT OF INFRASTRUCTURE.”

Professor Robert Mair OBE FREng FRS
Head of Civil & Environmental Engineering
at the University of Cambridge

Standards & Regulation

Standards and regulations that are highly prescriptive can stifle innovation. There has been little incentive or reward for exceeding or diverting from standards, encouraging the same tried-and-tested solutions to be re-used to meet requirements and prohibiting advances in technology from being driven forward, especially when not supported in regulated industries.

However, in other cases, the regulator can become the driver for innovation. Ofwat, the water industry's regulator, recently reduced the maximum prices that water companies could charge their customers, to create better value for customers and ensure cheaper bills^[22]. This has forced the water companies to think differently and find efficiencies in order to deliver the same service for less, but has also encouraged them to challenge standards by seeking alternative ways to meet the regulator's stringent requirements. By organisations collaborating with regulators to share expertise, it is possible to demonstrate that standards can be deviated from without compromising safety, introducing increased risk or increasing costs.

Throughout the industry, fast-paced changes in technology and processes are resulting in dated standards which are insufficient in keeping up with developments. To aid this, Publicly Available Specifications (PAS) have been developed. These can offer quicker routes to standardisation, typically taking just nine months from launch to publication. The PAS provides a sponsored route to standardisation; establishing standards in a sector, while implementing a rapid yet reliable standardisation solution^[23]. Consequently, they are helping organisations to meet regulatory obligations by providing product specifications, codes of practice, guidelines and vocabularies.

CASE STUDY Aerospace Industry ^[24] ^[25] ^[26] ^[27]

The aerospace industry is arguably considered as one of the most innovative industries despite being heavily regulated. The industry must enable the safe and rapid worldwide transit of customers, which is managed through a combination of working with their competitors to instil confidence that they are competent^[24], as well as with the regulators to create acceptable ways to evaluate new methods, such as on the Boeing 777^[25].

The aerospace industry itself notes that regulatory and legislative pressure are one of the main barriers to growth^[26] and for the industry to continue to improve, there is a need to work together with their competitors and with the government to help shape regulations and share technology openly^[27].

Embracing Technology

BIM, sensors, and smart construction technology will transform the way we design, construct and manage assets. With the rise of the digital economy and the need to move towards the Digital Built Britain agenda, embracing the technology that is already available to us in this industry will enable innovations to move from concept to reality.

BIM and other advancing computing systems should be exploited to the highest degree to enable new innovations to be implemented throughout the industry. BIM offers the ability to build projects multiple times virtually allowing for different approaches to be tested, problems to be identified and issues to be resolved before then being built in reality. This allows ideas to be developed in a safe environment, complex construction processes to be visualised, and risks to be identified and mitigated within a digital space.

Exploiting the technology available means designers have the capability to become predictive. Sophisticated sensor technology allows assets to be monitored during construction, giving real time results to feed into the ongoing works plan, then after the construction phase is complete to inform the maintenance strategy and reduce operational costs.

One of the government's Construction 2025 targets is to achieve 'a 50% reduction in the overall time from inception to completion for new build and refurbished assets'^[29]. Off-site manufacturing has the potential to change the way the industry delivers projects and will be crucial in making progress against this target. This process has many benefits: minimising production on site reduces risks thus making sites safer, projects can be constructed more quickly and more cost-effectively, and the automated factory process allows material requirements to be calculated with absolute precision removing defects and eliminating waste from the outset.



CASE STUDY The Leadenhall Building^[29]

The Leadenhall Building is a 52 story building in Central London that is 224m high. The building occupies the entire footprint of the building thus making material storage difficult on site. Off-site manufacturing allowed the materials to be delivered at the optimum time for installation. 85% of the building was manufactured off site including a steel frame weighing 18,000 tonnes, 75,000 m² of cladding, 11,252 pieces of structural steelwork and a total piece count (steel, concrete and services) of 39,283 units which were all manufactured off-site and then assembled.

