Institution of Civil Engineers

State Of The Nation 2017:
Digital Transformation

President's Foreword

In this year's State of the Nation report we take a look at the digital transformation of infrastructure; how advances in technology and data processing can be harnessed to revolutionise the design and delivery of the infrastructure services we all rely on. As the UK re-positions its economy on the global stage, improving the performance of our infrastructure networks has never been more important. And, with infrastructure at the heart of the Government's new Industrial Strategy, there has never been such a strong platform to build from.

However, as this report outlines, this means so much more than how we use existing technologies to keep doing what we are already doing, only faster and cheaper. We need to transform not only the tools we are using, but also our approach to the assets we build. Bodies of data on built assets are becoming increasingly important, and need to be managed as significant assets in themselves. Putting the end-user first should prompt us to embrace the full value of new technologies and data estates. The infrastructure and construction industries need to collaborate and coordinate not just with each other, but also with the technology and manufacturing industries if we are to keep pace with these advances, and seize the moment.

We have debated and discussed the issues explored in this report with more than 350 organisations and professionals, over the course of numerous regional workshops, focus groups, and interviews. Alongside passionate Civil Engineers, experts from the legal, planning, cyber security and technology communities have given their time to shape this report. I hope its publication marks only the start of a broader conversation as ICE prides itself on being a voice and home for everyone working to transform infrastructure.

I would like to thank everyone who has contributed to the making of this report, but extend my special gratitude to the project's Steering Group, its Chair, Anne Kemp, and the ICE project team.

Professor Tim Broyd
President of the Institution of Civil Engineers.

State of the Nation 2017 Steering Group:

Dr Anne Kemp (Chair), Director of BIM Strategy and Development, Atkins, and Chair of UK BIM Alliance and BuildingSmart UKI.
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Contents

Glossary of terms

Digital Transformation
The application of digital technologies to all aspects of human life. In this report it applies to the wholesale changes in how our industry designs, builds, operates, maintains and decommissions assets. It also refers to the transformation of how we value data, and the impacts upon processes and systems, and ultimately decision making.

Digital Delivery
Use of digital technologies as a core medium through which the work of project design, coordination, project management and governance is accomplished across the firms involved in delivery.

Smart Infrastructure
Smart Infrastructure is the result of combining physical infrastructure with digital infrastructure, providing improved information to enable better decision making, faster and cheaper. Cyber-physical is often used to mean the same thing.

Digital Infrastructure
Generally refers to communications infrastructure – both fixed (broadband) and wireless (mobile) assets.

Executive Summary

We know that infrastructure provides the basic means for moving and connecting goods, resources and people, in turn enabling economic growth and thriving communities. However, population growth, an ageing demographic and increasing demands on physical and virtual connectivity are putting increased pressure on our infrastructure networks and assets.

We cannot build our way out of these new challenges. We have to do more with what we already have. We must adopt new integrated digital approaches to managing and operating existing assets and building future infrastructure. We often think of infrastructure as fixed networks and assets, but the reality of this is changing. We must think about not only the physical asset, but also its digital twin – all the associated data and the information that this can reveal. If we truly consider infrastructure as a service, then making this mental shift is essential. Delivering infrastructure based on outcomes for users drives us toward whole life decisions and recognising the value of the entire data estate. This approach makes best use of the endless flow of data, information and knowledge we can use to improve the services we deliver.

Digital transformation, which includes digital delivery and smart infrastructure (or cyber-physical infrastructure solutions), is a more cost-effective way of adding value to infrastructure than traditional approaches.

However, the infrastructure sector has been slow to engage with the uptake of new digital technologies compared with other industries. In a recent McKinsey index of key sectors, construction was rated just above Agriculture & Hunting. And 64% of firms operating in Europe & the Middle East are rated as either 'industry following' or 'behind the curve' in terms of technology adoption. Our sector is still yet to fully reap the productivity and innovation benefits of digital transformation which have been enjoyed by other sectors.

Over the past year, the UK and Devolved Nations' Governments have shown a clear commitment to infrastructure; building pipelines of infrastructure and construction projects to improve investor confidence. Establishment of the National Infrastructure Commission to lead on strategic, future planning, and creating a National Productivity Investment Fund to target investment at infrastructure interventions which will improve national productivity. With infrastructure at the heart of the Modern Industrial Strategy, and the UK's world-leading position in Building Information Modelling (BIM), there has never been a stronger platform from which our sector can build on. This report focusses on three areas where the industry needs to act now, in order to drive the digital transformation of our sector. These are productivity, behaviours and resilience. We also set out where the UK Government can use existing levers, such as the Modern Industrial Strategy, to embed a digital transformation.

