Next generation technology

How next generation technology meets the architecture, engineering and construction (AEC) industry

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1. Introduction

The Architecture, Engineering, and Construction (AEC) sector is the key player in developing smart cities that are aligned to new styles of living and working. It has a broad responsibility to build a modern world, bolstering economic outlooks through infrastructure and it is consistently expected to solve urban problems.

According to a 2017 McKinsey report[1], The construction industry employs about 7 percent of the world's working-age population. The same report goes on to say the engineering and construction sectors are collectively worth more than $10 trillion a year.

However, despite its economic clout, the report warns that the construction industry is severely under digitised.
This is further supported by a report in 2016 which found that 70 percent of construction firms dedicated just 1 percent or less of their revenue to technology.

The AEC sector in the UK is suffering the same challenges as its global counterparts. Industry leaders agree it is at a pivotal point in its lifecycle and must catch up with its already digitised peers, such as manufacturing.

Fortunately, the UK's AEC sector is not all doom and gloom. Companies are joining the ecosystem economy and joint ventures are gaining ground as leaders see the vast benefits of a collaborative approach and letting go of blinkered thinking.

In this ebook, we look at how the sector reached this point, but, more importantly, we examine what needs to be done for it to futureproof itself and take its place in the Fourth Industrial Revolution. To properly explore this, we engaged with some of the UK's most respected thought leaders, entrepreneurs and top-tier movers and shakers in the AEC sector. The following ebook contains their exclusive insight, curated by connectivity provider Claranet.

[1] Reinventing construction through a productivity revolution McKinsey Global

Imagine you want to buy a new car. You find the make a model that you want, select your interior and finish the details, and place the order. The car company starts building the car to meet your specifications, and promises to deliver it in a few weeks.

But a few weeks turn into months and the car never arrives. It's nearly impossible to get an answer as to why. When you ask you are referred to the person in charge of the chassis, who blames the engine guy, who in turn says the steel wasn't delivered on time. You're left trying to chase down multiple people over phone and email.

Finally, after nearly a year, you get your car. But it arrives with a bill for 30% higher than the original quoted price.

No one would buy a car this way. More to the point, no car manufacturer or dealership would expect you to. But, somehow, we've come to accept this frustrating process as normal when it comes to construction." [4]

[4] Construction: The next great tech transformation McKinsey & Company

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2. The AEC sector's current deployments and investments

Seeking a balance between cost, ROI and margins

Data is playing an integral part in just how smart cities and mega developments can be, and this will continue. Already, vast amounts of data have gone into cities yet machine learning is still in its relative infancy. The possibilities are almost endless. The more data, the more in tune the city and the happier the people who live in it. Now, it is finding the right mix - merging the tools without one displacing the other, because if people and culture fall by the wayside in the pursuit of ROI and operational efficiencies, what is it all for?

Across the AEC sector, technology adoption is, finally, gaining traction in different areas and with different objectives. Firstly, it is within the organisation to drive operational productivity, manage data and culture, and preserve margins. And secondly, technology is being woven into external assets to create connected smart environments and leverage data.

Outside the organisation - connected construction investments

There is no denying that our cities are getting smarter and a lot more responsive. Today's tech integrations are giving us just a glimpse of what technology is capable of in the urban environment however, the population growth and migration into inner cities is putting the spotlight on infrastructural gaps which can no longer be ignored. This requires spending and investment, and the more connected that infrastructure, the easier it will be to manage these urban assets. With the wider adoption of technology in the sector it is not surprising that the IDC forecasts[5] that Smart Cities spending will reach $158 billion globally by 2022. Engineering and construction firms are key drivers of building in the sensing technology that can collect and apply data analytics to improve the lives of the people who move within and between cities. From building the roads and highways to designing residential and once buildings, one can now find multiple digital touch points of connectivity between people and their vehicles, homes, and workplaces.

Drones, wearables, augmented reality (AR), and GPS tracking services are revolutionising job sites, streamlining surveying, improving worker safety, and capturing valuable data. In the coming year, design, engineering, and construction firms are set to continue augmenting their portfolios with connected technology assets. From a delivery standpoint, the more complete the solution an engineering or construction firm can bring to the table, the more positive the outcome and ROI. The shift to the cloud and investments in things like networks and 4G are also making sites a lot more IT-enabled.

Taking a high level view on investments, Mark Enzer, Chief Technical Officer at Mott MacDonald, observes that, for manufacturing, an Industrie 4.0 type of approach has been adopted, which is the Fourth Industrial Revolution.

[5] IDC Forecasts Smart Cities Spending to Reach $158 Billion in 2022 IDC

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"Industrie 4.0 is all about cyber/physical systems. It's not just a case of taking the old things that we used to do and making them a bit digital; rather it requires whole new ways of doing things and really transforming the processes," says Enzer.

Enzer also notes that the technologies that are starting to become familiar such as AI, machine learning, blockchain, big data and IoT, should not be viewed completely separately; rather they will deliver even more` benefits as parts of a connected system that realises the value of information.

"What we really need is a 'data infrastructure' which is designed with connectivity and integration in mind. And the notion of 'smart infrastructure' moves us in the right direction. It's about applying digital transformation consistently and coherently across the whole of infrastructure. So, that's not just the delivery of new infrastructure, but also the operation, maintenance and use of existing infrastructure. Effectively, it's about applying the fourth industrial revolution to infrastructure. In this context, it makes sense to think beyond the remit of the traditional 'construction industry'; what I'm talking about here is a much broader transformation across the entire life-cycle of assets within infrastructure." says Enzer.

Regarding current technology investments, Simon Evans from SNC-Lavalin comments, "On the cost part, we're sometimes seeing this being driven down by the consumer market. Take, for example, virtual reality and augmented reality. VR has been around since the 1990s, when NASA first started using it to train astronauts, but it's the hardware targeted at the consumer gaming industry that has made it accessible, driving down costs and accelerating development. Likewise, AR is now present in most smartphones." says Evans.