The innovative crane strategy was integral to the project climbing cranes internally with a final height above ground level of 224m. The flooring was constructed using manufactured composite floor planks which achieved 700m² of floor area to be placed in 1 day this including 72 individual units using a gang size of 6 operatives. Ultimately, the Leadenhall building used many combined solutions which utilised prefabrication and innovation with a new type of engineering approach taking advantage of 'digital engineering' (or BIM) and off-site manufacturing.

Key Messages

CULTURE IS AT THE HEART OF INNOVATION

From conflict-saturated contracts, to a certain apathy towards new ideas, the traditional culture that has developed in the industry stifles innovation. A change in the industry is reliant on a new culture which welcomes and rewards new ideas, equitably shares benefits and liabilities, and creates space to create and test new concepts.

INNOVATION WILL DRIVE IMPROVEMENTS IN PRODUCTIVITY

Innovation can bring value in many ways and organisations who have embraced it report a variety of benefits in time-savings and efficiencies leading to improved productivity. These benefits also extend to employee job satisfaction, improved reputation and the ability to win work.

THE PROCESS OF INNOVATION CAN BE SYSTEMATISED

Innovation is not random; the notion of ad hoc innovation is holding the industry back. The best results come when there are processes and a strategy in place to assess ideas for a business case, take them forward, and feedback to the originator whatever the decision. Organisations who put processes in place to bring ideas forward will get higher engagement from their workforce.

THE TIME TO INNOVATE IS NOW

The UK construction industry lags far behind other industries in spend on innovation and R&D, and the UK is behind other advanced countries who have embraced innovation and smart construction and are already tendering for some of the UK's biggest infrastructure projects. The rise of the digital economy desperately needs innovation, and we have had the reports, the facts and the figures that show innovation can truly bring value to our industry. Now it is time to embrace it.

Recommendations

RECOGNISING AND CELEBRATING THE VALUE OF INNOVATION AT ALL SCALES

Parts of the industry have still failed to grasp the value of innovation, and a lack of recognition and reward threatens to drive our industry's innovators elsewhere. It is not just the big, shiny and new that should be celebrated; small improvements can bring great value and should be recognised. Only then will everyone be inspired to think differently and make innovation part of their everyday life.

TAKING INDIVIDUAL RESPONSIBILITY AND SUPPORTING OTHERS TO INNOVATE

Innovation is everyone's responsibility, but people need the time and headspace to think differently, with the security of knowing that failure can be accommodated. Leaders need to motivate and support, and ensure the attitudes in their teams are not stifling idea sharing. The person with the great idea may not be the one to develop the business case and implement it, so there should be support available to take ideas to the next stage. At a team and individual level, when someone voices an idea, we can all make the effort to pause for thought before passing judgement.

CHANGING OUR CULTURE AND PROCUREMENT APPROACHES TO EMBRACE AND EMBED INNOVATION

The simplest ways to encourage innovation throughout the supply chain are to share both the risk and reward of innovation, to engage early with clients to identify opportunities at the outset of a project, and be less prescriptive with project scopes. Procurement, processes, contracts and insurances should reflect this.

INVESTING IN INNOVATION

Despite the low margins construction organisations should commit to investing in Research and Development. This can be supported by making use of existing funding initiatives such as through the European Commission and Innovate UK. We should invest in innovation, and commit to training the workforce so they can embrace new technologies required for a digital economy.

DRIVING INNOVATION THROUGH THE INSTITUTIONS

ICE is crucial to facilitating a change in the industry and supporting its members to drive innovation. It can do more to work with other institutions and organisations to break down silo mentalities and share knowledge and best practice. More than ever, innovation needs to be on the agenda, and institutions should be supporting and training their members to develop the skills required to embrace it. We should ask whether this should be explicitly required in the Attributes required for professional review.

Innovation Checklists

GOVERNMENT:

- Benchmark national investment in R&D against other countries.
- Be a model client by adopting contracting practices that foster innovation.
- Provide resources and initiatives that make it easy for companies to compete on a global level.
- Support outreach activities in schools so that the construction industry can recruit the most able young people from society to create diverse teams.