Productivity

The UK Government recognises the link between improving infrastructure services and increased national productivity. However, making the shift towards a more productive nation, where regional differences in productivity are addressed through improved connectivity, requires a number of interventions from Government, regulators and industry. This report sets out how Government can use existing strategies and policies to catalyse change. It promotes a whole life approach to regulation which can incentivise an outcomes based approach to infrastructure delivery. Finally, it sets out how industry must change to become more productive and deliver better services.

Behaviours

The pace of change in digital processes and technologies mean that those responsible for delivering infrastructure have to be more agile and adapt to change in a pragmatic way. Leadership, organisational culture and skills within our sector will determine how we rise to this challenge. This report sets out how people, processes and technology can be used to optimise and secure the use of digital technology and data. It also sets out how behaviours need to change to embed a long term approach to digital transformation.

Resilience

On one hand, digital transformation offers a route to greater resilience via greater connectivity, but it also introduces fresh security and resilience challenges which have the potential to adversely impact the performance of our assets and networks. However, it is important that these aspects of digital transformation do not act as a barrier to implementation. This report establishes methods for managing the trade-offs between improved infrastructure performance and resilience. It identifies the human and process changes required to embed a security-minded approach to infrastructure delivery, operation and management. It also identifies areas of interdependency between infrastructure sectors and what actions are required to align policies across different sectors.

Now is the time to align Government initiatives with a renewed, coordinated commitment from industry to capitalise on the benefits digital transformation can bring to the productivity and resilience of our infrastructure services.

Dr Anne Kemp
Chair, State of the Nation 2017 Steering Group

Recommendations

The digital transformation of the infrastructure sector requires action from a number of stakeholders. Often these actors will need to work collaboratively to implement change. The following recommendations set out how we can make our infrastructure sector world leading.

PRODUCTIVITY

The UK needs infrastructure that enables productivity and an infrastructure industry that itself is more productive. Digital transformation can increase the performance of new and existing assets throughout the whole lifecycle. This can, in turn, optimise outcomes for infrastructure users, unlock economic growth and the UK's global competitiveness.

In order to realise the productivity potential of digital transformation:

1. The Department of Business, Energy and Industrial Strategy should put digital transformation at the heart of the Infrastructure Pillar of the Modern Industrial Strategy. This means enabling digital delivery and smart infrastructure solutions across all economic and social infrastructure, and realising the UK's potential as a world-leader in this sector.
2. The £23billion National Productivity Investment Fund, and consequentials to Devolved Administrations, should be targeted at digital transformation of both construction (digital delivery) and infrastructure (Smart Infrastructure) which increases capacity and performance of existing assets and networks. This should include continued support for existing programmes – like BIM Level 2 to ensure progress to date is fully embedded.
3. Regulatory frameworks across all infrastructure sectors should incentivise whole life investment decisions based on outcomes for the end user.

BEHAVIOURS

ICE's research identified human behaviour as one of the biggest challenges to realising the value of digital transformation. A step change in leadership and organisational culture for all players in the industry is required to drive digital transformation. Creating a system which rewards and enables appropriate behaviour change across industry and client bodies will be key to delivering the best outcomes for the ultimate customer: infrastructure users.

To enable digital transformation:

4. ICE, and other professional institutions, must work with industry and the Government's Digital Strategy to ensure that people at all points in their career have the right skills to adapt to advances in technology and information management.
5. Clients, contractors and Government should use major infrastructure projects as incubators for skills and innovation. To apply this at a smaller scale, groups of projects should be turned into programmes so that innovation and skills can be embedded through the whole asset lifecycle.
6. Clients should mandate data interoperability standards throughout the whole programme/project group as part of the procurement process. Data standards to drive interoperability should be prioritised to make data appropriately accessible and usable across all platforms.

RESILIENCE

Digitally enabled infrastructure will allow us to adapt to the future needs of society, the environment and the economy. However, the vulnerabilities created by increasing interdependencies and data availability will require us to manage tensions between productivity, security and resilience at national, regional and local levels. Clients, operators, owners and users must better understand their roles in achieving better performance from existing assets so that we can reduce the amount of new (physical) infrastructure we require.

To future-proof our infrastructure:

7. Security-mindedness should be mainstreamed within the industry - just like health and safety has been - in order to keep up with evolving security threats and vulnerabilities.
8. City deals and devolution agreements should include investment which is targeted at enhancing the quality of data assets and enables asset owners and operators in their area to map interdependency risks.
9. The National Infrastructure Commission should set out a needs based strategy to align energy and digital infrastructure policy. The interdependent nature of energy and digital infrastructure and the demands placed on electricity capacity by the digital sector requires an integrated policy.