Internal investments – driving efficiencies and accuracy

Internally, digital technologies like robotic process automation (RPA) have the ability to make a significant impact on back-office operations for engineering and construction firms. New digital tools are transforming the way engineering and construction companies run their businesses. Players are moving quickly to integrate technologies into operations as a means to increase safety, reduce operational costs, provide innovative solutions and identify competitive advantage with real-time data and insights that can modify project delivery. Building information modelling (BIM) systems that enable contractors to create 3D models and action design changes in real time are also evolving quickly. Add cost and project scheduling and the new 5D BIM systems will help meet project delivery and within budget. The software is becoming cloud-based.

> **Globally, labor-productivity growth in construction has averaged only 1 percent a year over the past two decades, compared with growth of 2.8 percent for the total world economy and 3.6 percent in the case of manufacturing."** [6]

[6] Reinventing construction through a productivity revolution McKinsey Global Institute

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Bestseller BIM 360 was recently refined and released, having not quite hit the mark until now. Adding a change control management section to that platform is seeing it become a powerful tool and a potential game changer.

Among the biggest focus areas for investment for many of the UK's AEC players is VR and AVR. In design, before acquiring the funding for major construction projects, one will now sit with investors and occupants, put the goggles on and be immersed in what the asset is going to look like and what it's going to feel like to live in. Asset condition, monitoring and maintenance for AVR is helpful so one can start to control the drone from a long way away with some goggles on and, in some instances, the drones can intervene with the condition of the asset as well.

Another common area of investment is 3D printing. A screw, a nut, a bolt, a wedge, anything that doesn't need to be connected can be 3D printed or commoditised and 3D printed. In major construction projects, AVR and VR reduce the costs and improves the accuracy of design and 3D printing reduces the cost of construction.

Maturing the offerings

It is a case of changing cultures for Simon Evans at SNC-Lavalin, rather than getting distracted by a particular software or vendor. "It's not really about technology itself, it's about the methodology and mindset of what you are trying to achieve, and the people involved in that process. Or, simply put, as it's often cited, "digital transformation" is not a technology problem, it's a people and process problem.'

The industry can expect further maturity of BIM into offerings that incorporate energy effciency and facility management, for comprehensive life cycle project management.

There has also been a large increase in quantum positioning which takes a lot of Einstein's learnings and brings them into the real world. This is proving useful where vehicles or assets need to constantly emit their positioning profile, bearing in mind that other methods like GPS and LIDAR can go down.

Quantum positioning is seeing a renaissance is because it's seen as an alternative to the 5G or WiFi network, if that fails. One can expect to see a bit more blockchain but there is a long way to go for blockchain. But the concept is distributed in energy pricing, construction and also financial reconciliation when there's a big consortium piling money into a project.

"" **We remove human error by removing humans."**

Lisa Jones,
Account Director, Claranet

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The tech landscape - bigger, better, faster, now

When it comes to automation, in a time where things always need to be done better and quicker, this area of digital development is now a key part of the technology landscape.

"Parametric modelling has significantly changed what we are doing over the last 12 months. Only over the last two to three years have we seen the rise of parametric modelling and machine learning, and big data becoming more mainstream and asset based," says Gavin Bonner, Global BIM Manager at Cundall

At Kier Group PLC there is a holistic blend of IT estate back and front office applications. "So the traditional IT estate tends to serve the back office really well. And Microsoft enables standardisation. We moved some of the complexity from the supply chain which has left us with point solutions for front office applications. It's about knowing what is being used and having a view of the entire ecosystem. There are things like HR management, time and attendance, surveying and a lot of disruptive technologies like drones and VR and 3D printing that largely operate from an IT system, but not one that's been visible to the teams looking after the back office," says Jim Griffiths, Head of Information Security at Kier Group.

Kier Group PLC has announced the start of a future proofing exercise which includes technology aspects. In the main, it looks to reduce supply chain complexity, standardise on solutions that offer more bang for buck, and phase out dependency on single point solutions in favour of more comprehensive suite capabilities. Another consideration for the Kier Group has been to overcome the 'growth through acquisition' problem that left the business with multiple ways of achieving the same goal.

"Standardising the tech solutions is a great enabler. The remainder of the business is then able to rotate around transformations. By far, the biggest benefit we've had is the mobilisation of the Microsoft platform itself. We actually uplifted our own costs a little bit but we reduced the security spend significantly. We've been able to identify our technical debt which has legacy systems that all companies have somewhere in the mix. Quite simply, Microsoft 365 is incapable of reaching that far back to some of the more aged, obsolete systems like server 2003 and server 2008. So, one of the problems I know I'm going to have in the coming months is, 'What do I do to take control of that aspect?' Do I virtualise it and then ensure the house is secure, or

do I push on the business to fundamentally change their approach and not sweep the technology assets as they've done in the past?" says Griffiths.

Lewis Wenman Lead BIM Manager at Bouygues UK points out that there is not a single platform that is leading industry investment and that every project and project team has different setup environments. There are market leaders mainly on the design side but on the collaborative side of information exchange, he does not feel there is one clear market leader.

"There's a whole host of various options and they all have their own different settings within that, but none of them, I would say, strive to meet what we want to do in the industry. I'm just kicking of a £200 million project and the key issue is how we're going to share all our data," says Wenman.

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Growth through human capital

Industry leaders are also acknowledging the need for human capital investment and how the upskilling of staff is becoming critical to the digital strategy.

Gavin Bonner, Global BIM Manager at Cundall, approaches technology investment as a complete ecosystem, recognising that the organisation needs its people to dovetail with its technology. As such, Cundall is investing heavily in upskilling their entire team as part of a digital skills development programme.

"We need to have the skills in place to be able to use the software. And I think that is part of the problem. If you look across the AEC industry, only about 10 to 15% of companies have really, really skilled people on board. Automation is also being weaved into the software rather than just making automation a delivery tool, and that also requires human capital skills," says Bonner.