ICE:

- Develop industry wide knowledge sharing platforms that foster innovation both within and outside the industry.
- Include innovation skills in the attributes for professional review.
- Foster diversity in the industry.
- Produce flexible and adaptable codes of practice that are not barriers to innovation.
- Promote awards that celebrate the success brought from innovation.
- Support training and conferences that guide the way to more innovation.

CLIENT:

- As well as defining the problem, work with the supply chain to be a part of the solution.
- Provide clear outcomes and expectations to allow the supply chain to align their goals with your own.
- Consult all stakeholders including the end users and the supply chain at the earliest opportunity, to gather and incorporate their input in defining the problem and/or solution.
- Choose a contract that fosters collaboration and shares benefits as well as liabilities equitably.
- Exploit contract arrangements that foster innovation.
- Help clear obstacles that hinder the supply chain from innovating.
- Allow standards and codes of practice to be challenged.
- Be aware of and tackle people in your organisation that may be blocking innovation.
- Encourage your contractors to share innovation with other contractors that work for you and consider incentivising this.
- Remember that not all new ideas work first time. If your contractor is really innovating there will be some failures.
- Work with your contractor in celebrating success.

CEO:

- Take a lead on innovation. Make it known that it is important to you personally.
- Keep innovation on the agenda. Discuss and review it regularly at board meetings.
- Build relationships with clients and regulators so you can effectively challenge concepts and standards to accommodate innovation as and when it arises.
- Monitor and celebrate success in your organisation.
- Negotiate contracts and insurance that will enable innovation to flourish.
- Put in place governance structures to manage innovation.
- Not every idea taken forward will lead to an innovation, accommodate failure.
- Set aside a budget for investing in R&D.
- Encourage collaboration and knowledge sharing within your company.

TEAM LEADER:

- Ensure your team is diverse. A good mix is more likely to produce innovation.
- Create and foster an environment where ideas can be freely shared.
- Focus on why a new idea might work rather than what might not, first impressions of ideas may deter future idea generation.
- Identify blockers to good ideas within your organisation, so you can overcome them.
- Ensure that new ideas are checked out through your knowledge networks to avoid reinventing the wheel.
- Make sure good ideas are fed back into your knowledge networks.
- If the idea needs proving, think about setting up a pilot project.
- Provide feedback for ideas that are not taken forward.

GROUP MANAGER:

- Establish processes that support and foster innovation.
- Check that your management structures are capable of supporting innovation, make them visible and ensure that they are used.
- Support your team leaders in exploiting new ideas and help them to prepare the business case.
- Provide backing for employees to continually innovate, especially when ideas fail. Try to avoid apportioning blame.
- Provide access to funds to support innovation.
- Celebrate the achievements of your group members internally and externally.

INDIVIDUALS:

- Focus on the outcome that a project aims to deliver rather than the project itself.
- Challenge the original concept. Are there different ways of achieving the same or similar outcome?
- Collect good data and apply sound science so that you really understand what you are trying to address.
- Make space to think and create new ideas.
- Share ideas with others in the team; ask questions, check ideas through your knowledge networks.
- Don't give up on an idea without working on it to test why it may or may not work.
- Consider how others will view your idea.
- Not all good ideas get adopted. Do not let that hinder you from trying again.
- Get feedback for your ideas.
- Remember to share your ideas, for innovation to happen ideas need to be shared before they can be developed.

About the Authors

The ICE President's Apprentice Scheme started in 2005 and provides the opportunity for graduate and technician members to work with the current President on a particular theme or project.

Working for President David Balmforth, the 2014/15 Apprentices have focused their work around innovation. Learn more about them below:

Beth Barnes



Beth works for Amec Foster Wheeler, primarily focusing on Northumbrian Water projects in the North East of England. Beth already had an active role in the ICE before becoming an Apprentice. In the NE Region she has played an active role in promoting civil engineering to U19s and helped to develop a zombie apocalypse school activity.