Introduction

The UK's productivity is poor compared to other G7 countries – 35% behind Germany and 18% behind the G7 average.[1] The UK's 2016 Autumn Statement suggested that as little as a 1% rise in productivity every year in the UK would, within a decade, add £240 billion to the size of the economy. There is a direct connection between the efficiency and effectiveness of our infrastructure and productivity within communities across the UK.

Improved use of smart technology, data and analytics offers a way forward in improving the performance of UK infrastructure and addressing the UK's ongoing productivity deficit. In the construction and engineering sectors, it offers opportunities to address persistent challenges, leveraging previously untapped resources, improving decision making, and reducing resource wastage. Fundamentally, it also offers the opportunity to improve outcomes for the end-users our sector serves.

The rise of disruptive new technologies is already transforming the built environment, but also the shape of our industry itself. They will also change expectations and demands around the level of trust required in technologies, the resulting flow of data and how it is used. Connected and autonomous vehicles (CAVs), Machine Learning, the Internet of Things (IoT), Artificial Intelligence (AI) and other disruptive technologies will change how our existing infrastructure is used and the demands placed upon it, as well as the skills required to design, build and maintain it. They will also change expectations and demands around the level of trust required in technologies, the resulting flow of data and how it is used. Our sector must modernise and adapt now if we are to harness the benefits.

However, low productivity, leadership fragmentation and a lack of Research & Development (R&D) investment have contributed to the construction sector's poor performance, and have impacted upon its ability to respond to market requirements. This has been reinforced by a culture of performance defined by outputs rather than outcomes, and capital cost-driven procurement models. Our sector must modernise and adapt now if we are to harness the benefits.

1. ONS (2016) International comparisons of UK productivity (ICP), first estimates: 2015. Available at: https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/bulletins/internationalcomparisonsofproductivityfirstestimates/2015.

This report sets out three areas where Government, industry and regulators should focus their efforts in order to benefit from current and future digital transformation. These are productivity, behaviours and resilience.

Productivity challenges to performance

- Taken together, the Northern Powerhouse city regions have a population comparable with that of London; however, labour productivity is £17k lower per worker than in London.
- The fastest train journeys between major northern cities are 32 minutes from Liverpool Manchester, 87 minutes from Newcastle to Leeds and 49 minutes from Leeds to Manchester.
- Currently it takes longer to travel from Liverpool to Hull by train than from London to Paris.
- The UK ranked as the 4th most congested developed country in the world, with drivers spending an average of 32 hours a year in congestion during peak hours and the direct and indirect costs of congestion for all drivers totalled £30.8 billion in 2016.

1 Productivity

In this section of the report, we discuss some of the key challenges to infrastructure productivity and how digital transformation can help us to overcome them.

In order to realise productivity potential of digital transformation:

1. The Department of Business, Energy and Industrial Strategy should put digital transformation at the heart of the Infrastructure Pillar of the Modern Industrial Strategy. This means enabling digital delivery and smart infrastructure solutions across all economic and social infrastructure, and realising the UK's potential as a world-leader in this sector.

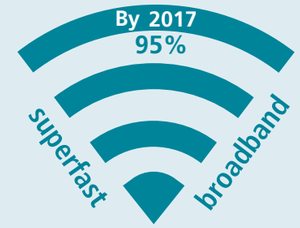
2. The £23billion National Productivity Investment Fund, and consequentials to Devolved Administrations, should be targeted at digital transformation of both construction (digital delivery) and infrastructure (Smart Infrastructure) which increases capacity and performance of existing assets and networks. This should include continued support for existing programmes – like BIM Level 2 – to ensure progress to date is fully embedded.

3. Regulatory frameworks across all infrastructure sectors should incentivise whole life investment decisions based on outcomes for the end user.

The current Modern Industrial Strategy Green Paper recognises that investment in innovative, high performing infrastructure will be fundamental in addressing the UK's productivity gap, growing the economy, and creating an attractive market for private investment.[2] This is supported by funding commitments made in the 2016 Autumn Statement for a £23bn National Productivity Investment Fund[3] (NPIF), and the National Infrastructure Commission's (NIC) current exploration of which emerging technologies have the most potential for improving infrastructure productivity.[4]

Our current infrastructure network is subject to a range of capacity constraints and different funding regimes. While some networks operate with sufficient capacity in different parts of the country, networks in other areas are challenged, impacting productivity.