Wenman echoes this sentiment. "Companies may be investing in the technology but are falling short when they fail to address the human skills required, leading to wasted investments, minimal require ROI or even investments dumped in human capital.

At J Murphy & Sons Limited there are significant investments being made in common data environments or a single source of truth, where all data, all systems, CRM, the ERP, procurements, finance, HR functions all sit under one data point. At deployment, it gives a comprehensive view and continues to do so at every stage of the project. With one click, the user can see details like the program manager's name, the teams, what experience those people had, the financial reporting of that project, the project performance matrix, the resources required, procurement lists and so forth. It aggregates diverse and disparate data into one place.

Connected assets aside, technology and data are being used to push boundaries in precision engineering. J Murphy & Sons Limited is also using tech investments to push the boundaries in precision engineering. On the Crossrail underground rail project in London, many technologies, such as laser guidance and sensors allowed 1000-ton Tunnel Boring Machines to pass just 60 centimetres away from existing assets such as escalators, the tube network and buildings, notwithstanding the rabbit warren of underground services and pipelines.

"Despite not being regarded as a technologically savvy industry we have to use loads of data and really rather advanced technology to be able to drill under London without causing serious issues. Using laser scanners, photogrammetry, LIDAR to create some 3D models that we can then manipulate, interrogate, overlay to the design to add value and better plan. We are also exploring the use of drones, which has many opportunities for us, for example before we take ownership or have access to a piece of land, we can fly a drone over it to do a topography survey and understand the lay of the land before we start making decisions on how we mobilise our teams. Then very easily do progress monitoring, creating snapshots, logistics planning, as well as of course creating 3D models and more advanced data capture capabilities," says Reddaway.

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Networking and Cloud: migrating aged legacies and outdated mindsets

As already highlighted, the adoption of cloud technology by the AEC sector has been slow. C-level management in construction companies are typically uncomfortable with technology conversations and the hassle of change is not perceived to outweigh the benefits. Until now. Finally, the merits of scalable and secure storage in one place for a lower investment are being recognised, and the industry is on the cusp. Cloud platforms are challenging traditional business models, and software and infrastructural expenses are being reduced. New areas of innovation are opening up and the cloud also addresses growing data storage needs where so often graphic programs, animation and high quality photographs necessitate a massive amount of storage.

According to Gavin Bonner at Cundall, the cloud-based software is disrupting traditional construction processes but once everyone is accustomed to the cloud models and has access, it will be a big step forward.

"If you look at the BIM Level Two to Level Three mandate, Level Three has pretty much everything in the cloud. The industry just needs to understand how that works. And it's all about changing processes. The whole cloud solution is definitely one area of technology that has moved on," says Bonner.

For Jim Griffiths at Kier Group, cyber / cloud is a principal risk and uncertainty. "We have a risk-averse appetite to anything cyber related and we continue to invest in that. The issue is changing the mindset of the business, to move away from applications that they've become dependent on. And largely they have an attitude that if it's not broke, why fix it? Fundamentally, they missed the point that it's broken because it's aged, it's obsolete and it can't be at the centralised management security control," says Griffiths.

> **There are many great solutions, but if you haven't got the connectivity, they can often be useless."**
>
> Simon Evans, Director, Digital Engineering at SNC-Lavalin

> J Murphy & Sons Limited is rolling out an innovative approach in a joint venture with Bentley Systems, a market leader in program management software, authoring tools and 3D modelling, and Aconex (by Oracle), also a market leader in project controls, planning and document control. J Murphy & Sons Ltd has made them work together to deliver the ultimate solution.
>
> For us, it's a really mature approach because a lot of solutions can be half-baked, creating data silos which is completely contrary to what a common data environment should provide. We are deploying this joint solution to allow us to tie all our data together, creating a clear and simple "single source of truth". It is a major transformation exercise, we have also invested significantly on a complete finance, CRM, ERM transformation, all with a common data environment in mind. It is hugely exciting so, for us, it's a major piece of work, it will take time, but it will truly change how we work."
>
> **William Reddaway, Group Head of Innovation, J Murphy & Sons Limited**

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3. Data & security

Keeping the single source of truth on track and protected

Data and the optimal use thereof is classified as one of the AEC sector's top technology challenges.

City leaders are beginning to realise that smart cities are not a case of patching software and re-purposing digital interfaces designed for traditional infrastructure, rather they are about the purposeful use of data and tech to meet expectations of those who live in the space. Many in the AEC sector also don't fully grasp that for data to become big data that actually yields useful insights, it needs to be captured at enterprise level, not at project level.

It is encouraging to see that the AEC sector is now embracing data and its potential to bring about change, but it is also finding that the sheer volume of data that is now being generated is adding complexity. Construction companies now need to work out how they will secure, store and manage their data in such a way that it adds value, remains relevant, and provides that much sought-after single source of truth. There is a right way and a wrong way to use data, and innovation grinds to a halt when data is not being used to full potential. This leads to a lot of missed opportunities. Machine learning and AI don't work if there is no data set to learn from or build on.

"Where many niche applications are used, one ends up with a bunch of applications all doing different things like estimates, planning and scheduling but unable to talk to each other," says John Bromilow, an experienced construction industry CIO. "So all the data that those applications need is very siloed and the upshot of that is that information doesn't really flow across that construction lifecycle. The problem that creates is a loss of efficiency because of a lot of double entry of data. So people don't tend to move data if they can get away with it."

Gavin Bonner at Cundall neatly summarises the data environment. "The common data environment is fundamental to being able to provide that single source of truth, and without that it doesn't exist."

> **Data needs processing to release its value."**
>
> Mark Enzer, Chief Technical Officer, Mott MacDonald

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The data tale

Data is moving business decisions from being reactive to being predictive which in turn enables engineering and construction firms to get ahead of their competition. A solid data and analytics strategy underpins delivery of smart buildings and identifies diminishing margins and scope creep on projects. It is a fundamental tool when it comes to AEC storytelling and will answer the key questions – what went wrong, how did we fix it, what is needed to prevent it happening again?

