ice

Knowledge

Infrastructure in 2022:
A horizon scan of the year ahead for civil engineering

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Foreword

Richard Threlfall
ICE Trustee for Learning Society

As civil engineers, we are responsible for the infrastructure around all of us. The roads, bridges, power cables and drains we deliver are part of the daily fabric of life – and are often taken for granted in wider society.

However, climate change and the need for net zero carbon emissions have demolished the status quo. Other trends, such as growing urbanisation and new technologies, underline the need for an urgent, profound response. The Covid-19 pandemic has brought a stark warning of what challenges could lie ahead.

Reducing our carbon footprint is crucial for a sustainable future and, with infrastructure being responsible for more than half of the UK's total carbon emissions, civil engineers know they can, and must, play a vital role. That is why we are proud and excited to have established a vibrant group of experts, through our new community advisory boards, to make a significant contribution to ICE's vision, especially for net zero.

Still, this commitment from civil engineers cannot take place in isolation – the solutions have to be collaborative and smarter. As an example, flood defence strategies – such as Hull's multi-agency 'blue-green' approach – are increasingly a mix of natural and engineered solutions.

Our sustainable resilience community has highlighted how, when Hurricane Katrina struck New Orleans in 2005, it was as much the absence of an organised social response as it was infrastructure failure that prompted the state of emergency. And yet, in Indonesia, the fishing boats of Banda Aceh were back on the water two days after the 2004 tsunami, with the local community proving to be more resilient than their counterparts in the southern US.

Engineers can also help to drive productivity by playing a more substantial role in the whole asset lifecycle of our infrastructure. This means reviewing the training of those people entering and, just as crucially, already working in the industry. It also means boosting diversity in the sector. In addition, we need to be more proactive in educating clients about the need for greater efficiency, including far more sharing of ideas and collaborating in alliance-based engineering.

Policy-makers can help by advocating sustainable procurement, a shift that would affect entire supply chains and ultimately have a profound influence on the private sector. Toolkits exist to make this happen and we hope that a revamped PAS 2080 in 2022 will also help to bear down on the whole-life management of carbon in infrastructure.

The challenges – and potential solutions – identified in this report reflect the wide and experienced constituency of knowledge and opinion within our community advisory boards. Their insights include whole-systems thinking, smarter guidance and standards, engaged supply chains and those crucial relationships between policy-makers, clients and engineers.

I'm grateful that so many members of our new knowledge community have volunteered their time and expertise for this vital work. This report, looking ahead into 2022, is the first showcase of their commitment. I look forward to many more rich offerings.

Lastly, my personal thanks to the sponsors of the report who have helped to bring this important exercise to fruition.

About this report

In May 2021, the Institution of Civil Engineers (ICE) launched new community advisory boards (CABs) to identify problems and challenges faced by engineers, the environment and society as a whole.

The aim is to drive trusted, authoritative and independent insights into the issues affecting our national infrastructure. Each advisory board is made up of industry experts and representatives of supporting communities who will help to build respective knowledge programmes, drawing on the expertise of peers and other relevant groups.

As an initial step, each CAB has held individual sessions to assess the current situation and what is needed in the year ahead. The chapters and case studies in this report reflect their discussions. ICE thanks sincerely those advisory board members who contributed:

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Case study: Contractor goes digital for estimation tasks

An ultimatum from a large client prompted Solid Earth Civil Constructors to use engineering and construction software company Bluebeam's Revu solution for digital estimation and bid submission.

Before that, estimation was a paper-based workflow and the US company lacked the IT staff necessary to undergo the required digital transformation.

Revu digitised the traditional workflows for take-offs and bid submission and established real-time mobile collaboration between the office and field. This brought several benefits:

- The first time Revu was used for digital estimation it picked up a US$50,000-US$60,000 mistake on a project take-off.
- Going digital resulted in big time reductions in the tendering process, with estimation cut from two weeks to a day.
- Bid submission capabilities more than trebled, with more bids in the first quarter of the following year than the whole of the previous year.
- The Studio component in Revu made it easier to collaborate with field staff, minimising time spent in the office coordinating data.
- Modernising project workflows increased trust, communication and opportunities.

Drake Carter, project manager and estimator at Solid Earth, said: "We have immensely changed the way estimating [works] for the company and have been able to produce so much more work for ourselves that we actually have to pick and choose the jobs we really

01 Data and digital

Proving the value of information management is the key to encouraging meaningful transformation in working practices across the civil engineering industry – and the journey has to begin in 2022

Although a raft of innovative techniques and technologies has sprung up in different pockets of the sector in recent years, there remains limited, if any, means of evaluating the impact that good data handling has on a company's bottom line.

The goal now is to convince company chiefs to make pro-digital decisions based on the knowledge that failure to do so would make them less profitable, less able to attract investment and subject to higher insurance premiums. This will require a big push to find a measurement system that can be widely adopted and trusted.

Digital transformation is a goal worth pursuing as, fortuitously, technology is evolving at the very time it is needed to tackle a growing to-do list for civil engineers that includes lower carbon use, higher productivity and managing with tighter resources at a time of global crisis. Collection and analysis of data to inform decision-making, and the use of digital tools to deliver positive outcomes, are seen as an essential way forward for the sector.

ICE's data and digital community believes digital transformation is built on four cornerstones: information, technology, process and people. Technology is useful only as a means of collecting and distributing information, which is itself valuable only when it assists people to make decisions that improve processes and make projects quicker, safer and cheaper to ensure that the built environment we all live in is better suited to our needs.

It is often remarked on how far construction is behind the manufacturing industry – that it is still creating almost every building on a bespoke basis from scratch rather than standardising, replicating and streamlining. In fact, the reality could be far worse: in its 2016 report Imagining Construction's Digital Future, US consultancy McKinsey and Company ranked construction 21st out of 22 industries for its rate of digitalisation. Despite growing impetus – not to mention huge sums of money invested in engineering and construction technology in recent years – the sector still lags far behind many others it could aspire to.

> If the pump and the pipe is the technology, then the water that flows through it is the information. If we don't recognise the value of that information then we have missed the point. It's all about the right information in the right hands at the right time to make the right decision.
>
> **Mark Enzer, co-chair, ICE Data and Digital community advisory board**

One major problem, which echoes the need for evaluation of data management as a practice, is the lack of consistent and widespread measurement of the rate of change in digital practices in the UK civil engineering industry. Again, finding ways of benchmarking and comparing is a vital goal for the coming year. Understanding the difference between operational technology – the tools used to run a physical asset – and information technology – which focuses on management of data to boost the capabilities of the asset – is important. Progressive clients are starting to incorporate and integrate the two facets, which is positive but brings challenges that need to be addressed.

In September this year, the Infrastructure and Projects Authority (IPA) published its Transforming Infrastructure Performance: Roadmap to 2030. Cabinet Office minister Lord Agnew said in the foreword that the Government must "rewire its decision-making and other processes in order to embed… better data sharing".

Progress against the actions set out in the report for 2022 and 2023 is crucial for the industry to achieve the long-term digital

transformation it seeks, the ICE data and digital community believes. These actions include: developing a consistent measurement of a project's digital maturity using a standard tool and monitoring change in organisational digital maturity; embedding awareness of the requirements of the UK BIM framework and working to improve interoperability; and continued focus on targeting high-performing built assets to help realise better public-sector value from the construction process.

Critically, the IPA has also set out plans to publish guidance in early 2022 for measuring the economic, social and environmental value of location data to support its wider adoption. Its report says a Geospatial Commission will deliver pilots on land-use data to improve the findability and accessibility of such data by autumn next year. This will demonstrate "how a joined-up approach to data could support more coordinated policy-making and local delivery", the report says.

Meanwhile, work on a National Underground Asset Register, a standardised and interactive digital tool showing the location of underground pipes and cables, will, by 2023, complete a minimum viable product for north-east England, Wales and London.

There is a concerted centralised effort to see progress on key themes critical to construction's digital transformation over the next 12 months. The ICE community also senses a willingness from local leaders to go on this journey. Councils are under pressure to achieve more from less and several have made strides towards more digital working. Stoke-on-Trent, for example, has published its Silicon Stoke Prospectus, which outlines measures under way to create a 'smart city', including a 113km full-fibre network with the opportunity for city-wide 5G connectivity.

Deployment of 5G networks is seen as a game-changer for construction, with its potential to remove a significant block to technological innovation. Fast, reliable connectivity on sites could make several new processes viable, from real-time monitoring of resources to automated machinery. Working with Nokia and Telent, this autumn Ferrovial deployed one of the UK's first operational standalone private 5G wireless networks at the Silvertown Tunnel project in east London.

The ICE community is heartened by the range of trailblazing initiatives afoot but believes the next challenge is to convert this activity into simple best-practice guidance that can be cascaded throughout the sector to make a real difference. There is a big role for clients to play in specifying the best use of data and technology at the procurement stage, but also for the industry to set the agenda and ensure lessons are learnt and shared widely.

At a more granular level, civil engineers need to be trained to think about the importance of data at all stages of an asset's lifecycle. Digitalisation must become core to all roles in the sector, not just discrete tech teams.

> 66 The next challenge is converting digitalisation into simple best-practice guidance that can be cascaded throughout the sector to make a real difference.

Further reading

- **IPA (2021) Transforming Infrastructure Performance: Roadmap to 2030: bit.ly/tiproadmap**
- **Geospatial Commission Annual Plan 2021-22: bit.ly/geospatialcommission**
- **Barnes, P (2020) Emerging Technologies, in BIM for Project Managers: bit.ly/BIMforPMs**
- **Schunmann, D (2021) Five Critical Steps for Engineers Going Digital: bit.ly/schunmann**
- **McKinsey and Company (2016) Imagining Construction's Digital Future: bit.ly/mckdigifuture**
- **Silicon Stoke Prospectus: Establishing Stoke-on-Trent's Plan for a Gigabit Connected City: bit.ly/siliconstoke**

Case study: Ferrovial Earthworks vehicle monitoring

In 2021, Spanish construction giant Ferrovial Construction revealed plans to bring to the UK a ground-breaking initiative to improve monitoring of earthworks vehicles.