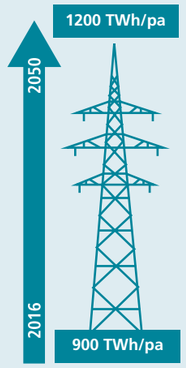
Direct and indirect costs of congestion[5]



UK superfast broadband coverage was around 90% in 2016[7]

Between 2015 and 2016[6]

Costs associated with flooding[8]



GB electricity consumption could grow[9]

2. HM Government (2017) Building our industrial strategy. Green Paper. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/586626/building-our-industrial-strategy-green-paper.pdf

3. Over the five years between 2017/18 and 2021/22

4. National Infrastructure Commission (2017) NIC launch technology study call for evidence. Available at: https://www.gov.uk/government/news/nic-launch-technology-study-call-for-evidence

5. INRIX (2017)Traffic Congestion Cost UK Motorists More Than £30 Billion in 2016. Available at: http://inrix.com/press-releases/traffic- congestion-cost- uk-motorists- more-than- 30-billion- in-2016/

6. ORR (2017) Rail Trends Factsheet - January 2017. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/590561/rail-trends-factsheet-2016- revised.pdf

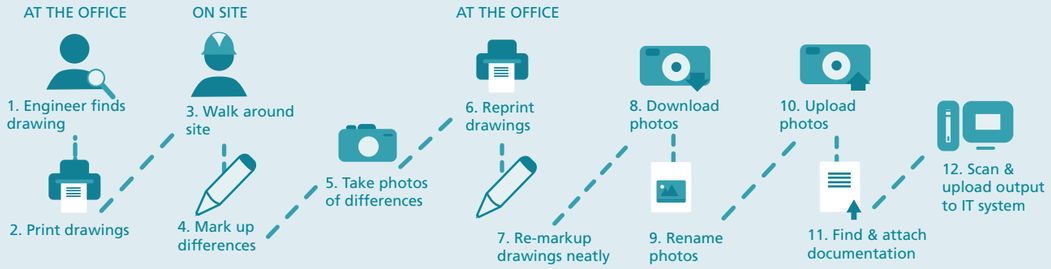
7. ICE et al (2016) National Needs Assessment – A vision for UK infrastructure. Available at:https://www.ice.org.uk/media-and- policy/policy/national-needs- assessment-a- vision-for- uk-infrastr

Case study:
Cost and time savings from use of existing technologies

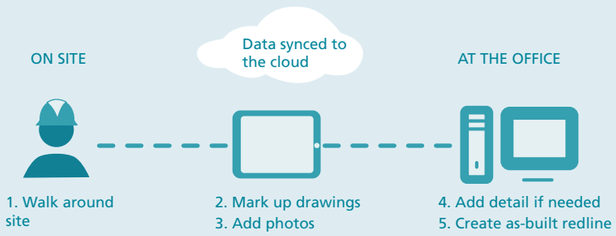
The Redline drawing review process[10] used by Crossrail is heavily paper driven, time intensive, and easily leads to confusion - particularly when information is required to be accurately captured from the field and then used to create as-built redlines and reports. Engineers become frustrated at not having the right information to do their jobs. Simple tasks often take more time than necessary, delaying the whole project.

The digital redline review process using BaseStone as an integrated system eliminated half of the steps compared to the traditional approach, achieving an average speed increase of 2.5x. This translates into cost savings of 60% compared to the traditional paper-based method. Cost savings are calculated based on time savings as well as reduced paper and printing costs.

Before: Redlining process



After: Redlining process with BaseStone



8. ICE et al (2016) National Needs Assessment – A vision for UK infrastructure.

9. ICE et al (2016) National Needs Assessment – A vision for UK infrastructure.

10. The process where drawings are annotated with new information about the 'as-built' structure.

Encouraging uptake of smart infrastructure

For asset owners and operators, smart infrastructure will enable the optimal operation of key infrastructure. Systems – like smart electricity meters, smart motorways and the Digital Railway - will gather more data, building a better picture of current demand, monitoring performance, and helping generate information to inform future investment decisions.

It will also change how people use infrastructure services. For example, mixed transport data sets and real-time monitoring can realise 'mobility as a service' – leveraging a mixture of public and private assets to deliver the best travel outcomes for asset users. Smart Ticketing and the proliferation of travel apps enabled by transport data sharing is already influencing users' decisions. Smart meters in homes and building systems are already helping customers understand their energy usage and reduce costs, and make adjustment, in turn contributing to a wider smart grid where peaks and troughs of demand are better managed.

However, productivity through innovation is not only realised by the advent of new technologies - it is also derived through the uptake of existing technologies and processes, and development of the systems which use them. For industry, the use of currently available mobile technologies – like tablets – have huge potential to reduce duplication of work created by transfer of data from paper to digital systems.