Peter Coppenhall



Peter is a tunnel design engineer for Underground Professional Services; currently he is working on Crossrail and is a key member of BBMVs construction management team. Before he became an apprentice Peter was on the management team for the British Tunnelling Society Young Members group.

Takomborerwa Hove



Takomborerwa is a graduate bridge engineer with AECOM Infrastructure and Environment. He is currently based in Scotland where he graduated from the University of Strathclyde. Takomborerwa is also involved in other ICE work with the ICE Glasgow and West of Scotland (GVoS) Exhibitions and Archives committee.

Joanne Huett



Jo is a Graduate Engineer with Eurovia and is currently playing a key part in the company's PFI contract on the Isle of Wight. Her present role is managing a significant programme of improvements to the Island's highway structures against a very short timescale.

Philippa Jefferis



Philippa is a Management Graduate at Amey, and is currently on secondment with Amey in Australia, working on the South Sydney roads. A keen STEM ambassador, Philippa has been involved in a careers video and written a number of blogs to inspire the next generation of engineers.

Sophie McPhillips



Sophie is an Assistant Engineer working on the Eight20 Alliance for Atkins. Sophie joined the Apprentice team after winning the title of NCE Graduate of the Year 2014.

Michelle Roche



Michelle is a site engineer at Laing O'Rourke. She is currently working in a project delivery role for Expanded on site at Clarges Estate, London.

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References

[1] Report of the Construction Task Force, "Rethinking Construction," 1998 [Online]. Available at: http://constructingexcellence.org.uk/wp-content/uploads/2014/10/rethinking_construction_report.pdf.

[2] Constructing Excellence, "Never Waste a Good Crisis," 2009 [Online]. Available at: http://constructingexcellence.org.uk/wp-content/uploads/2014/12/Wolstenholme_Report_Oct_20091.pdf.

[3] Engineering UK 2014 – The state of engineering, Foreword The Rt. Hon Dr Vince Cable MP, Page II. Found at: http://www.theengineer.co.uk/Journals/2013/12/06/v/x/t/EngineeringUK_Report_2014.pdf.

[4] Engineering UK 2014 – The state of engineering, Foreword The Rt. Hon Dr Vince Cable MP, Page II. Found at: http://www.theengineer.co.uk/Journals/2013/12/06/v/x/t/EngineeringUK_Report_2014.pdf.

[5] Engineering UK 2014 – The state of engineering, Part 3 – Engineering in Employment, 15.0 Skills Shortage Vacancies and employment projections, 15.1 Business investment in skills, Page 216. Found at: http://www.theengineer.co.uk/Journals/2013/12/06/v/x/t/EngineeringUK_Report_2014.pdf Original source - Training in Britain – First Findings from the Skills and Employment Survey 2012, Francis Green, Alan Felstead, Duncan Gallie and Hande Inanc, p.3.

[6] New Civil Engineer (NCE) Magazine – 27/08/2015 Issue – Equality: Attitudes in Construction Survey p.14.

[7] New Civil Engineer (NCE) Magazine – June 2014 Issue – Crossrail Half Way Major Project Report.

[8] Crossrail, Crossrail Website (2015) [Online]. Available at: <http://www.crossrail.co.uk/>.

[9] Crossrail, Innovation Strategy: Moving London Forward, 2012 [Online]. Available at: <http://www.crossrail.co.uk/sustainability/innovation/>.

[10] Major Projects Association, "What makes an intelligent Client? - Report of seminar 166 held on 16th November 2011 at the Institution of Civil Engineers, 1 Great George Street, London," 2011. [Online]. Available: http://www.majorprojects.org/pdf/seminar_summaries/166summaryintelligentclient.pdf.

[11] HM Treasury, "Infrastructure Carbon Review," 2013. [Online]. Available: www.gov.uk.