Called Ferrovial Earthworks, the system uses sensors to collect information about machinery performance. This data is sent to an online platform to be stored and processed using proprietary algorithms before being translated into a simple overview of fleet activity. Users can download daily or customised fleet activity reports and receive real-time alerts.

The aim is to give project managers useful data relating to what their earthworks vehicles are doing at any one time to allow better decision-making, leading to more efficient projects. Measured variables include a driver identification number, speed of travel, position onsite and volume of material carried.

After an initial test run on Ferrovial's A73 highway project in Spain, the system was trialled at the contractor's machinery park at Seseña, near Madrid. Although these were not complete pilots as the devices were used intermittently, Laura Tordera, Ferrovial Construction's global head of innovation, told New Civil Engineer that they worked "perfectly".

More extensive trials took place in summer this year in the Canary Islands and the US, and Ferrovial also worked to establish the best place for the system to debut in the UK.

In the meantime, further work to grow the value of the system has been taking place. An ambitious second phase aims to develop artificial intelligence that will offer data-driven control of vehicle movements. Ferrovial has also signed an agreement with Massachusetts Institute of Technology (MIT) to collaborate on new initiatives.

"The construction sector is one of those with the lowest productivity and digitalisation and we should work to change this," Tordera told NCE.

ICE's data and digital community is keen to see progress on initiatives such as this and for a path to be established for the industry to come together to share digital innovation and collectively move towards lasting and meaningful transformation.

02 Decarbonisation

Two of the biggest challenges facing the civil engineering industry are the delivery of large-scale projects and the transformation of our existing systems to meet carbon reduction goals towards net zero

According to the Treasury's Infrastructure Carbon Review of 2013, more than half of UK carbon emissions were related to infrastructure. Even back then, when the official target was to cut emissions by 80% between 1990 and 2050, the review said that "urgent action" was needed.

In 2020, the Green Construction Board (GCB) found that while some promising progress had been made over the previous seven years, the pace of change had to accelerate fast. It called for the infrastructure industry to "rapidly gear up" to help meet the new goal of net zero carbon by the middle of the century, warning that the urgency of this drive was "greater than ever".

In November, significant announcements were made at the COP26 climate summit in Glasgow, including plans to move away from the burning of fossil fuels for energy and road transport. Hybrid trains that could be powered by hydrogen, battery or overhead electric wires were also showcased in the city.

ICE's decarbonisation community welcomes the initiatives that have been undertaken to date and recognises that the relatively long lead times between early planning stages and delivery are causing real tension, with transformational carbon-led change essential if the net zero goals are to be met. The construction of Hinkley Point C nuclear power station in Somerset, for example, was approved in 2013 but is unlikely to start providing energy to homes before 2030, when circumstances will be very different. Similarly, Network Rail is working with suppliers in a bid to ensure that 75% of emissions created on the railway are within science-based targets by 2025. But by then, will the goalposts have moved again? Ambitions need to be continually revised and 2022 is no exception.

A key area of focus in 2022 should be the way infrastructure contracts are awarded and structured. The GCB's update report in 2020 described "disappointingly little movement away from traditional lowest-cost procurement and confrontational contracting" and added that lack of progress on procuring for low-carbon outcomes "holds back almost everything else".

The ICE community believes policy is finally sparking action in this field. The UK Government's Green Book revision in 2020 stressed that decisions on spending taxpayer money should be based on a range of factors, including net social value, while the Construction Playbook, published by ministers late last year, urged contracting authorities to adopt whole-life carbon assessments to minimise the footprint of their projects.

It is felt that these measures will prompt public sector procurement chiefs to demand more from their contractors by way of slashing embodied and operational emissions from infrastructure. This will then be passed down the supply chain and should filter into better performance on private sector jobs.

Another significant factor driving changing client behaviour in 2022 is the impact of legal decisions such as the UK's Court of Appeal ruling in 2020 that approval of Heathrow's third runway was unlawful because a critical government policy framework did

> 66 Civil engineers are at the heart of the real-world delivery of rapid change that supports net zero goals to 2050 and beyond. We have to make the case for decarbonisation across everything we do and then deliver real change at pace, as this is crucial for decarbonised economies and lower-carbon lifestyles across the world.
>
> **Rachel Skinner, chair, ICE Decarbonisation community advisory board**

not take account of decarbonisation commitments in the 2016 Paris Agreement. Although this was subsequently overturned by the Supreme Court, the future of the project remains uncertain as pressure increases on ministers in the wake of COP26. The same is true of the proposed new coal mine in Cumbria, which is awaiting a planning inspector's recommendation following a lengthy inquiry but which is subject to intense scrutiny. Investors will be closely watching how projects such as these progress.

The ICE decarbonisation community awaits the publication of the UK Construction Innovation Hub's Value Toolkit in 2022, which could bring more clarity in the use of environmental outcomes to guide government decisions. Another landmark for next year will be the publication of a rewritten PAS 2080 – the standard for whole-life management of carbon in infrastructure.

As well as the need to press on with projects that will lead to huge cuts in operational emissions, such as electrifying transport and cleaning up energy supplies, innovation will be necessary to slash the embodied carbon of all new structures. The ICE community believes engineers will sometimes have to stand back and not build in the traditional sense but instead find ways of getting more from existing assets and achieving results from the environment. For example, one answer to wetter weather is bigger flood barriers but natural solutions such as sustainable drainage could have far greater benefits for society.

Digital tools, with improved data collection and sharing, must be used better. Whole-life carbon assessments require reliable information and manufacturers can help by being open about the emissions already in their products and the carbon cost of their use. Scanning a barcode to read this data, for example, would bring infrastructure design into the 21st century. Engineers could work towards standardised building models that are more carbon effective in both the short and long term and more resilient and adaptable in the future.

Continuing to win hearts and minds will be critical in 2022 if meaningful and rapid progress is to be made within the next three decades. The UK public is already on board with the broad agenda: research from Ipsos Mori in October found that the public supported seven out of eight of the key net zero policies, with 83% saying that they were extremely, very or fairly worried about climate change. It is the task of infrastructure professionals to align with the public demand for – and the needs of – a net zero economy and to transform our existing systems and new infrastructure investment accordingly.

COP26 reinforced and revalidated the need for urgent climate action globally. With the event behind now us, ever more countries are committed to the creation of net zero carbon outcomes over the next few decades. With that, there is an emerging understanding of the real complexity, scale and pace of change that is needed by 2030.

> 66 It is the task of infrastructure professionals to align with the public demand for – and the needs of – a net zero economy and to transform our existing systems and new infrastructure investment accordingly.

Further reading

- **BSI (2016) PAS 2080: Carbon Management in Infrastructure: bit.ly/BSIPAS2080**
- **HM Government (2021) Industrial Decarbonisation Strategy: bit.ly/Decarbstrategy**
- **Committee on Climate Change (2019) Net Zero – Technical Report: bit.ly/cccnetzero**
- **Newton, P et al (2019) Decarbonising the Built Environment: Charting the Transition: bit.ly/Newtondecarb**

Case study: Utilities team up on Climate Resilience Demonstrator

Utility giants Anglian Water, BT and UK Power Networks have announced a pioneering initiative: a Climate Resilience Demonstrator.

The infrastructure asset owners have teamed up with researchers and innovators at the National Digital Twin (NDT) programme, which is run by the Government in partnership with the University of Cambridge, to develop a virtual replica of their networks.

The project uses skills in systems engineering, digital asset management and climate change modelling to create a digital twin that can be used to plan a more resilient built environment for the future. Asset and operations data from the three companies is combined with climate and weather data within the model to inform an increased level of infrastructure resilience.

Looking specifically at the impact of flooding caused by climate change on the energy, water and telecoms networks, the demonstrator is designed to showcase how information shared across sector boundaries can be used to plan for and mitigate the effect of flooding on network performance.

Using an information management framework approach developed through NDT, the partners can access the data across a secure platform. The demonstrator is expected to show how connecting digital twins in a principled, scalable way can inform decision-making on capital and operational projects, reducing the cost and disruptive impact of extreme weather events and increasing resilience, with minimal need for fresh carbon emissions from new construction.

Project lead Sarah Hayes said the scheme could demonstrate that connected digital twins offered increased climate resilience and that collaboration across different parts of industry, academia and government could "unlock solutions to reaching net zero".

David Riley, head of carbon neutrality at Anglian Water, added: "We have already begun seeing the real-life benefits that digital twin technology can bring to how we plan, construct and maintain our assets as a water company, while ensuring we remain on track to reach our net zero target by 2030."

DRPG

Case study: High Speed 2 M42 bridge

2

Number of days taken to install 65m-long bridge over the M42

1,610t

Amount of precast and in-situ concrete delivered

A raft of modern approaches came together to allow a 65m-long bridge to be installed over the M42 in the West Midlands in only two days as part of the HS2 rail project.

The crossing formed part of a major remodelling of the regional road network last year to improve the flow of traffic in Solihull and connect it to the rapid rail line's new Interchange station.

Traditional construction methods to build the bridge would have meant several weeks of lane closures on both motorway carriageways, and possibly weekend and overnight possessions. However, disruption was significantly reduced using digital tools to design the structure virtually before elements were manufactured in purpose-built facilities and swiftly put together onsite.

A total of 1,610t of precast and in-situ concrete was delivered, including modular abutment shells and deck components. Large structural elements of the bridge supports and deck were made at Laing O'Rourke's Centre for Modern Construction, while Cleveland Bridge supplied 1,130t of steel plate girders.

The project was led by engineering contractor Expanded and HS2 enabling works contractor LMJV, a joint venture of Laing O'Rourke and J Murphy and Sons. For the final installation, the 2,750t bridge structure was carried along the motorway on a self-propelled, 448-wheel modular transporter. It took one hour 45 minutes to move the bridge span 150m, to be affixed to a composite concrete deck to complete the overall bridge structure.