Data itself comes from a multitude of sources, many of them independent of traditional enterprise resource planning (ERP) systems. The data strategy now has to evolve and collect data from all of these sources, then extract the insights and ensure they reach the right people – the decision makers.

Asked if workforces need to become more data analytical or technology savvy, John Bromilow observes that the culture in construction is still quite old fashioned and needs to shift. "It's a very physical industry and the mindset is all very manual centric."

Asked how he sees competitive edge realised through technology, Mark Taylor, Digital Construction Manager, BAM Construct UK, talks about greater productivity and efficiency in the field. "I hate saying it but data is the new oil. We need to improve the quality outcome for the clients and make sure that people are safer. We have so much data that no one can access and we have to rely on people for it. So we ended up clouding it, which was hard." BAM Construct UK is trying to consolidate multiple data sources, realising now that they were collecting data that they didn't realise was valuable.

"Previously, we were making sure that the right people were on site. Now we have CCTV and sensors in concrete. All these different things are all very project related and, in the industry, all projects are very siloed so we need to join them up. It can really avoid problems. By linking up sites better and deploying the same technologies or linking from data points on the sites, you can see trends and hopefully prevent an issue with quality or health and safety issue from ever happening six months down the line, because you can almost predict it," says Taylor.

" **Applications age like fish, data ages like wine.**"

Mark Enzer
Chief Technical Officer at Mott MacDonald

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> ❝ **It is sometimes joked that if you want a job for life, you should work in cybersecurity.”**
>
> Simon Evans, Director, Digital Engineering at SNC-Lavalin

With data, another challenge is around cyber protection. As we connect ourselves to everything, it is expected that there'll be 10 billion micro process views connected into the global economy at the end of this year. Basically, that means that the world is one big supercomputer.

We can't undo that, so one might pose the question: are we really sure that once we've connected them all, are we really completely certain on how secure, how watertight and how resilient and stable it all is? There may be pockets of complete certainty around national security, around health, around transport, but when one starts to connect energy into transport, into housing, into health, into law enforcement - no one's ever done that before, anywhere in the world. Mass connectivity and then security becomes really important. And the architecture, engineering or construction, the fibre risks - not just through those three domains, but across the supply chain - will be profound.

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4. Culture, skills & talent retention

Critical to competitive advantage

In the UK, the skills shortage is expected to reach crisis proportions in 2019. The inability to find and match skills to market needs is negatively impacting the sector and innovation in a multitude of ways. With the expected growth in the AEC sector, companies at all levels of the food chain are now having to get smart about talent attraction, recruitment and retention. In addition, there are vast skills residing in the retirement-age talent pool which need to be tapped into before they leave the system.

Considering the rise of digital, it is also important to first understand how skills requirements are changing and then design an appealing talent and knowledge management strategy that reflects this and, furthermore, resonates with talent in the millennial category.

For Mark Taylor at BAM Construct UK, one of the most pressing issues he sees in the AEC industry is the skills gap and an ageing workforce. While there are a lot of skilled professionals in the industry, it is proving hard to attract new people. "The skills and experts that we need are different now. And we're only just coming to terms with that so we're operating in a market where we compete for staff. Our biggest resources are people and the knowledge residing within those people so we nurture our talent and focus on employee retention," says Taylor.

Asked what skills may be lacking at BAM Construct UK Taylor points out that they are digital natives and 50% of the workforce comes from a 'paper process' world, and the mobile era still feels slightly alien.

"You just have to be technically competent, digitally savvy people. The pool of people we are attracted to are also attracted to other industries so our talent pool is getting smaller. We now need to work on keeping candidates within our organisation because it has become so competitive. With new people and new skills, it has become tricky in terms of career development. You have all these new people and new roles and you are not sure what to do with them. Organisations that have worked around these new skills are able to offer these candidates something different. So it is fundamentally about organisational change and having something that supports these roles," says Taylor.

> **The thing about systems is that the whole system must improve. You can take new tech and stick into the old system, and it may make that part better but not the whole system."**
>
> Mark Enzer, Chief Technical Officer at Mott MacDonald

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Gavin Bonner at Cundall believes the answer to skills shortages lies within the existing workforce.

"Consider what the industry is aiming to achieve now with increased adoption, machine learning and the power metrics of the model. Now if one then has to go out and recruit the skills, it becomes a big issue. If everyone is in the same situation and skills are already limited, it just compounds the skills shortage situation. It comes back to upskilling being driven from within the organisation as a means to overcome the barrier," says Bonner.

Another stumbling block for people in organisations is the conflicting age of technology investments. Many invested in technology a long time ago but now the infrastructure and those technology investments are not the same across the board, and the upgrading process doesn't not happen directly. This disparity has a knock-on effect on those using the technology.

Simon Evans at SNC-Lavalin sees that workers don't have the right hardware and technology to deliver against technologies available.

"We see this in some of our clients. They're still using Microsoft Link and Office 2003 and you're on Skype for Business 2016 or Microsoft 10 in other parts. You have a huge disparity between what the workforce has. So what we are really focussing on is more the people and delivery challenges rather than next generation technologies," says Evans.

Finding digital talent is a prominent concern for executives across the industry, and it will be critical to digitisation. According to research by McKinsey's Digital Academy[7], investing in talent increases the odds of digitisation success by 2.5 times. There's a balance that must be found between entrepreneurship, industry and business acumen.

> **Take a complex construction project which takes between 18 months and two years to complete and bring some advanced analytics into that space, coupled with a rich historical data set to learn from, you could take months off construction projects and save millions of pounds."**
>
> Construction industry CIO Jon Bromilow

[7] Seizing opportunity in today's construction technology ecosystem McKinsey

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Digital transformation - a long-term investment tied into the business culture.

"You can't suddenly have all this data available without changing the culture of the business, which is not easy to do. I think it ultimately brings about a bigger payback over the long term. If we can get to the point where we've got a rich data set and we can start using AI to automate a lot of the processes that we have in the industry, particularly around estimating, scheduling and planning the project with management, we could end up saving a lot of money," says John Bromilow.