The NPIF's focus on connectivity,[11] and the development and deployment of new infrastructure technologies is critical in ensuring our infrastructure network is future-proofed, especially as it is generally accepted that much of the infrastructure which will be in use in 2050 already exists. However, there is also a considerable opportunity to optimise the capacity and performance of the UK's existing infrastructure assets, encouraging the uptake of smart infrastructure now as well as preparing it for the impacts of new technologies on our infrastructure systems.

The NPIF's current spending profile rightly focuses on supporting the development of future transport technology, digital connectivity, and R&D for the development of new technologies (see Figure 1). However, £7bn for spending after 2021 remains unallocated.

11. At Autumn Statement 2016, the UK Government announced £1bn of new funding to boost the UK's digital infrastructure, including funding for a new programme of 5G and fibre trials.

Figure 1: National Productivity Investment Fund spending profile

Future Transport Technology:

- £390m in future transport technology including driverless cars, renewable fuels, and energy efficient transport
- £100m for testing infrastructure for driverless cars
- £150m to provide at least 550 new electric and hydrogen buses, reduce emissions of 15,000 existing buses and support taxis to become zero emission
- £80m to install more charging points
- £450m to trial railway digital signalling technology to expand capacity and improve reliability

Digital Connectivity:

- £1bn to invest in full fibre broadband and trialling 5G networks

Research and Development

- £2bn in R&D: funding for businesses and universities to back the scientific research and development of technologies such as robotics, AI and industrial biotechnology

Future spending:

- £7bn remains unallocated to any sector and is not scheduled to be spent until 2021-2022

The NPIF should be targeted at the digital transformation of both construction (digital delivery) and infrastructure (smart infrastructure) which increases the capacity and performance of existing assets and networks. This does not just include funding towards trials of new technologies, but also could be used to continue and strengthen support for existing programmes – like BIM Level 2- to ensure progress to date is fully embedded beyond big capital investment projects.

Digital transformation should also be at the heart of the Infrastructure Pillar of the Modern Industrial Strategy. Digital delivery and smart infrastructure solutions should be embedded across all economic and social infrastructure. This will not only bring benefits to end-users, but also realise the UK's potential as a world-leader in this sector.

The NIC's current work to identify the emerging technologies with the most potential - in terms of optimising management, performance and maintenance of existing and future assets - should be considered in informing how the remaining unallocated £7bn is spent. Its learning should also inform the spending of the £1.1bn allocated to reduce congestion and upgrade local roads and public transport, as well as the £2.3bn new Housing Infrastructure Fund to be used for roads and water connections which will be spent in the life of this parliament.

Optimizing outcomes for customers

Infrastructure regulators play an important role in ensuring value to infrastructure customers from infrastructure investment. The water industry's shift toward a total expenditure model (TOTEX) from a capital expenditure (CAPEX), driven by Ofwat and the Water Industry Commission for Scotland (WICS) the water industry regulators, is allowing industry to begin to make risk-based interventions other than capital replacement, such as extending the life of an asset. This creates a flexibility of approach which can help deliver better outcomes for customers. Ofgem has been encouraging companies in the power sector to consider innovative solutions like demand-side response or storage as alternatives to building more capacity, supporting resilience and environmental outcomes.[12]

Key outcomes for users may change further:

- As user requirements of infrastructure change
- Interdependencies alter demand across sectors
- The impacts of a growing population and climate change are felt

The shift toward TOTEX represents movement toward a more outcomes based approach. Regulatory frameworks across all infrastructure sectors should incentivise whole life investment decisions based on outcomes for the end user. This would enable the consideration of 'value' beyond cost, effectively redefining 'value' in the industry and would also unlock a wide variety of integrated digital/physical solutions.

12. Utility Week (2015) The Topic: totex. Available at: http://utilityweek.co.uk/news/The-Topic-totex/1196702#.WKxlDvlW7dU

2 Behaviours

This chapter considers the challenges to industry and infrastructure from disruptive technologies, and the opportunities from recognising the value of data. It also explores the importance of strong aligned leadership and organisational change to realising the right skills profile for the future.

To enable digital transformation:

4. ICE, and other professional institutions, must work with industry and the Government's Digital Strategy to ensure that people at all points in their career have the right skills to adapt to advances in technology and information management.

5. Clients, contractors and Government should use major infrastructure projects as incubators for skills and innovation. To apply this at a smaller scale, groups of projects should be turned into programmes so that innovation and skills can be embedded through the whole asset lifecycle.

6. Clients should mandate data interoperability standards throughout the whole programme/project group as part of the procurement process. Data standards to drive interoperability should be prioritised to make data appropriately accessible and usable across all platforms.