ICE's productivity community believes that the M42 bridge scheme showcases what can be achieved with sufficient forethought, collaboration, innovative thinking and careful planning, as well as flawless execution onsite.

It is hoped that mega-schemes such as HS2 can be a catalyst for productive methods of construction. At the same time, it is critical for the civil engineering industry to learn lessons from small contractors working on less high-profile jobs.

03 Driving productivity

Boosting the efficiency of the sector will be a key concern for ICE in the coming year – with educating decision-makers and improving training among the ways to achieve it

Fresh procurement models will be needed in 2022 to drive a step change in the efficiency of the civil engineering industry, ICE's productivity community believes.

Members feel that while the blueprint for this shift has already been laid down by initiatives such as the UK Government's Construction Playbook, focused guidance to decision-makers – along with a rethink of education and training for engineers – is needed to haul it from theory to practice.

Improving productivity will be critical next year if the industry is to help society to achieve major aims such as decarbonisation and energy resilience in a world of increasingly limited resources. And the clock is ticking. There are also many benefits to be had for the workforce, including better mental and physical health and more career opportunities if the industry can secure greater investment.

Towards the end of this year, it emerged that one flagship UK project – the redevelopment of London's Euston station to accommodate the £100bn High Speed 2 project – was being amended from 11 platforms to 10. This will allow the project to be delivered in one stage rather than two, creating a number of efficiencies and reducing the risk of cost rises from the complex job. The productivity community backs design changes such as this but hopes to see them being made earlier – by bringing in the right skills at the earliest opportunity, productive construction methods can be baked in from the start of the design process.

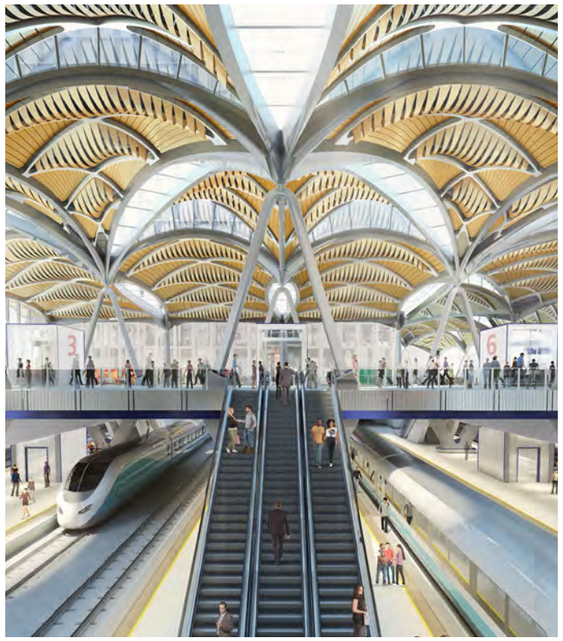
Use of state-of-the-art shuttering systems for the secondary lining of the shafts and tunnels of London's Tideway, the 25km-long super-sewer being constructed under the Thames, is an example of how years of collaboration and planning can result in productive systems. This has enabled the delivery of a repeatable pattern onsite that has avoided costly errors or redesigns. Optimisation of the design to reduce lining thickness, costs and carbon shows the benefits of engineers working together to create efficient outcomes.

Looking forward, the community is keen for civil engineers to explore options and innovate at far earlier stages of their projects before locking down the design, construction methodology and delivery. As well as avoiding cost and time overruns on projects, this approach can have a transformational effect on the industry as a whole, improving how it is viewed and sparking a positive cycle.

> "The community's focus on current best practice and a clear definition of productivity is a powerful platform for us to provide genuine tools to help civil engineers to positively influence the whole asset lifecycle. 2022 will be a year of outputs.
>
> **Darren James, co-chair, ICE Driving Productivity community advisory board**

Encouraging different ways of working relies heavily on changes to procurement methods. Published in late 2020, the Construction Playbook set out objectives such as greater use of offsite manufacturing, earlier supplier engagement and longer-term deals as part of a broad attempt to use public spending power to generate quicker, better, greener projects. Much of this is not new, having been laid out in big-ticket reports in the previous century. The challenge is how it can be brought into practice in a meaningful, game-changing way in 2022.

The ICE productivity community believes that a key role for the industry at this point is to educate decision-makers, who, it should be noted, are rarely engineers themselves. To this end, it intends to publish practical guidance to help construction clients at all levels to understand the imperative for productivity-inducing procurement – and how to achieve it.



Rendering of how new Euston HS2 terminus will eventually look

> Improving productivity will be critical next year if the industry is to help society to achieve major aims such as decarbonisation and energy resilience in a world of increasingly limited resources – and the clock is ticking.

Beyond this, there is a communication challenge for the sector to convince governments of the importance of procuring for productive construction. Many of the rules and processes in the way of modernising the industry should also be removed.

As well as driving efficiencies through greater collaboration and a willingness to share ideas, a move towards more alliance-based civil engineering would create more time for innovation by removing the constant drag on resources that comes from conflict. A shift from adversarial contracting models means people can focus on smarter ways of building infrastructure rather than sitting in meetings about contract clauses and complex claims.

This virtuous circle can be seen elsewhere. If more modern methods of procurement are enacted, increasing efficiency by even small amounts, this will create marginal slack in budgets for a slight loosening of the purse strings, encouraging more value-driven activity that ramps up productivity still further. As margins improve, research and development spending can increase. With continuous improvement at the heart of everything, both at the project level and in a wider industry context, the productivity community believes that big gains can be made from small beginnings.

As well as educating policy-makers and clients about the importance of efficiency in construction, and how to spark it, members are keen to see better training for civil engineers next year. This could include ensuring that all new entrants to built environment professions, from architecture to quantity surveying, have a grounding in each other's disciplines to promote wider understanding of what is required to build and maintain assets. Encouraging more off-piste thinking from engineers, who have traditionally been taught to follow pre-ordained processes, would also improve innovation and therefore productivity.

Training requirements do not stop at graduation level – many industry long-timers need to refresh their skills if they are to continue to be productive in 2022.

Diversity of the workforce is another key area for next year – the greater variety of people in the sector, the greater the breadth of thinking and the more chance of finding a better way of doing something that can then be agreed upon and delivered efficiently. Diversity has many faces: learning from small projects from jobbing engineers is just as important as drawing down the lessons from mega-schemes and international joint ventures.

Other industries also have much to teach civil engineering. For example, in the marine maintenance sector, huge cruise ships are regularly refurbished on the high seas in a fraction of the time that many infrastructure assets are maintained on dry land.

Overcoming traditional standards and in-built ways of doing things will be critical if the civil engineering sector is to achieve the gains it needs to make in the year ahead.

Further reading

- **HM Government (2020) The Construction Playbook: Government Guidance on Sourcing and Contracting Public Works Projects and Programmes: bit.ly/constructplaybook**
- **Seadon, J and Tookey, J E (2019) Drivers for Construction Productivity, Engineering Construction and Architectural Management 26(2): bit.ly/productivitydrivers**

Case study: Maintaining concrete level crossings using geopolymer injections

As operators cope with greater demand on the UK's railway infrastructure and growing financial pressures, more productive and sustainable construction methods are vital. Operators often face emergency works that can skew their spending plans, so routine maintenance is reduced to compensate. In the long term, this maintenance backlog will have an impact on the overall condition of the railway infrastructure.

Concrete level crossings often experience significant settlement, which affects ride quality and may compromise the safe operation of the line. The conventional solution of reconstruction is time-consuming and expensive. Maintaining crossings using ground engineering specialist Geobear's geopolymer injection method is less time-consuming and cheaper – and, if adopted on a large scale, could also boost productivity.

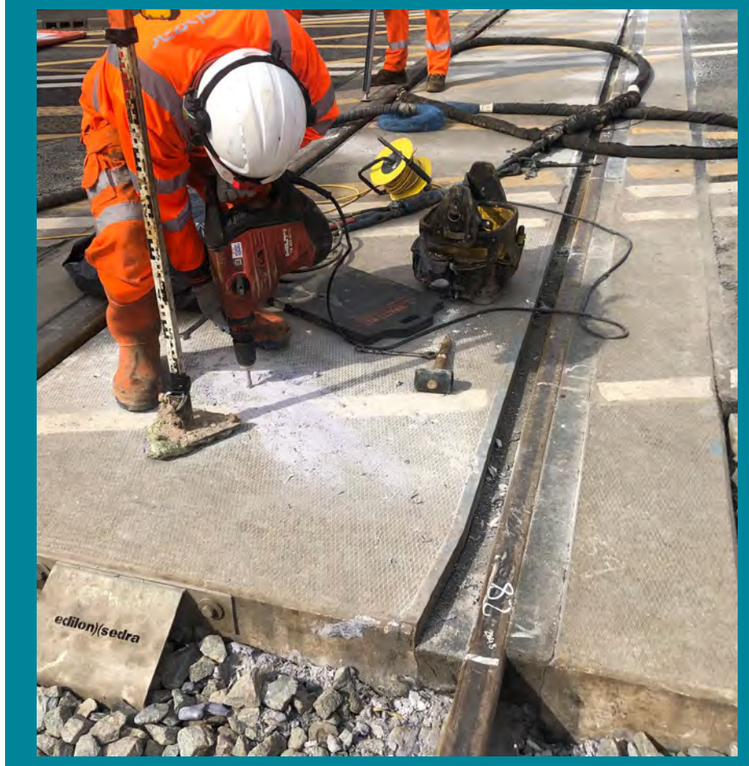
A concrete level crossing in north-east England was deteriorating because of soft underlying conditions and poor drainage, resulting in a sub-grade settlement of up to 60mm deviation from vertical design geometry. Geopolymer injections lifted the slab to design geometry with a tolerance of +0mm/-10mm and strengthened the sub-base layer. Geopolymer was injected into the Type 1 sub-base, 50mm below the slab, via 12mm drill holes. A surveying team monitored the site afterwards using laser levels.