On looking after a workforce, William Reddaway explains that cultural issues are also of concern, with workforces suspicious of or sceptical about tracking devices and sensors that may highlight absenteeism, poor performance at work or no value added, fostering an unwelcome Big Brother culture and making it easier for leadership to dock their pay. In short, there's a lot of worry about the access and control of data, and how it is used and how technology moves the industry forward. "Unfortunately, these overshadow the opportunities and benefits that sensors and monitoring can bring. We can learn a lot about our projects, and workforce with sensitively and carefully gathered data, and some operatives are very keen to explore them but we have a way to go before the cynics are in the minority."

Infratructure is a system of systems whose pupose is to deliver effective sevices to people. In the picture, outcomes really matter, lead to better outcomes for the ultimate customers. The place of technology is an enabler within this information value chain."

Mark Enzer, Chief Technical Officer at Mott MacDonald

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5. Initiatives

The technology and innovation that is shaping the future of the AEC sector

The McKinsey Global Institute estimates that the world will need to spend $57 trillion on infrastructure by 2030 to keep up with global GDP growth. This is a massive incentive for players in the construction industry to identify solutions to transform productivity and project delivery through new technologies and improved practices.

Mark Enzer from Mott MacDonald gives a pragmatic overview. "Technology without a purpose is just a toy. But technology as enabler of the information value chain, has real purpose and great value. That's the kind of technology we want. Shiny and fun is not enough."

Jim Griffiths at Kier Group PLC says he sees sensors being built into everything these days but there is some inherent risk.

"Within our buildings, buildings are smart. They always have been in recent years with the application of heating and ventilation systems being joined to the enterprise back end. But then you start to build in sensors. The easy one is smart card access systems, right down to office occupancy, desk occupancy, level solutions, lighting controls and so forth. If done wrong, that can be devastating for an organisation. If we took a consumer grade sensor and deployed it into an organisation that has a clear benefit of giving us that information but fundamentally is not secured by design, that would be devastating to us as an organisation. Our brand and reputation would take a huge, huge hit if we got anything wrong that put any other systems at risk," says Griffiths.

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Slashed IT budgets are forcing a more agile approach, according to Mark Taylor. Organisations have to transform the way they deliver because the historical way is just not suited to the future. "We have significant market share and our turnovers are pretty stable, but with the new entrants coming in, they are pretty agile and it is a bit of a race to see who can acquire what.

"As we digitise the industry, or digitise our construction projects, or the way that the processes that the teams are using, you've got to invest and make it easy for the guys to access these tools and technologies. We have got thousands of iPads now on-site. Back in 2012, when I started deployment at sites, everyone thought that we were mental! But giving them iPads to use in the field was the best thing we ever did. Mobilising a workforce and enabling them to work were they need to work with the tools they need to do the job is absolutely where we need to be. And that requires investment in different infrastructure," says Taylor.

Another pressing issue that runs across the AEC industry at present is autonomy. Autonomy doesn't just mean automation, which is making a process more efficient and even removing a human from most of that process. Rather, autonomy for these particular industries is not just that the process has been done by a third party, software or hardware, but it involves the physical movement of things.

Autonomy for advantage

There is an increasing proliferation of autonomous vehicles conveying hazardous or extremely heavy, cumbersome materials. In the industry, autonomy is evident in construction itself and in artificial intelligence in surveys. So initially, one would have had a group of architectural surveyors conducting surveillance of the site with an eyeball, some telescopic materials and more recently, some software. Now, that has evolved into one person on the ground controlling a drone. And in the not too distant future that single person will become redundant because software will control the drone. This is now a complete round the clock way to survey areas or perform any intervention that requires a survey with outputs of really high quality and granularity.

The back office, the brain that controls a series of processes or entire architecture could also be autonomous, bringing autonomy to the front line and autonomy throughout the entire architecture of the business. It's wholesale autonomy and, when flushed through architecture, engineering, construction, defence, health, financial services and transport, it will completely transform the way that the industry engages with services and designs them.

Machine learning gaining traction

In the next 5 to 10 years, one can expect a lot of displacement to labour for commoditised tasks through artificial intelligence, robotics and automation, because robots find the things that we find easy, hard and the things that we find hard, easy.

> **People are coming up with soultions to problems that we didn't know we had. We have a pretty traditional industry and a pretty traditional way of looking at things. We're not agile in the way we look at things."**

Mark Taylor, Digital Construction Manager, BAM Construct UK

> **We were doing some roadway inspections in the US, scanning roads to identify cracks and defects. We used to have teams manually mapping defects from this data, which is hundreds of thousands of photos and videos. So we developed a machine learning algorithm that would scan through all the data and use what we've already done to train the model, which is the key part. The solution offers a very high accuracy rate, and significantly reduces the amount of time taken."**

Simon Evans from SNC-Lavalin

Robots are stronger and have more stamina. Getting them to understand emotion and ethics is completely different. Robotics and automation, not autonomy, but automation is disrupting the sector a lot.

Mark Taylor at BAM Construct UK feels that technologies are coming online quicker than organisations can probably cope with.

"In our organisation, we are working with startups and we try to work with their innovations, hoping that they turn out well and that we can make use of them in our projects. You've got to be able to sort of work with these people and support them," says Taylor.

Looking at the greatest investment spends Gavin Bonner at Cundall, says "We're not just talking BIM models, we're talking the entire project documentation. The likes of Autodesk BIM docs is like a common data environment that is a cloud-hosted solution where we host all the project information - the whole project from inception, right the way through to demolition. It manages the lifecycle side of things as well, which is something to look more into in the future. And I think there'll be a lot more people developing solutions for that for the industry as well."

At Kier Group PLC, AI and machine learning requirements have certainly been identified with various proof of concepts and deployments currently rolling out.