The changing skills profile

There has been much debate about how automation and standardised design will transform the civil engineering profession. However, there is a balance to be struck between the benefits of automated decision making, standardised design and human engineering expertise. While data and processes can be standardised, the effective application of information still requires judgement. Time previously spent on process-driven tasks could be applied to the innovation and aesthetics aspects which automation won't deliver. Upskilling staff, particularly in 'soft skills', will be vital to ensure that 'human value' is maximised in a changing industry.

Traditional role profiles will change, and the boundaries between engineering, technological and data disciplines will blur. A sector driven increasingly by data and evidence-based decision making will require more data management and analysis expertise. However, the rise of AI and automation will increase the value of social and creative skills, what are traditionally thought of as 'soft-skills' and the added value of human judgement.

Digital skills development requirements will change over time. Assessment of skills requirements and attainment is not a one-off exercise, and skills requirements will change with time.

Currently, skills shortages are most significant among engineering professionals, followed by IT professionals.[13] This is a problem for the infrastructure sector where both current and future skills requirements are represented in these shortages.

There is an increasing trend toward contractors and consultancies partnering with or buying out small technology firms, bringing new skills in-house, which are beginning to blur traditional lines and structures. The infrastructure sector has the potential to be an attractive industry for data analysts and ICT professionals, but industry needs to recognise the need and value of these skills and ensure they are embedded and not silo-ed. This will involve upskilling and educating senior decision-makers about the value of data in informing better decision making in a changing environment. There was a consistent feedback across the evidence gathering process.

By rethinking how the data generated on complex projects is captured and leveraged throughout the project lifecycle, clients and owner operators achieve better outcomes.[14] But in order to do this, better client specification of the 'need to haves' for the whole lifecycle of an asset will be key to the creation of better information, to inform better decision making.

The pace of technological change means skills requirements will change quickly so we will need to up-skill and re-skill people across their working lives. The majority of stakeholders we consulted agreed that that we needed to focus our efforts on mid-career professionals within the sector – those less likely to be 'digital natives' – and not just the next generation.

The recently published Digital Strategy announced Government's intention to establish new 'Digital Skills Partnerships' to coordinate various programmes and best practice sharing between local government, local businesses, charities and technology companies. These partnerships will also examine options for improving the coherence of digital skills provision at a local level especially, with the view to tackling regional skills shortages. A number of technology companies have supported the initiative; there is scope here for the construction industry to use these to share best practice. In the meantime, organisations should consider how Apprenticeship Levy funding might be used for the purposes of upskilling existing staff in these skill sets.

> ***"The industry isn't really multi-disciplinary enough, and there is a need to bring in the right people with the right skills for the future. If this includes IT and analytics skills, they need to demonstrate that the industry is a valid and competitive route."***
>
> *N Wales & NW England workshop participant*

13. UK Commission for Employment and Skills (2015) Reviewing the requirement for high level STEM skills. Evidence Report 94. Available at:https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/444052/stem_review_evidence_report_final.pdf

14. KPMG (2016) Building a technology advantage: Harnessing the potential of technology to improve the performance of major projects - Harnessing the potential of technology to improve the performance of major projects - Global Construction Survey 2016. Available at: https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2016/09/global-construction-survey-2016.pdf

ICE, along with other professional bodies, has a responsibility to take a lead on this, ensuring that its members are prepared for the digital transformation of their professions, projects and industry.

However, greater collaboration between professional institutions is necessary if we are to meet the needs of an increasingly multi-disciplinary infrastructure sector. ICE fully supports the IET and Royal Academy of Engineering's report *Connecting Data, Driving Productivity*[15] recommendation that professional bodies should work together to suggest changes in higher education as well as CPD to reflect the new demands for multi-skilled individuals and teams with data science skills.

Knowledge sharing

Going forward, industry will also need to work more collaboratively. This will be driven in part by contracts, alliancing models and use of collaborative information sharing platforms, but also by a need to overcome shared risks and realise long-term outcomes. Knowledge-sharing and collaboration will be required to overcome challenges like improving data quality standards. Professional institutions and industry should support and participate in the work of knowledge-sharing groups to address perceived risks from new technologies and processes. These include, for example, the UK BIM Alliance, which was established to lead the industry-wide drive for awareness, education and adoption of BIM Level 2 compliance.

More effective knowledge-sharing within and across organisations is also required. Commercial memory is lost as teams break up toward the end of a project, or when people move on from short term contracts, meaning opportunities to reflect on lessons which could benefit future projects are missed.[16] This is sometimes referred to as 'corporate amnesia'.