Track geometry recordings from a measurements train were monitored monthly to assess the treatment's performance. It was shown to have improved track geometry by 69% on the down line and 75% on the up line. Subsequent deterioration has been slow and it will take eight and five years for the down and up lines, respectively, to reach pre-treatment track quality.

Although full reconstruction provides an asset life of 15 to 20 years, the geopolymer treatment delivers cost savings and advantages in a number of aspects:

- The geopolymer solution is 43% cheaper than full reconstruction.
- Full reconstruction takes longer, often leading to network disruption and penalties from private train operators.
- Full reconstruction generates large amounts of track spoil, posing logistical challenges related to its disposal.
- The geopolymer treatment has a lower carbon footprint because it requires less materials, logistics and plant.

Although a full reconstruction will be needed at some point in the crossing's asset lifecycle, geopolymer injections can prolong this cycle while maintaining an adequate level of performance with minimal impacts on spending budgets and network disruption.



60mm

Amount of sub-grade settlement deviation from vertical design geometry

75%

Percentage the geopolymer treatment improved track geometry by on the up line

43%

The geopolymer solution is 43% cheaper than full reconstruction

Case study: Flood management, Skipton

A hybrid flood risk management project close to the Yorkshire Dales showcased how hard and soft engineering could be combined to protect properties while benefiting the wider community.

The £17.8m scheme in Skipton was led by the Environment Agency and was completed in 2018. Primarily, its aim was to stop water from Eller Beck and Waller Hill Beck from flooding nearly 400 homes and 165 businesses in the town centre over the next century. A life was lost in floods from these streams in 1982, while four significant events have occurred since 2000.

To tackle the problem, two storage areas, which can hold a combined total of 111 million gallons of water, were created upstream to slow the flow of water from the surrounding hills.

At the larger of the two storage areas, a 13m-high, 610m-wide earthworks dam was built to hold 95 million gallons. Normal flows pass unrestricted through a culvert within the dam but a barrier, or penstock, can be lowered to block this off during a flood event, holding water back to form a reservoir.

At the other storage site, a 9m-high, 105m-wide dam can hold 16 million gallons. A concrete culvert with inlet and outlet has been built to allow the beck to flow during normal conditions but hold back water at peak times.

The scheme also includes 300m of new flood defence walls at locations such as a supermarket car park, near private gardens and close to a children's play area. Some of the defences have been clad in matching stone to blend in with other buildings. Consideration has been given to allowing local otter populations to thrive. In addition, the scheme will open up land to development for businesses.

ICE's flooding community believes the scheme shows the benefits of using nature-based solutions while recognising the importance of hard engineering to manage rare yet potentially devastating extreme water flows.

04 Flooding

Messaging must change in 2022 to ensure a broad range of skills is brought into the civil engineering sector to shift the focus of flood risk management

This year the Intergovernmental Panel on Climate Change provided updated predictions confirming that climate change is happening to a greater extent and at a faster pace than previously thought. The impact is set to worsen even under the most ambitious carbon reduction plans. In a sobering report, the committee said that the UK's winter rainfall could be 16% higher by the middle of this century and described flooding as a "major climate hazard". This threat is not limited to the UK, of course, as evidenced by devastating incidents in northern Europe and China, among others.

ICE's flooding community believes that changing climates will easily overwhelm engineers' ability to fully protect all communities from excess water, so a change in approach is needed. Rather than building ever-larger structures to hold back water, a more holistic view must be taken to create places that not only minimise flooding but also cope with it when it happens and recover swiftly. This will need to be combined with more nature-based solutions, both in rural catchments and in cities.

Blue-green measures, using natural resources to manage water levels, have a significant role to play in protecting communities and limiting the carbon emissions embodied in interventions. A positive cycle can thus be created and the ICE community is keen to pursue this, but it cautions against a belief that sustainable methods can act as a panacea. Hard engineering will be necessary to keep people safe in some instances for the foreseeable future, while a hybrid model that takes all factors into account should be aspired to longer-term.

In Leeds, 700 sq km of the River Aire catchment is being managed differently to reduce the flow reaching the city. This includes planting, swales, bunds, leaky barriers and ponds. In China, the 'sponge city' concept involves cities built to contain rainfall in ponds and meandering, vegetated rivers that provide pleasant natural spaces within dense urban areas.

The ICE flooding community backs such innovative thinking but stresses that these schemes still require engineering – people thinking of them as landscaping or planting initiatives often undervalue the extent of engineering involved in tackling flooding using modern methods.

Greater thought is needed to ensure that resilience to flooding – be it coastal, fluvial or surface-water related – is baked into all new development and retrofitted where possible into the existing built environment. Infrastructure and buildings should be expected to cope with excess water events in the same way as they are required to deal with high winds or cold weather. Beyond this, catchment-wide thinking must be ramped up to ensure decisions in one area do not add to the flooding burden on another.

To achieve such holistic thinking, a shift in both funding and policy is necessary. It is a complex change that will require more freedoms at local authority level and more funding to manage this requirement in planning, ensuring correct construction and long-term maintenance.

> We have locked in climate change that is far bigger than we anticipated and we cannot protect people from it. We have to make sure flooded cities can function and allow people to recover quickly. We must start thinking about this in a joined-up way when designing roads, rail or other infrastructure.
>
> **Fiona Barbour, co-chair, ICE Flooding community advisory board**

Securing funding and political will for the projects to implement this new thinking will be a struggle, especially as governments around the world battle to restart economies and pay off debts after the Covid-19 pandemic. New ways of framing the issue are imperative, moving the debate on from protecting against floods to showing the broad benefits of better catchment management, resilience built into the public realm and nature-based solutions.

Communities and politicians are more likely to be motivated by moves to increase the quality of bathing water, for example, or to create landscaped recreational areas. A place-based approach to delivery would generate designs that deliver multiple societal benefits.

Reports expected in 2022 could help to plot a course. In the spring, an analysis is expected into why the flash floods of summer 2021 in London had such a devastating impact, with water pouring into properties and Underground stations. This is expected to include a set of broad recommendations on urban flood prevention that will be closely watched by policy-makers. Meanwhile, the Government's Stormwater Overflow Taskforce will report in September on measures to eliminate harm from sewage spills during extreme wet weather.

A greater skills base will be needed in civil engineering to ensure the broad spectrum of knowledge is there, along with the ability to steer clients and policy-makers towards the approaches necessary to manage excess water in the future.

Diverse talents are essential, whether in biology, ecology, data analysis or communication, and the industry should seek as broad a range of applicants as possible – particularly attracting more women and people from black, Asian and minority ethnic backgrounds. The industry can start by broadening its culture and showcasing its opportunities better to school and university leavers.

Technology can also be harnessed to improve how we manage exposure to floods. Drones, for example, can collect useful data from disaster zones without hampering the emergency response. Artificial intelligence can help to get the most out of existing assets using information gathered from sensors to manage water flows. People who can make the most of this technology are needed, combined with systems to better share data.

Above all, communication will be vital in 2022. Engagement with universities, graduates, other industries, the public, policy-makers and those working in civil engineering and flood management will be critical to reframing the problem of excess water. A review of early-warning systems – including experiences in other countries – is also recommended as communities adjust to find ways of living with this growing challenge.

The ICE community hopes that lessons will be shared and learnt. More flood events are inevitable and it is important that a better environment to deal with them is created.

> 66 The more diversity in engineering, the better our chance of finding the right mix of talent and knowledge to drive the flood-risk management agenda in the right direction.

Further reading

- **Environment Agency (2020) National Flood and Coastal Erosion Risk Management Strategy for England: bit.ly/EAfloods**
- **UK Water (2021) Storm Overflows Evidence Project: Final Report: bit.ly/ukwater**
- **Scottish Government (2021) Water-resilient Places – Surface Water Management and Blue-Green Infrastructure: Policy Framework: bit.ly/scotgovwater**
- **Thorne, C R (2020) Blue-Green Cities: bit.ly/bluegreencities**
- **Shao, W et al (2020) Characteristics and Effectiveness of Water Management Methods for 'Sponge Cities' in China: bit.ly/spongecitiesChina**

Case study: Elephant Park, London

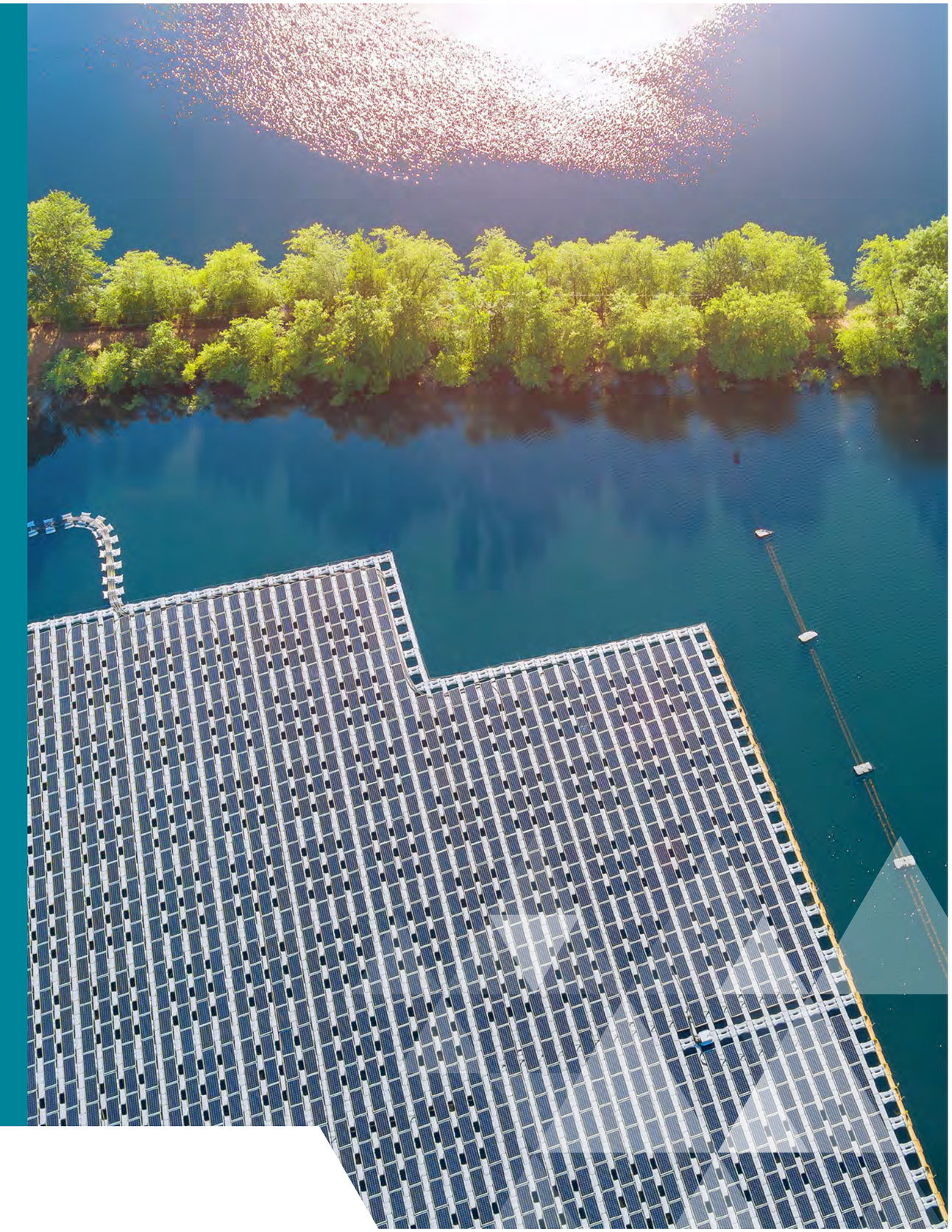
Martin Lambley, stormwater management product manager for north-west Europe, the UK and Ireland at Wavin, explains how the Elephant Park development in London will reduce flood risk at the same time as benefiting residents:

Climate change has brought a dramatic increase in flooding incidents across the UK, both from widespread winter fluvial events and localised flash flooding in the summer. Scotland and northern England are projected be the worst-affected areas, both in terms of intensity and frequency.

So how can we ensure infrastructure is prepared to cope with more rain and stormwater? Traditional techniques of collecting water through a pipe and moving it to a water course or infiltration/attenuation tank before release will still have a role to play in future drainage. However, this solution cannot be used in isolation and it is imperative that it is part of wider schemes involving upstream catchment management and sustainable drainage systems (SuDS) within developments and urban areas.

For the Elephant Park development in London, surface water management was at the centre of the project from the outset of the design. It includes a park, the largest new green space in central London for 70 years. While its primary function is to create an amenity space for future residents, it also plays a critical role in the management of surface water. Water from the roofs, roads and paved areas is collected and channelled into a series of basin and rain garden features.

All of these are underpinned by Wavin rainwater management systems that are designed to give additional capacity at peak flows, helping to mitigate flooding risk. This was central to the design, as managing water within the development reduces the impact on London's ageing drainage infrastructure. Elephant Park shows how good, collaborative design can deliver a multitude of benefits to the local area, as well as helping to reduce the risk of future floods.



05 Low carbon energy

Rolling out renewable forms of energy will be a key focus in 2022 – and civil engineers will have a crucial role to play not just in creating the infrastructure needed but in encouraging public buy-in

As 2021 draws to an end, both COP26 and the ballooning price of gas have highlighted the importance of a diverse, decarbonised energy system if the UK is to meet its 2050 net zero target.

The ICE energy community understands that how we obtain, generate and use energy within the three 'trilemma' parameters of decarbonisation, security of supply and affordability is critical. Civil engineers will play a crucial role in delivering the infrastructure needed.

The UK Government is carrying out a review to ensure that its 10-year-old National Policy Statements for energy continue to provide a suitable framework to support decision-making for nationally significant power infrastructure. Various technologies, some mature, some barely out of the lab, are under consideration: offshore (including floating) wind; solar photovoltaic; wave; tidal range; tidal stream; energy-from-waste; biomass; natural gas; low-carbon hydrogen; large-scale nuclear; small modular reactors; advanced modular reactors and fusion power plants – several paired with carbon capture and storage. A recent government consultation document said starkly: "The need for all these types of infrastructure is established as urgent."

As this national policy framework is being established, the ICE energy community is aware that this is the beginning of a journey and most of us are barely at the foothills of a steep path that has yet to be charted. One member said: "Yes, everyone realises renewables are the way forward but we have a long way to go. Take wind farms – the gestation from first appearing to being accepted by the wider population has taken a long time." Another pointed out: "Climate change is only now finally hitting home with people." Renewables could be seen as a panacea to all of our energy problems and politicians may be overplaying that card without realising how change will be achieved.

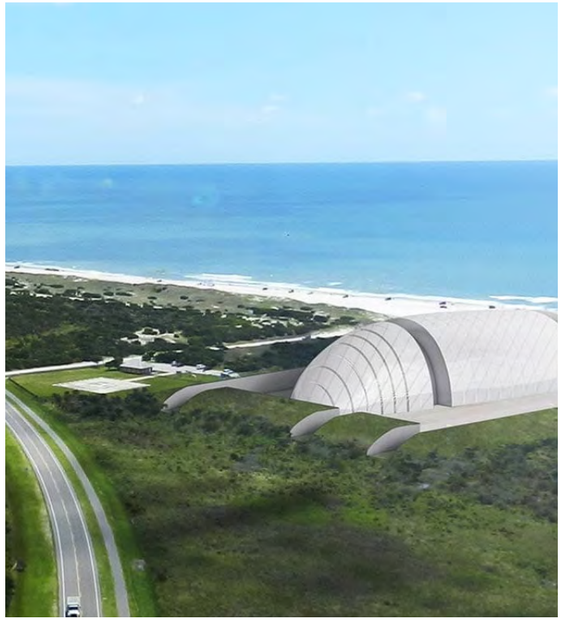
A wide-ranging set of technologies must be learnt and managed but civil engineers have a strong track record of being flexible and solving problems smartly. Delivering energy infrastructure requires solutions on many levels, from the biggest nuclear project to installing charging points for electric vehicles. Taking the second example, can the local grid cope with large numbers of people plugging their cars in at 6pm when they finish work?

At the moment, the answer has to be no, which means sustainable infrastructure for batteries is vital. Among the pioneers, one energy provider has built a battery plant at one of its power stations, providing 50MW for half an hour. Scores of such sites across the UK could meet that specific surge in demand.

Meanwhile, solar panels on domestic roofs have been a key part of the early adoption of renewables by consumers. It is important that ICE, as an institution, embraces this interest and encourages homeowners to become even more involved.

The timeframes that engineers often work to can be a challenge. Taxpayers, for example, may be wary of the costs of projects that are 10 to 15 years from fruition. The energy community believes that big business is more receptive to the benefits of future

> 66 Climate change is perhaps the greatest challenge humanity has faced but I've no doubt civil engineers have the ability to adapt and be a significant part of the solution. 2022 will be a milestone year with society, supported by civil engineers, continuing and accelerating the transition to zero carbon.
>
> **Ian Parke, chair, ICE Low Carbon Energy community advisory board**



Rendering of Rolls-Royce small modular nuclear reactor

> Renewables could be seen as something of a panacea to all of our energy problems and politicians may be overplaying that card without realising how change will be achieved.

Further reading

- **BEIS (2021) Net Zero Strategy: Build Back Greener: bit.ly/beisnetzero**
- **Arcadis (2021) Supercharging Net Zero: The Race to a Faster, Fairer Energy Transition: bit.ly/arcadis2021**
- **Queen Elizabeth II Reservoir Solar Project: Floating Solar Powering Thames Water: bit.ly/qeiireservoir**
- **Arup: Five-minute Guide to the Energy Trilemma: bit.ly/aruptrilemma**

energy technology than SMEs owing to the scale of the likely investment. Politicians also now appear to be more open to embracing long-term challenges rather than being driven solely by shorter-term vote-winning considerations.

That said, cost is important. Greater familiarity with technology – and related infrastructure – will ultimately mean lower costs. Offshore wind over the past two decades is an example. At the start, government finance was essential but industry has largely weaned itself off such support to stand on its own. This then paves the way for enhancement of the technology, such as EDF's innovative floating offshore wind farm project at Blyth, off the north-east coast of England (see case study, opposite).

In 2015, in another advance on existing solar photovoltaic infrastructure, Thames Water and its partner Lightsource Renewable Energy installed a solar farm that floats on the Queen Elizabeth II reservoir in Surrey. Some 23,000 panels, covering 10% of the water surface, generate electricity to offset the utility's operating costs for nearby water treatment and pumping stations.

In 2022 and beyond, the ICE community expects more companies to take greater responsibility for their energy needs. As ever, the role of civil engineering will be crucial: it is not a matter of choice whether engineers want to take part in this; they cannot say, "We've not done this before, it's in the too-difficult-to-do box." Everyone in the profession needs to embrace the shift and show leadership.

Also in the coming year, the jump in energy prices will act as a catalyst for more and more people and businesses to take ownership of their own electricity generation and embrace renewables. Financial support for homeowners to install solar panels has tapered away but the community believes that a government rethink on how it supports householders to make their homes more sustainable should again include solar panels.

Then there's nuclear. In the autumn, Rolls-Royce announced £400m backing from a consortium of private investors and the Government to develop up to 16 small facilities to boost the proportion of the UK's electricity generated by nuclear (currently 16%). Many civil engineers with relevant experience of nuclear technology will no longer be in the industry and so replacing that skillset will be a big challenge in the coming years.

The public's perception of nuclear technology also needs to be a consideration. The energy community believes civil engineers need to understand that it is not enough merely to build something and expect people to accept it. Engineers could have been better at saying: "Look, this is what we do; you wouldn't have any of this without civil engineering."

We have got better at telling our story and ICE has played a leading role in this. That proactivity must continue in 2022 and beyond.