"Everybody in the space is learning as they go. With such a diverse environment to manage within Kier, it's an opportunity to take a little more care than a mass deployment would normally afford," says Griffiths. "We work very closely with the innovators in this particular area. We work with the clients' security teams and clients' management teams to fundamentally understand the reasons they're asking us to consider this. We have a dedicated Innovation Forum within Kier that manages the workflow. And that's a move away from buying big box Tier One commercial off-the-shelf products and perhaps having the conversations that we would have shied away from just a couple years ago."

"Digital tools are creating higher expectations and more accountability, according to William Reddaway at J Murphy & Sons Limited. He agrees with others that AEC as a sector is a late adopter of technology and, as an industry, is very distrustful of technology and intangible things like data. This comes from being typically risk-averse when it comes to exploring new ways of doing things. The thinking can be summarised as 'Why stop or change something that's worked for dozens of years?"

Greater accountability through processes and technologies

But in a digital world and a digitally integrated society, at J Murphy & Sons Limited the clients are expecting better quality assurance, better verification of design, builds, audits etc. And that is driving the initiatives.

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"We also have a responsibility in terms of environmental and socio-economic impact as well. Technology can help reduce those impacts, speed up process assurance and project assurance. When handing over a project, instead of handing over reams and reams of paper, you can offer a digital handover with all the assets' data and capabilities of the projects for far quicker assurance, furthermore, we can track projects better and over progressive assurance to our clients and relevant stakeholders" says Reddaway.

According to Brom low, the biggest potential benefits coming from AI and ML are around scheduling, which at the moment is done from experience, best practice or industry templates. Virtual design in construction is proving a far more efficient route.
"If we could take those models and turn them into SD models, where you've got not just the 3D representation but also the time element and the costume, then what you can actually do is start to build the building virtually and using AI, you can potentially build it thousands of times to find the most optimum way of constructing that building," says Bromilow.

Lewis Wenman at Bouygues UK believes that AI and ML adoption is pretty slow and still in its early stages, with the industry still writing and defining the rules.
"We have not been able to consistently roll this out on projects because every project we work on is unique. Even though the design of a building will look the same, the environmental conditions and the materials that we use are completely different for that project. But AI and ML is where we want to go because we want to find better processes. The recording of the data and monitoring the performance I think will actually eventually lead to programming of AI and get us there, but it is very slow," says Wenman.

Of all the many sector issues, Mark Enzer at Mott MacDonald narrows the most pressing one down to productivity, which in itself is multifaceted when one considers things like how much it costs e.g. the initial cost, the lifetime cost and the usual cost-type of issues.

"We've basically got to get more for less. There's a really stark comparison between the productivity gains that we have seen in manufacturing and those in construction. Manufacturing has transformed. So I think that we need to apply the fourth industrial revolution to infrastructure. If we take on board that kind of digital transformation, then we'll have a very good shot at closing the productivity gap," says Enzer.

William Reddaway goes on to explain that the industry doesn't make original mistakes. The same mistakes are made time and time again.

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"What we should be aiming to do is to start making original mistakes, but we don't always learn from what we do. Mistakes are good if we learn from them (it also implies we are pushing boundaries), improve what/how we do things, and share it across the industry. And the reason we don't learn is that when we do something well, or when we do something badly, we don't always record it but even if it is recorded, it will be held in isolation. Centralising the knowledge is key to understanding what went wrong as well as what went right. This does not have to be overly complex, case studies are a great way of capturing knowledge and skill. So when we're deploying to new projects, there's almost no intelligence. So there's a maturity aspect there as well."

The flip side of improved productivity

Enzer points out that initiatives that improve productivity may actually be a double edge sword. "When it takes only 4.5 seconds to do something that used to take 15 days, it does not work to bill by the hour. This highlights the need to redefine our business models for the new environment. It would be good if we could be rewarded for the value we add to information rather than the time we spend doing it," says Enzer.

So around about a year or so ago we had the opportunity to renew our Microsoft estate. I wanted it at that time to be able to answer the questions around 'What have we got and where have we got it?' answered really, really well, and essentially identified Microsoft in the 365 space and licensed and at the E5 level. They gave me four clear benefits. First around discovery. So being able to answer those questions really well. Moving on from discovery, having to actually bring you all those devices and solutions on their centralised management capability, improve. Our information protection across the board and giving me an unrivalled reporting mechanism that really covers the high level information and the exact layer right down to the detail for our security operations.

It does cover pretty much everything I want it to do. We mobilised back in January and a lot of the cloud solutions within the stack pose no problem at all in mobilising them quickly and achieving a "secured-by-deign" kind of philosophy. Solutions that deploy at the endpoint, we take a little bit slower, just taking a little more care that we don't actually break anything in the organisation when rolling that out. And the only key gap in the Microsoft 365 stack that I'm aware of today is around content filtering for web-based sessions. But in the main, certainly around connectivity and endpoint protection, I certainly ticked all the boxes. "

Jim Griffiths, Head of Information Security at Kier Group PLC

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6. Asset management
Achieving ultra efficiency

On any construction project, being able to monitor assets is critical. As the traditional management processes fall away in this digital world, big data is also coming into its own in the realm of asset management. Forward-thinking leaders are increasingly open to the concept of leveraging big data to monitor construction assets. Data driven tools are helping construction managers improve operational efficiency through the ultra efficient monitoring of construction equipment, people and other assets.

Construction firms are now trying to understand what IoT can deliver in the way of sensors in and around work sites, how that can capture data from head counts to vehicle tracking, and all sorts of things that can yield better assets. IoT is definitely going to be big for the construction industry. The next five years are very, very key.

John Bromilow feels that IoT has potential for impact but with construction sites changing daily, it can present challenges.

"You can go into a site one day and then a week later, it may be completely different. I've dabbled with things like putting beacons on a construction site to give location awareness, and a map that works. It has proved quite useful but the challenge is how fast the site is evolving so it becomes quite an effort to upkeep those beacons. Once IoT can go beyond insights in the construction phase, that's when its true value will emerge. At the moment though, there is no incentive for construction businesses to put the cost of all that IoT data into the project. So unless it's mandated by the client, it's not going to happen," says Bromilow.