[12] DEFRA, "London 2012 Olympic and Paralympic Games, The Legacy: Sustainable Procurement for Construction Projects," Department for Environment Food and Rural Affairs, 2013.

[13] Royal Academy of Engineering, "Public projects and procurement in the UK: sharing experience and changing practice," Royal Academy of Engineering, London, 2014.

[14] Major Projects Association, "London Games - From Construction to Commissioning Report of Seminar 165," Major Projects Association, Oxford, 2011.

[15] R. Arnold, C. Baniste, A. Weir, D. Dabsia and D. Goodlife, "Delivering London 2012: The Velodrome," Proceeding of the ICE: Civil Engineering, no.164, p. 51-58, 2011.

[16] Engineering UK 2014 – The state of engineering, Part 1 – Engineering in Context, 3.0 UK Engineering research and innovation, 3.3 The international context, Pg. 24 and Fig3.0. Found at: http://www.theengineer.co.uk/Journals/2013/12/06/v/x/t/EngineeringUK_Report_2014.pdf.

[17] Engineering UK 2014 – The state of engineering, Part 1 – Engineering in Context, 3.0 UK Engineering research and innovation, 3.3 The international context, Pg. 24 and Fig3.0. Found at: http://www.theengineer.co.uk/Journals/2013/12/06/v/x/t/EngineeringUK_Report_2014.pdf.

[18] European Commission - Research and Innovation Performance in EU Member States and Associated countries – Innovation Union progress at country level – 2013, Key Findings, Table: Overview of R&I performance in Member States and Associated countries, Pg. 5. Found at: https://ec.europa.eu/research/innovation-union/pdf/state-of-the-union/2012/innovation_union_progress_at_country_level_2013.pdf.

[19] Engineering UK 2014 – The state of engineering, Part 1 – Engineering in Context, 3.0 UK Engineering research and innovation, 3.3 The international context, Pg. 24. Found at: http://www.theengineer.co.uk/Journals/2013/12/06/v/x/t/EngineeringUK_Report_2014.pdf.

[20] Cambridge Centre for Smart Infrastructure and Construction, Who are we, CSIC at a glance. Found at: <http://www-smartinfrastucture.eng.cam.ac.uk/who-we-are>.

[21] Cambridge Centre for Smart Infrastructure and Construction, Continuous strain sensing using fibre optics on piles, Assessing pile performance and design. Found at: <http://www-smartinfrastucture.eng.cam.ac.uk/what-we-do-and-why/focus-areas/sensor-data-collection/projects-and-deployments-case-studies/pile-performance-fibre-optics>.

[22] OFWAT. (2014). Setting price controls for 2015-20 - Overview. Retrieved from www.ofwat.gov.uk.

[23] BSI, B. S. (2015). PASs from BSI. Retrieved September 07, 2015, from <http://shop.bsigroup.com/navigate-by/pas/>.

[24] Twarog, E. (2015, February 06). What Aircraft Manufacturers Can Teach the Nuclear Industry. Retrieved September 15, 2015, from <http://atomicinsights.com/aircraft-manufacturers-can-teach-nuclear-industry/>.

[25] Birtles, P. (1998). Boeing 777 (Illustrated ed.). MBI Publishing Company.

[26] KPMG. (2012). Aerospace & Defence Industry 2012 Outlook Survey. Retrieved 14 September, 2015, from <https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/2012-aerospace-defense-outlook-survey.pdf>.

[27] Strategy. (2014). How rapid growth and change are reshaping aviation. The global.

[28] HM Government, Industrial Strategy: government and industry in partnership, "Construction 2025," 2013. [Online]. Available: www.gov.uk.

[29] Interview with Karl Wilkinson from Laing O'Rourke.

[30] HM Government, UK construction industry: digital technology, "Digital Built Britain, 2013. [Online]. Available: www.gov.uk.

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Institution of Civil Engineers
One Great George Street
Westminster, London SW1P 3AA
t +44 (0)20 7222 7722
website: ice.org.uk

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