Case study: Blyth Offshore Demonstrator wind farm

EDF RENEWABLES UK AND IRELAND

99.9MW

Current consent for BOD wind farm

16km

Distance from shore of the location identified for phase two

2025

The year it is aimed that phase two will be fully commissioned by

Half a mile off the coast of Northumberland is the first energy project of its kind to use float and submerge technology.

The turbines at Blyth Offshore Demonstrator (BOD) wind farm are supported with gravity-based foundations, transported by floats. Not having to drill foundations into the seabed is a significant cost saving.

Commissioned in 2017, BOD has five 8.3MW turbines with a tip height of 191.5m. EDF Renewables now plans to build phase two to use the Blyth site for the installation of up to five further turbines. This would be in an already identified array location nearly 16km from the shore in water depths of about 55m. The capacity for phase two has still to be finalised but the current consent for BOD wind farm is for a maximum of 99.9MW, leaving a remaining capacity of 58.4MW. The aim is for phase two to be fully commissioned by spring 2025.

The turbines to be installed in phase two will be constructed on floating sub-structures. A key requirement of the project is to demonstrate new and innovative technologies that have the potential to reduce the cost of offshore wind (floating and fixed) developments in the future. As a result, EDF Renewables is working closely with suppliers and research organisations, including the Offshore Renewable Energy Catapult, to ensure that such technologies and approaches are fully explored and incorporated where appropriate.

Michele Schiavone, director of offshore wind at EDF Renewables, said: "We want to further the demonstration of construction and operation of floating turbines to show that floating wind is technically feasible and cost-competitive in water depths of 50-60m.

"With the contract for difference [CfD] mechanism providing a potential route to market, we are confident that floating turbine technology can accelerate the UK's journey to a net-zero future where clean energy powers all our lives."

As ever, the wider sustainability impact has to be borne in mind, especially with the extensive use of concrete in the sub-structures. There are complex calculations to be made in weighing up the pros and cons of new approaches, but at BOD engineers are pushing the boundaries of what is possible in the race to net zero.

06 Structures and geotechnical

The failure of recent high-profile civil engineering projects to pass smoothly through the planning process should act as a wake-up call to the sector

In the past 18 months, UK Transport Secretary Grant Shapps has overruled official planning inspector advice to approve controversial infrastructure schemes such as the A63 upgrade in Yorkshire and the dualling of the A303 between Sparkford and Ilchester in Somerset – while his consent for the Stonehenge Tunnel was quashed by the High Court in summer 2021.

This suggests that the civil engineering sector has some way to go to deliver projects that meet modern society's needs. It is time to deliver real progress on themes that have been given little more than lip service over the past decade: productivity, social value, sustainability, safety and collaborative working.

Existing guidance points the way for the industry. The Treasury's Green Book demands that publicly funded projects are built on business cases that "identify the proposal that delivers best public value to society, including wider social and environmental effects". The Cabinet Office's Construction Playbook demands standardised design, innovative construction, improved risk management and better assessment of suppliers. And the Department for Business, Energy and Industrial Strategy's Net Zero Strategy outlines plans to set limits for embodied carbon in infrastructure and increase the use of certain modern methods of construction.

Culture change is necessary in 2022 to start overhauling how the industry works so it can work for society rather than propose projects based largely on minimising time and cost. Budget and programme parameters are firmly entrenched in the way that civil engineers create infrastructure and it is a challenge to add the third dimension of impact on community, whether that be in terms of biodiversity, carbon, jobs, open space or any other metric.

Experienced project designers in senior positions often understand intrinsically the amount of money or time a certain intervention will require – but do they grasp social value in the same way? Changing that mindset requires concentrated effort, collaboration and training. The industry needs to attract and nurture its own data analysts, carbon scientists and productivity gurus without losing its core ability to create great infrastructure.

One risk, ICE's structures and geotechnical community believes, is that the modern ways of working needed to meet tomorrow's challenges can take key people away from the raw elements of building infrastructure. A designer who has spent years in trenches onsite may be better able to understand the meaning of a certain soil strength rating on a diagram than someone who has only run digital models in an office. It is seen as critical that the specialists of the future retain the hand and eye calibration of past generations – the innate sense of whether something on a screen feels right for situations onsite. Continuing professional development is critical if the industry is to take its workforce with it over the coming years.

> My generation spent a lot of time onsite calibrating our fingers to understand soil strength. My eyeball is calibrated to know what looks right on a drawing. As we adopt more automation and complex modelling, how do you check that designs look right? Is the next generation calibrated in the same way?
>
> **Alison Norrish, co-chair, ICE Structures and Geotechnical community advisory board**

Similarly, codes of practice need to keep up with technological progress. The pace of development of tools to enhance projects far outstrips the cumbersome process of updating industry guidance. The ICE community would like to see quicker methods of testing technology and securing its adoption within Eurocodes, adherence to which is still seen as best practice in the UK. There is a role for an engineering community forum to probe the effectiveness of emerging tools and feed them into the mainstream.

In addition, the efficiency of designs needs to be improved to reduce carbon and boost productivity. A specific recurring technical challenge is control of crack widths, which is required to specified limits within Eurocode 2. Steel reinforcement is often added to underground structural elements to achieve this, at a cost in terms of time, money and carbon emissions. Emerging evidence suggests that certain environments could be identified in which this activity is unnecessary with no discernible benefit. The community would like to see focused effort on proving this and approving alternative crack-width control processes in specified situations.

Clients could help by taking innovation risk from contractors and consultants, running their own evaluation processes and approving trusted methods for use on projects. This could not only lead to cost and programme benefits but also strengthen the community impact of a scheme and help it to secure approval. Without planning consent, there is no project. Technology can help engineers to achieve the sustainability and productivity benefits to get an application through – but only if they are helped in adopting it.

Procurement is key. If clients set up commercial contracts to incentivise innovation and consideration of social value, while minimising the risk that engineering companies take on for pursuing these goals, everyone benefits. The ICE community has seen inappropriate risk being passed down the construction supply chain on too many occasions, leading to adversarial working relationships and a race to build as cheaply and quickly as possible.

There is a sense that everyone involved in shaping infrastructure would do well to slow down in 2022 to pick up greater speed later on. Clients are often motivated by politics to get shovels in the ground, while contractors want to get the job done as soon as possible and then move on to the next opportunity. Designers and consultants are often under pressure to deliver to rushed timetables, which hinders the ability to drive innovation and set up a project for the best chance of delivering on its goals. When an application is rejected by planners, the timetable can drag on for far longer than would have been needed to find measures to secure approval.

While this lesson should have been learnt by now, another potential high-profile planning mess in 2022 could ram home the message to those in positions of power. Ministers have until April to rule on the mammoth Sizewell C nuclear project. If this suffers the same fate as, say, the Stonehenge Tunnel, the industry will be forced to take another hard look at its processes.

> 66 Everyone involved in shaping infrastructure would do well to slow down in 2022 to pick up greater speed later on. Clients are often motivated by politics to get shovels in the ground, while contractors want to get the job done as soon as possible. Rushed timetables hinder the ability to think carefully to drive innovation and set a project up for the best chance of delivering on its goals.

Further reading

- **HM Treasury (2018) Green Book: Central Government Guidance on Appraisal and Evaluation: bit.ly/govtgreenbook**
- **Dobson, J (2020) Maximising Social Value from Infrastructure Projects: ICE Useful Projects: bit.ly/ICEsocialvalue**
- **Fujiwara, D and Dass, D (2020) Measuring Social Value in Infrastructure Projects: Insights from the Public Sector: bit.ly/RICSsocialvalue**

Case study: National Highways Lower Thames Crossing scheme

Highways England found itself in the spotlight in late 2020 when it withdrew a planning application for a nationally significant 23km-long highway, including a 4.3km tunnel under the River Thames between Essex and Kent, in the wake of feedback from the Planning Inspectorate.

The organisation responsible for managing the strategic road network in England – now rebranded as National Highways – has spent several months, considerable effort and hundreds of millions of pounds on changes to the Lower Thames Crossing scheme before it can be resubmitted.

The client body said planning inspectors had, among other things, requested more detail on the long-term management of environmental mitigation proposals; asked for a greater level of information on how construction vehicles would affect traffic conditions; and "shared feedback from local authorities on our approach to consultation".

A raft of adaptations has now been made to the scheme, based on extensive local consultation, starting with a reduction in the amount of land required, a move that put 20 properties outside the site boundary. Proposals for more than 100 utility works were revised, with an emphasis on lowering the impact on communities and the environment. An extra lane was added to a link road to improve traffic flow. A flood relief channel was added next to the Mardyke River.

Another change has been to alter plans for two public parks which local authorities said would limit the potential development of the proposed Tilbury Freeport. It has also pledged to spend £1 in every £3 on local businesses and has recruited apprentices from the area.

National Highways now says that submission of its development consent order application has been put back until "some time in 2022".

The ICE structures and geotechnical community wants to see projects at all levels set up to serve their communities by incorporating measures to maximise sustainability and social value from the outset. This will require an understanding of the value of taking time at design stage to optimise outcomes.

23km

Length of the highway, to include a 4.3km tunnel under the Thames

100+

Number of proposals for utility works that were revised

07 Sustainable, resilient infrastructure

Resilience assessments for large projects, incentives for contractors and stress tests are some of the strategies that civil engineering could focus on in the coming year

It is known that climate change will bring flooding, drought, rising sea levels and other threats to our way of life, but how these disruptions will manifest themselves is far from certain. They could be local, they could be widespread; many will be of significant magnitude.

Even if governments deliver everything they promise on cutting carbon emissions, resilience will still be critical for any new project because of these uncertainties. For civil engineers designing the infrastructure of the future, the challenge of resilience is – and will be – fundamental to their work.

For the UN-backed global campaign, The Race to Resilience, this means: "Putting people and nature first in pursuit of a resilient world where we don't just survive climate shocks and stresses but thrive in spite of them."

To underline the supreme importance of this approach, the recent COP26 conference in Glasgow staged, for the first time, a resilience hub with the aim of "sharing best practice and building collaboration, momentum and new opportunities on adaptation and resilience".