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Failing fast and failing safe is an operational outlook at J Murphy & Sons Limited who own their own plants. Bulldozers, JCBs, cranes etc to the value of £110 million are being retrofitted with cameras, sensors and other technology to enhance safety. When a digger or bulldozer moves around site, the logistics manager can know exactly where it is on a very large site. People in the vicinity are automatically detected so that the excavator can stop moving to prevent accidents. Emissions are also tracked as part of environmental commitments but also potential preventative maintenance triggers. If emissions start going up without a clear cause, that machine can be set aside and the issue addressed.

"It's a really exciting time for us but these are small steps and still being explored to understand how it can add value. However, by exploring it, we can learn we can hopefully learn from it. My role is to challenge everything that we do. If we do make a bit of a loss on it, it shouldn't really matter as we are just challenging the status quo and are happy to fail fast and fail safely without a detrimental effect on the overall business," says Reddaway.

Health and safety remains a critical area in the AEC sector but after that, focus is around ensuring quality control and the ability to guarantee outcomes for the client, taking into account that a happy client is a referenceable client.

Simon Evans from SNC-Lavalin elaborates on their investments and expected ROI.

"There are a few areas of interest to us. One of them, which we announced publicly with Autodesk, is how we're leveraging technology to help ourselves with a generative design style process. So how we can basically go from sketching outlines or 2D drawing to a full 3D model with indicative plans and architecture layouts within a matter of seconds using algorithms and preset rules. Design reuse centres around how can we leverage what we've already done in the past to inform the future. That is what everyone misses," says Evans.

We are going to drown in data. I think IoT is going to bring us relief for many of our ailments but it's also going to have a price to pay. There's a lot to go wrong. It's a case of careful what you wish for."

Lisa Jones, Account Director, Claranet

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"SNC-Lavalin is deploying a number of solutions to our clients; for example, using existing data systems to optimize the spare parts holdings of assets and fleets. We do this by blending data analytics with our engineering expertise to deliver greater insights and outcomes. This is an important differentiator - the algorithms are produced by experienced engineers working with data scientists and mathematicians to create a real-world analytical capabilities. Following its implementation on a major O&G operator's range of assets, we ultimately identified potential savings of USD 214 million operational spares inventory in one basin alone. To date, the client has confirmed savings of over USD 94 million. These solutions, when deployed properly, can generate serious cost saving benefits."

Simon Evans, Director, Digital Engineering at SNC-Lavalin

Digital Twins: proactive problem solving

Digital Twins are also gaining ground and relevancy. The technology creates a virtual model of the asset and pairs the virtual and real world together. It is directly driven by transparency and proactive problem resolution, enabling stakeholders to minimize rework in the field by allowing a dynamic view of the project and real-time comparison of progress to design blueprints. Drones and satellite imagery, as well as LiDAR and photosphere based solutions, are key components of this twin reality capture.

The most exciting applications can be found in the seamless integration of 3-D models generated by drone imagery, amplified by live performance indicators that are monitored using Internet of Things sensors. This approach creates an exact digital replica of a project's physical reality, allowing the rapidly advance of data accuracy.

SNC-Lavalin is weaving digital twins into its Brownfield and Greenfield projects.

"The term "digital twin" has entered the regular vocabulary of the AEC industry, but the broad scope of its concept makes a common definition difficult. Most focus on the 'unicorn' of what a twin can potentially achieve when fully implemented (even if currently cost-prohibitive). Few refer to the milestones along the journey, or incremental value-proving developments. For us, it is this journey that is the most important. We've start by creating the baseline data set needed to manage an asset, and then convert and develop that into a more advanced twin that will then provide benefit to the client. Think big, start small, scale fast." says Evans

IoT is steadily transforming AEC frameworks in multiple ways, capable of enhancing every aspect of the built environment, from design and fabrication to building and services management. Sensors have already created smart homes and now intelligent tagging is transforming commercial and industrial sectors with significant impact forecast for the near future.

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On track or behind the curve?

Where are you in the planning of your technology changes?

Many of the respondents in this research exercise noted the slow adoption of new technology but found that the entire industry has traditionally matured at a similar rate across the board given the nature of joint ventures and the need for players to be on the same trajectory. That seems to be shifting now with some players perceiving themselves further ahead of the curve than others.

AHEAD 19

BEHIND 15

ON TRACK 13
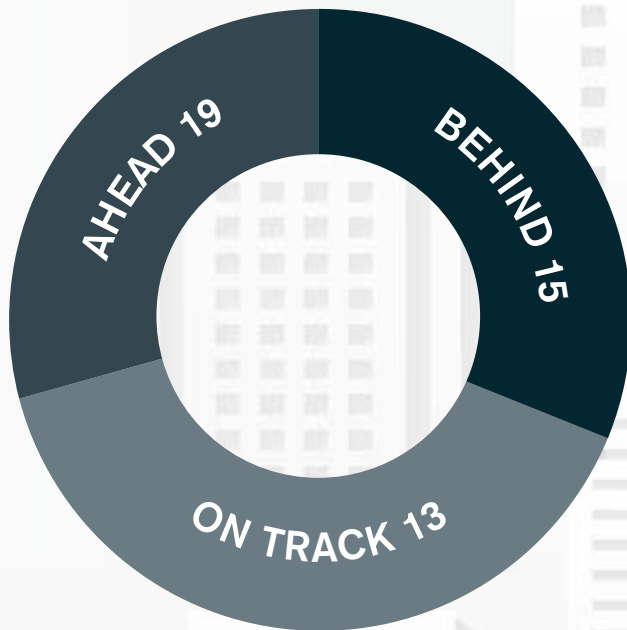
Some of the stuff we've been delivering not only in AEC, but in other sectors has been mindblowing. With a few weeks of minor effort using data analytics, we were able to save $200 million worth of money on the bottom line just by being smart about how we manage data. So we're unlocking savings for our clients. And, we've always been driven by the fact that it's about practical use cases and what we can deliver now. We did this world record attempt to have the most people collaboratively using VR. Over a period of five days across 32 countries, we had 3000 of our staff take part in this experience, and we were rolling 24/7 for those five days. To pull that off is not a sideline capability. I would be very surprised if another company of our type in the industry could do what we did."