Major infrastructure projects have been shown to be effective incubators for both innovation and upskilling the workforce,[17] and Government should consider how this can be further encouraged. Projects like Crossrail and Thames Tideway have offered the opportunity to promote innovation through the supply-chain. Crossrail has implemented a shared innovation scheme - I3P-[18] with supply-chain partners who created an incentive to innovate and the potential for shared gains. Successes in publicly funded projects can demonstrate the benefits of innovation investment, educate decision-makers and create a skills and evidence base to support future decisions.

However, major infrastructure projects represent only a small percentage of overall spend on the UK infrastructure. The majority is spent on smaller projects, and repair and maintenance of our existing infrastructure. Innovation through operation, use and maintenance phases of the asset lifecycle are harder to realise, but potentially represent considerable savings through optimised processes. Grouping a number of smaller projects into larger programmes of work – as is done in the water industry and by Highways England[19] – is a mechanism by which innovation can be translated into smaller projects and through the whole asset lifecycle.

The importance of interoperability

A lack of interoperability between information systems means firms expend considerable time and resources when moving between, and within, projects. Better, consistent data standards, along with better metadata, will enable this. Greater interoperability between systems is essential, and clients can enforce this.

Open standards, increasingly favoured by public sector clients, work on the principle of software interoperability, data and document formats in line with public client specifications. This reduces the risk of clients contracting for systems which don't work with existing systems. Development of open standards can be relevant to a wider group of organisations of different sizes

Case study:

Open data standards and the challenges of development in a fast changing environment

The onset of digitisation brings with it a demand for new standards. Curiously, this is at a time when expectations for rapid answers have been set based on the implementation of open data standards in other industries.

buildingSMART reaches its 21st anniversary this year. It is the organisation responsible for the creation of the preeminent data standard for open data exchange in the built asset sector. More than 25 nations are represented and a robust international harmonisation process to develop new capabilities is in place. However there is much more to be done.

Standards follow solutions, open standards are either a gift or created from shared best practice. In the absence of a major benefactor the built asset industry must learn to work in new ways to first of all create the new digital solutions and then develop international consensus. For the standards to be open this often means competitors working together or doing things for free. This is a major cultural challenge to the industry. New opportunities are becoming available to help accelerate the process; web-based solution development portals aimed at harnessing crowd sourcing approaches are foreseeable.

All this needs governance and expertise to lead and coordinate. buildingSMART is a community organisation that understands these complex needs and can provide the needed neutral independent safe place for the creation of open standards. This cannot be done alone; the pace of new standard creation is set by the willingness of industry participants (be they firms or individuals) to contribute.

15. IET & RAE (2015) Connecting data and driving productivity. Available at: http://www.raeng.org.uk/publications/reports/connecting-data- driving-productivity

16. BBC (2016) Too Good to be Forgotten. Available at: http://www.bbc.co.uk/news/business-35821782

17. Langdon et al (2016) The case for internalising externalities in a sustainable rail asset base. Infrastructure Asset Management, Volume 3 Issue 3, pp. 97-105.

18. https://www.i3p.org.uk/

19. Highways England. How we Commission Work. Available at: http://www.highways.gov.uk/knowledge/how-we-commission- work/ Last accessed 08.03.17

A fundamental shift is required in the way clients, organisations and industry understand and value their data assets. There is enormous potential for better design, efficiency of delivery and management of the built environment through better use of data and analytics. Good data leads to better information which in turn enables better decision making and ultimately should enable better user outcomes and greater efficiencies. Data assets can have as much, if not more, value than their physical counterpart.

However, opportunities for better insight are lost through persistent organisational silos, lack of trust in data, poor data management and governance, and poor validation. Furthermore, organisations generally only analyse a small amount of their data – 12% on average.[20] This means that there is a large body of potentially problematic legacy data. This data might be stored in a range of physical and digital formats[21] across multiple sites, with variable availability and quality of supporting metadata. While it is increasingly possible to make use of unstructured data, understanding the quality of the available data, even if that means knowing where data is poor quality, is essential if it is to be leveraged as a resource in decision making.