The ICE resilience community understands that this approach is about more than just building better and smarter bridges or power cables. Resilient design for the future will have to anticipate climate-related changes as well as taking into account new technologies, cybersecurity, economic and social priorities, and much more.

This means greater emphasis on systems thinking and, fundamentally, involving people. As one community member put it: "As civil engineers, we often think: what's the next infrastructure we have to build? But first of all we must think about people, nature and the planet and from that will come the infrastructure needs."

Hurricane Katrina, which tore through New Orleans and surrounding areas in August 2005, is seen by the resilience community as an example of a tragic failure not only of the infrastructure itself but of the collapse of social structures. The consequences were terrible: 1,800 fatalities and damage estimated at US$125bn. One of the world's most technologically advanced and richest nations watched chaos ensue within hours.

Part of the answer to avoiding a repeat is less about infrastructure as it is traditionally thought of and more about putting in place social infrastructure such as community hubs in public buildings where people can come together, fully prepared, during extreme events.

Another challenge for more developed economies is a dependency on technology, meaning individuals may have

> Resilience goes hand-in-hand with decarbonisation in tackling the climate change challenge. We will be looking at a range of ways to assist civil engineers in achieving 'resilience in the round', including longer-term and systems thinking, approaches for infrastructure integrated with nature, people and planet, and associated guides and standards.
>
> **David Smith, chair, ICE Sustainable, Resilient Infrastructure community advisory board**

insufficient skills to cope in national disasters. In contrast, when a tsunami devastated Banda Aceh in Indonesia in 2004, fishermen possessed the skills to repair their boats within two days and go back out on the water.

The resilience community advocates resilience in the round, taking a broader approach than just in terms of technology or conventional engineering. Key to this is a joined-up approach using systems and long-term outlooks: there is too much silo thinking dominated by short-termism, particularly from political leaders. The introduction of city mayors in the UK is encouraging as they tend to embrace a more holistic community agenda – for example, by advocating for integrated regional transport systems. If engineers join such projects with that broad mindset, they can certainly be a catalyst for resilience in the round.

One approach to building resilience is nature-based solutions, potentially combining physical infrastructure and natural elements such as green spaces, porous surfaces and detention areas to mitigate floods (see case study, page 18).

Historically, risk has taken priority over resilience, but climate change is playing havoc with established calculations of probability, cost, risk and benefit. Environmental and social aspects are tougher to quantify. Civil engineers who understand such change can present new solutions to help stakeholders with their decision-making.

ICE's resilience community considered possible factors that could hinder progress towards greater resilience in the year to come, including economic shock (as in 2009); economic growth after the pandemic diverting attention from climate change strategies; shifting social priorities; and short-termism in policy-making. A failure to persuade fragmented stakeholders to sign up for building in greater resilience on major projects is another possibility.

One focus could be to entrench resilience assessments for large-scale projects. Typically, when a well-known structure such as a suspension bridge fails, those that replace them are built with updated codes of practice. But the reality is often that the failure was something quite trivial that was not envisaged in the original codes – in other words, the engineers had followed an obvious, traditional response route but not observed real-world assumptions. An open mind is crucial.

Another strategy would be for governments and other public authorities to insist that low carbon becomes a key part of the decision-making process, with a contractor benefiting and potentially winning work if it has a proactive approach to resilience.

That leads on to another area for future effort: greater guidance for resilience in the conception and delivery of projects. It's not just about design – it's about adding associated preparedness and emergency response plans, warning systems and so on. It means that designing for the long term, for climate change, and having response plans for when disruption strikes would all become the norm.

One way to encourage engineers to play more of a role with wider stakeholders could be a resilience stress test, under which people not directly involved in plans or projects are invited to "tell us how this will fail". A low score would be a red flag requiring a review by the engineer. Ultimately, though, that engineer would always be constrained by the commitment of coordinating with the client or asset owner.

A further activity for 2022 would be to assess how engineers work with owners to build resilience into their projects: both need to go on the journey together.

The community believes that the training of engineers should be reviewed to adapt to these new, wider roles. Civil engineers will have to engage with more groups, understand wider perspectives and figure out how the profession can deliver the solution that works best to thrive in spite of whatever climate shocks and stresses are ahead.

Further reading

- **UN Race to Resilience campaign: bit.ly/unracetoresilience**
- **Colker, R M (2019) Optimising Community Infrastructure: Resilience in the Face of Shocks and Stresses: bit.ly/colkerresilience**
- **Hay, A H (2021) Planning Resilient Infrastructure Systems: bit.ly/haysystems**
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> 66 The answer is less about infrastructure as we traditionally think of it and more about putting in place social infrastructure such as community hubs in public buildings where people can come together, fully prepared, during extreme events.

Case study: Living with Water, Hull

Hull is the second-biggest flood risk area in the UK outside of London. A local partnership is aiming to build understanding across the city and East Riding about the threats and opportunities water brings to the region.

Stakeholders including Yorkshire Water, Hull City Council, East Riding of Yorkshire Council, the Environment Agency and the University of Hull all play a role in managing water in Hull and East Riding. They are working together to build flood resilience, develop innovative water management systems and highlight the region as somewhere to live, work and visit.

Hull borders two confluent rivers – the Hull and Humber – and is close to the Humber Estuary and the North Sea. It sits in a basin of low-lying land below sea level. The area is at risk of flooding from rising tides in the River Hull and high spring tides from the estuary, as well as the effects of climate change. Globally, intense storms are becoming more frequent and sea levels around the UK coast are increasing.

Living with Water was created following floods in 2007 and is a partnership between the four organisations responsible for water management in the region. Building resilience, driving sustainable solutions and showcasing the region are core parts of its work.

Raising awareness of flood risks in communities and delivering practical advice and information to help people protect their homes and businesses and make them feel safe are fundamental.

The aim is to achieve a year-on-year reduction in flood risk through innovative water management systems, collaborating with local communities and global experts to develop long-term urban water resilience.

One of the latest initiatives, to be delivered by Stantec, is a 'Blue-Green Master Plan', seen as an innovative approach using sustainable drainage solutions at a city-wide level to reduce flood risk across Hull and East Riding.

08 Transport and mobility

The pandemic has highlighted how difficult it is to forecast society's transport needs and develop the right infrastructure to meet them. Fresh thinking will be necessary in 2022 to deliver the right solutions for the 'new normal'

Traditional methods of relying on past data to extrapolate future activity do not account for unforeseen events that can trigger seismic change in behaviour. Figures from the Department for Transport show that car use was 77% below pre-Covid levels on one particular day at the end of March 2020 – and it was far from a short-term blip. On 11 November 2021, car use was down 10% from a comparator date before the first lockdown, train journeys were 29% lower and bus passenger activity had reduced by 19%.

No historic model foresaw these numbers and predicting future trends from here is extremely difficult – that's even before factoring in the challenges facing the sector in terms of meeting decarbonisation targets, improving user safety, boosting air quality and becoming more effective in a world of tightening budgets.

An encouraging opportunity presented during the pandemic was a policy shift in England towards more active travel. In May 2020, local authorities were handed £225m from Whitehall to create short- and long-term road space for cyclists and pedestrians based on community needs. Part of the overall package that also included Low Traffic Neighbourhoods, the challenge for local authorities was to introduce their schemes within a matter of months whereas such changes can typically take several years. Many responded well, often in the face of vocal opposition from unsympathetic car users.

ICE's transport and mobility community appreciates that moving people from cars and buses on to bikes and feet will have huge benefits for the immediate environment, the long-term sustainability of the planet, public health and, in some cases, local economies. The agenda should always be about creating places where people want to live and continue to live.

This requires a new approach from clients and policy-makers at all levels, driven by an economic imperative to achieve pressing goals with limited resources. Regeneration of urban centres that were hit hard by the pandemic can create attractive neighbourhoods with active travel networks, lower carbon use, better air quality and safer spaces. Joined-up funding pots will be required in 2022 to allow councils to think holistically about the creation of place.

Civil engineers will need strong influencing skills to convince politicians and the public of the benefits of such an approach. Their opinions are not always as influential as others when it comes to issues such as neighbourhood design and active travel infrastructure, but their input is critical to ensuring a coordinated and innovative approach that prioritises travel investment aligned with better places to live and work.

Clearly, road and rail transport will continue to play a vital role in the social and economic recovery post-pandemic and it remains crucial that these networks are maintained and kept fit for purpose as times change.

The UK Government will be under pressure in 2022 to decide on the future of all-lane running 'smart motorways', where there is no permanent hard shoulder, after the Commons' transport

> 66 As an industry, we must think differently about the future of transport and mobility. No longer is it about getting between places as quickly and cheaply as possible – we need to consider why people want to travel, what influences their choices and what we must do differently to deliver this efficiently and sustainably.
>
> **Rand Watkins, chair, ICE Transport and Mobility community advisory board**

committee called for their roll-out to be paused while more data was collected. The system helps to squeeze more use from existing assets, which must be a strategy in the years ahead – laying more tarmac is not seen as a viable solution if carbon and air quality targets are to be met.

A significant policy in this area would be to charge road users travelling at peak times. This would raise cash to replace lower fuel tax revenue as more people switch to public transport, active travel and electric vehicles. As well as creating more funding to promote this modal shift, a rush-hour levy would flatten out demand for the road network throughout the day, reducing the need for more highway that is busy only for short periods.

Meanwhile, sustained and committed long-term investment in the maintenance and development of surface rail and urban mass transit networks is essential to give confidence to the public and wider stakeholders that the quality of public transport will not fall behind as demand starts to pick up.

There is also an expectation, rightly, for a fully inclusive and accessible network. Safer public transport for all users, fully considered journey paths for mobility-impaired passengers and digital tools and data-driven solutions to provide up-to-date information and guide journey choices – these are the demands of the current and future customer that the civil engineering industry must respond to.