Simon Evans, Director, Digital Engineering at SNC-Lavalin

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7. Summary
Looking ahead, seeing around corners

With the silos, bubble thinking and other limitations being overcome, the AEC sector is emerging in a new light. Digital is playing an integral role in levelling the playing field and making all areas of projects and asset management more accessible. The skills shortage is not going away but it makes the argument for technology and data more compelling. Sector growth will lead to more mega projects and smart cities will have more things like AR, VR and data infused and woven into their core. Digital is going to keep coming. It will get cheaper, more scalable and securing it will become easier, but it will never replace culture. Humans are perhaps the single biggest end consumer of the built environment, whether it is to live, work or play in it but, no matter how slick the robotics or intuitive the autonomy, humans have a critical role in building it too.

All this unfolding against the backdrop of the Fourth Industrial Revolution places AEC as a sector in one of the most exciting and dynamic periods in its history. Engineering, design and construction organisations have a unique opportunity to contribute to urban heritage and leave a mark on the cities of tomorrow. As AEC visionaries distil vast amounts of information and attempt to create digital-focused transformative business strategies that can see around corners, they also remain acutely aware of uncertainties and headwinds.

There is one sure bet in all of this - standing still in a freshly digitised environment is not an option.

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8. Contributors

John Bromilow

John Bromilow is a senior technology leader, innovator and digital strategist. John is currently Chief Information Officer at Rendall and Rittner where he joined in February 2019 to develop and lead the company's technology strategy. He has worked with large global corporates such as Balfour Beatty where he spent 12 years delivering IT services and digital transformation projects. Most recently he was Group Technology Director for ISG driving their digital business strategy. A widely respected technology leader, John has over 15 years' experience delivering technology solutions in the property and construction sectors.

Gavin Bonner

Gavin is heading up the implementation of Digital Project Delivery within Cundall. This is an integrated International approach across 19 offices, Setting the company BIM strategies, tracking objectives and delivering on the BIM Maturity Matrix to international ISO standards. Gavin has over 20 years experience working in the Construction industry and has co-ordinated the delivery of design information both in the UK and overseas. Gavin is currently promoting the use of Digital Engineering throughout the industry, bringing clients to the forefront of the latest technology.

Mark Enzer

Mark is Mott MacDonald's Chief Technical Officer. In this role, he is accountable to the Executive Board for technical excellence across the Group. Mark is a keen champion of innovation in the context of collaborative delivery models and he is particularly interested in transformational change in infrastructure engineering, including the application of digital transformation, Smart Infrastructure, low-carbon sustainable solutions, platform-based delivery and design for manufacture and assembly (DfMA).

Mark is the chair of the Digital Framework Task Group, part of the Centre for Digital Built Britain, and is the Digital Director of the Construction Innovation Hub. Mark was the leader of the Digital Transformation workstream as part of "Project 13" for the Infrastructure Client Group, which represents the UK's major infrastructure client organisations and he was the Lead Author of the Infrastructure Carbon Review, published by HM Treasury.

Jim Griffiths

Jim Griffiths has been involved in protection information for the last 30 years and believes that securing information is an ongoing apprenticeship, blending physical, personnel and cyber security disciplines to achieve. Griffiths is currently the CISO at Kier Group Limited, operating in the Buildings, Infrastructure and Housing sector.

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Contributors

Simon Evans

Simon is Director of Digital Engineering at SNC-Lavalin - a key role in the global transformation of the +$Sbn consultancy and construction group. A technology developer and chartered mechanical engineer, Simon has a passion for the transformational applications of digital engineering, and regularly speaks on the subject at events around the world. Prior to this, he led development of digital engineering within Atkins' Energy sector, embedding technologies from virtual and augmented reality to data analytics and robotic, into the business.

Simon's background is in the structural/mechanical design and analysis of offshore structures, and he has experience of living and working internationally. He was elected to Council for the Institution of Mechanical Engineers in 2017, and has received numerous awards for contributions to the engineering profession.

Lewis Wenman

With over 30 years' of industry and 24 years' of delivering BIM Lewis has advanced knowledge and experience throughout the project lifecycle from concept design to project completion and handover. His past experience of working for the Design Team, Contractors and Clients have enabled him to gain a clear understanding with practical delivery along with working knowledge of BIM processes and supporting software applications.

William Reddaway

Will attained a degree in Electronic & Systems Engineering from Loughborough University and went on to work in the niche market of multimillion dollar super-yachts.

Will was appointed as Group Head of Innovation at J Murphy and Sons Ltd, in March 2017, where, as part of Murphy's 10 year plan, to grow and improve the business, innovation has been identified as one of the key drivers to achieving this success. He will be seeking to embed a culture of creativity and innovation to improve how Murphy delivers projects, via technology, products and also by improving systems and processes. Will is a Fellow of the Institute of Innovation and Knowledge Exchange.

Lisa Jones

Lisa is an Account Director for the AEC sector at Claranet. She forms long-term partnerships to provide services which simplify the management of IT, so clients can concentrate on getting and staying ahead.

Claranet combine pioneering technologies, practices and expertise to propel your business ambitions. We are experts in migrating and running critical applications and infrastructure 24x7, and are one of only 5 companies in the world to have all three audited Managed Service Provider certifications from the top hyperscalers.

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9. Acknowledgments

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About Claranet

Quick facts

- Founded in 1996
- Owner managed
- £350m (€370m) revenue
- Over 6,500 business customers
- Global reach with operations in nine countries
- Over 2,200 staff in 24 offices
- Leader in Magic Quadrant for Managed Cloud Hosting, Europe

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