HS2 is bringing new skills into the industry and helping it to prepare for future demand, as well as challenging the way things are done during delivery. The ICE community is keen to see a step change in productivity in 2022 and this can be driven in part by powerful client bodies on large projects simplifying processes, investing in new technology and removing the bureaucracy that holds back progress. One example is the application of digital twins and immersive design tools to build projects virtually, identifying and eliminating dangerous or wasteful practices before they move to delivery.

Ministers are expected to publish the long-awaited Cycling and Walking Investment Strategy 2 next year, setting out a multi-year funding settlement that could give councils a breakthrough ability to commit to recruiting and training staff to deliver meaningful change on active travel. Both England's National Bus Strategy and the long-awaited refresh of Local Transport Plan guidance should also help in this direction, hopefully with a strong focus on the need to decarbonise local transport networks.

On a more macro level, civil engineers will be watching for the Government's full plan to implement Peter Hendy's union connectivity review, published in late 2021, which outlines a number of proposed road, rail, air and sea projects to improve transport infrastructure across the UK. The future remains uncertain but this is the landscape in which engineers will thrive, using their skills to support greener transport systems and a more inclusive society.

> 66 Moving people from cars and buses on to bikes and feet would have huge benefits for the immediate environment, the long-term sustainability of the planet, public health and, in some instances, local economies. The agenda now should be about creating places where people want to live and can continue to live.

Further reading

- **Hendy, P (2021) Union Connectivity Review: Final Report: bit.ly/unionconnectivity**
- **National Infrastructure Commission (2021) Behaviour Change and Infrastructure Beyond Covid-19: bit.ly/NICbehaviour**
- **Commission on Travel Demand (2018) All Change? The Future of Travel Demand and the Implications for Policy and Planning: bit.ly/CTDFutureoftravel**
- **Parkin, J (2018) Designing for Cycle Traffic: International Principles and Practice: bit.ly/cycletraffic**

Case study: Elephant and Castle Underground station

An integrated ticket hall is integral to Transport for London's vision for its Elephant and Castle Underground station serving the Northern line and the planned extension of the Bakerloo line. The subsurface area is to be constructed as part of a major town centre project by a third-party developer above ground, with the station box being integral to the developer's foundation structure.

TfL required the station to be delivered in phases: one for the new station and connections to the Northern line; the other safeguarding future connection to the new Bakerloo platform tunnels.

Lead designer Atkins' design team agreed a new concept for the station with the developer, while increasing its capacity to safeguard space and a delivery strategy for the Bakerloo extension. The architecture team's layout for the ticket hall and possible options were presented to the client and assessed collaboratively. It considered customer movements, staffing facilities, security and safety, and operational needs, while ensuring safe access and egress for maintenance activities.

While the ticket hall and station itself was subsurface, the portal entrance at ground level was designed to ensure seamless integration with the vicinity of the station and to blend into the developer's above-ground scheme. Facilities were designed to comply with TfL's standards for the required levels of capacity and accessibility to ensure that the station would be inclusive and fit for the future.

Sustainable principles and a targeted approach to reducing carbon on the project were central to the design requirements and evolution. As well as working towards BREEAM accreditation and aligning to TfL's carbon energy and efficiency requirements, the scheme also tracked carbon throughout each phase of the design using a calculator tool.

By reducing excavation, sharing support with the oversite development, maximising natural ventilation and other measures, the project has been planned to reduce capital and whole-life carbon from the outset.

09 Water and sanitation

Getting clean water and wastewater services to those who desperately need it while slashing the impact of this activity on the environment should be the big drive for the coming year

More than one in four people globally lacks safely managed drinking water and more than one in two is unable to access safe sanitation services. It is against this backdrop, from a World Health Organization report in 2019, that the scale of the decarbonisation challenge for the global water and sanitation industry becomes clear.

Although there has been progress this year, the pace of change needs to quicken considerably. To this end, a revolution is needed urgently in terms of leadership mindsets and strategies.

The water sector showed that it could rise to challenges during the pandemic when, despite huge resourcing difficulties, sudden shifts in demand and – in some cases – undermining of business models, taps kept flowing and toilets kept flushing. The industry has embraced different ways of working and got the job done. This same energy and inventiveness must be transferred into the next mission to tackle water scarcity and climate change head-on.

Construction itself will not solve either problem. Smarter ways of working are needed: greater use of technology, thinking creatively and collaborating with a wide range of stakeholders. Both senior people at utility firms and the engineering companies that serve them must be convinced of the urgency to act in 2022 so that they can pull the levers of change in time to steer towards looming targets.

Technology can help in many ways, most obviously by helping utilities to get more benefit from their existing assets to meet demand for water without incurring the carbon cost of new building works and digging up roads for maintenance. Sensors, powered by vibrations in pipes, offer sustainable data that can be used far better to inform positive decisions to increase water supply and reduce carbon use. There is a feeling that water companies need to become more agile to take on innovative processes and tools more quickly.

'Blue-green' infrastructure is being adopted widely in some countries but remains largely untested in others. The advantages of this model, which essentially uses nature rather than manmade materials to manage water, include energy savings from reducing flows to sewage treatment works and obviating heavy infrastructure projects. The ICE water and sanitation community believes this approach should already be seen as business as usual, but it needs to be encouraged more by clients and policy-makers in 2022.

Meanwhile, collaboration with other engineering disciplines, wider industry and global utility providers could ensure that knowledge and solutions are shared more quickly to overcome the problems we all face in terms of water availability and climate change. Isle Utilities' Water Action Platform, which was started during the Covid-19 pandemic and now involves more than 1,000 organisations from almost 100 countries, provides a useful forum for the sharing of learning and best practice. Exponential growth is now needed in the way such platforms are used.

The regulated nature of the water sector in many countries acts as a barrier to rapid change. The ICE community would like to

> The UK water industry has led the world with its commitment to achieving net zero operational carbon by 2030. Without extra effort, the improvements will diminish so it is essential that the industry embraces new approaches and new technology.
>
> **Jo Parker, chair, ICE Water and Sanitation community advisory board**

> Smarter ways of working are required: greater use of technology, thinking creatively and collaborating with a wide range of stakeholders. Both senior people at utility firms and the engineering companies that serve them need to be convinced of the urgency so they can pull the levers of change.

see the value of water recognised and utilities worldwide able to charge a premium for its non-essential use.

There is also a desire to see third-party funding injected into the sector to spread the cost of big investments and bring forward sustainability projects such as solar panels on reservoirs, anaerobic digestion treatment facilities and the generation of energy from sewage.

As meaningful change happens, traditional civil engineering skills will be less widely needed and the industry will require people who understand infrastructure enough to model it, but who are also specialists in technology, data and communication. Much of this will happen naturally at intake level but it will also be important to train engineers already well into their careers.

While different approaches will be needed to tackle the challenges of the 21st century, these new purposes will themselves help to attract the right people. The ICE community notes a genuine passion among graduates to design solutions for society's pressing problems and to use modern methods in doing so. However, positive communication is necessary to attract the skilled people of the future who could otherwise take their talents into other industries. The benefits of careers in civil engineering and the water industry need to be sold at a time when the current workforce is dwindling.

The age of much of the infrastructure for water services created by traditional construction is also a challenge. Following the evacuation of 1,500 people from Whaley Bridge in Derbyshire in 2019 because of damage to the spillway at Toddbrook reservoir, an independent report was commissioned by the Government. This called for certain asset-specific information to be made available to inspecting engineers and for guidance on precautionary measures to be published.

The Whaley Bridge incident, and others around the world, show the importance of continually striving to understand the infrastructure already in place for safety and supply reasons as well as reducing new carbon-intensive construction. Indeed, engineers are always learning new things about existing assets – an official report this year found that a "rare" type of ground failure led to the collapse of a 100-year-old Michigan dam, sparking the evacuation of 10,000 people.

Increased knowledge of both historic infrastructure and future ways of working is essential to speak in the right way to those powers holding the tools to drive change in the water and sanitation sector, the ICE community believes. It is only by continually pushing the boundaries of learning and disseminating lessons that the twin challenges of resource scarcity and climate change can be tackled, along with all of the other threats and opportunities that present themselves along the way.

Further reading

- **World Health Organization, WHO Global Water, Sanitation and Hygiene: Annual Report 2019: bit.ly/WHOglobalwater**
- **Choe, E Y, Kenyon, A and Sharp, L (2020) Designing Blue Green Infrastructure for Water Management, Human Health and Wellbeing: Summary of Evidence and Principles for Design: bit.ly/bluegreeninfra**
- **Morley, M, Savic, D (2020) Water Resource Systems Analysis for Water Scarcity Management: The Thames Water Case Study: bit.ly/ThamesWatercasestudy**

Case study: Thames Water digital twin technology

A virtual replica of Thames Water's vast clean water network is helping the company to prevent up to one million litres of water leaks every day.

The digital twin uses data from a range of devices, including smart meters and acoustic loggers, to show how pipes are performing in real time and act as an early warning system for potential problems. Thames Water is trialling the technology in south London, where it has identified a number of leaks caused by high pressure and damaged valves.

As well as highlighting these issues so they can be fixed quickly, the digital twin can be used to simulate the effects of different repair methods and identify the best solution.

The twin is among a number of digital tools feeding into Thames Water's recently launched system risk visualisation (SRV) initiative, which is used to build an overall picture of the performance of the network.

The SRV compiles various sources of up-to-date information on flow rates, pressure and reservoir storage levels, which can then be viewed on schematics, maps, tables and graphs. A traffic light system is in place to flag potential problems.

As well as providing an overall health check of the network, the SRV can be used during major incidents such as bursts or to anticipate problems that could escalate and have an impact on customers.

David Gable, Thames Water's project delivery manager, said that reducing leakage was one of the utility's highest priorities – and one of its biggest challenges. "Being able to capture a range of data streams and present them in a simple format adds another tool to our armoury in the fight against leakage," he said.

The ICE community celebrates this kind of use of technology and digital working to tackle leaks that may reduce the volume of water supplied to those who need it and often involve carbon-intensive repairs.

There is a desire to see more innovation like this and for lessons to be shared throughout the industry to generate meaningful change.

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