Both industry and clients must ensure they have robust data governance and quality management frameworks in place. Asset data should be robust and accessible for the lifetime of the physical asset itself, as well as across the systems it impacts upon and which are dependent upon it. This requires that it should be maintained and resourced like the physical asset. Consideration should be given to the appointment of Chief Information Officers (CIO) and Chief Data Officers (CDO),[22] and upskilling for senior officials, to embed good data specification, governance, use, security and resilience as the foundation for better decision making. A survey of over 3000 global data and analytics decision-makers found that 45% of respondents indicated that their company had appointed a CDO, and that those companies with strongest growth were 65% more likely to appoint a CDO than those with weak growth.[23]

> ***Good data management will need to become mainstreamed in a way which it currently isn't. This will require a huge culture-shift.***
>
> *Data workshop participant*

20. Forrester (2014) The Forrester Wave™: Big Data Hadoop Solutions, Q1 2014. Available at: http://resources.idgenterprise.com/original/AST-0127029_The_Forrester_Wave_Big_Data_Hadoop_Solutions_Q12014.pdf

21. Some of which may no longer be accessible through format obsolescence.

When procuring a physical asset, clients also pay for the data about that asset – its 'digital twin'. Clients need to be able to specify with clarity the information they need, and of what quality, from the designers and contractors to operate the asset for the full duration of its lifespan. Bringing in Asset Managers at the beginning of a project helps to ensure that lifetime information requirements are understood, leading to better lifetime operating costs. This will lead to better lifetime value from assets through optimised operation, and better outcomes for infrastructure users.

> ***If the correct data requirements aren't agreed at the procurement stage, then there won't be the correct data for the full life of the infrastructure.***
>
> *Scotland Workshop participant*

Case study: *Client Leadership*

The Environment Agency (EA) received the BIM Level 2 mandate from the Government Construction Board in 2011. One of the first activities was to gain a better understanding of how data and information was used and managed within projects. The amount of information formally delivered during and at the end of projects was relatively small and opportunities missed to utilise a wider range of information needed to manage the assets over the next 75 to 100 years. The EA had to be proactive and lead the digital transformation.

Early steps included definition of information requirements during the procurement process, adopting open exchange standards where possible and taking the lead in defining data standards and deliverables for this segment of the industry. The EA had a robust asset hierarchy but had to work with NBS to ensure its assets were represented on Uniclass 15. Bringing technical specialists together within supply chain partners to understand how information is managed and the barriers which prevent digital working proved essential.

The construction industry relies on data and information about others infrastructure assets to deliver their own projects. The industry spends considerable time gathering this information which creates a burden for the respective business and unnecessary contractual costs. The flood risk asset dataset, made open in 2016, is proving to be a popular data download and software vendors have started to use it within their product offering. Being able to share trusted and reliable digital data in this way will push forward the digital transformation within the industry.

22. CIO: most senior executive in an organisation responsible for the information technology and computer systems. CDO: Responsible for organisation wide governance and utilisation of information as an asset, via data processing, analysis, data mining, etc.

23. Forrester (2014) The Forrester Wave™: Big Data Hadoop Solutions, Q1 2014. Available at: http://resources.idgenterprise.com/original/AST-0127029_The_Forrester_Wave_Big_Data_Hadoop_Solutions_Q12014.pdf

3 Resilience

This chapter explores the resilience considerations of increasingly connected technology and interdependent infrastructure, and evolving security requirements.

To future-proof our infrastructure:

7. Security mindedness should be mainstreamed within the industry – just like health and safety has been - in order to keep up with evolving security threats and vulnerabilities.

8. City deals and devolution agreements should include investment which is targeted at enhancing the quality of data assets and enables asset owners and operators in their area to map interdependency risks.

9. The National Infrastructure Commission should set out a needs based strategy to align energy and digital infrastructure policy. The interdependent nature of energy and digital infrastructure and the demands placed on electricity capacity by the digital sector requires an integrated policy.

> ***Our built environment is quickly becoming too complex for rules of thumb or intuition – therefore digital is critical!***
>
> *Data workshop participant.*

Mainstreaming Security-mindedness

Infrastructure data has commercial value as a resource. Rapidly growing volumes of data, accessibility and the increasing ease with which datasets can be overlayed offer many potential benefits to industry, but these also create vulnerabilities which need to be managed if the benefits are to be realised without compromising safety, security or resilience. It is vital that the industry treats security as an outcome, not a process or tick-box exercise.

In addressing security challenges there is a risk of 'prioritisation overload', making it hard to define what is essential. Identifying what is critical to the safety, security and resilience of assets, including systems; data and information; the services assets help to deliver; and personnel, and taking appropriate and proportionate measures to protect those first will be key.

There are parallels between security now and health and safety in the industry over the past two decades. Mainstreaming of security awareness will require industry investment, and will be required at all organisational levels.

The profile of cyber security has been heightened in recent years. The work of CPNI[24] and the development of the National Cyber Security Centre (NCSC), highlight that this is a key priority for government. Recent figures suggest that NCSC has blocked 34,550 "potential attacks" on government departments and members of the public in a six month period.[25] The resilience of critical national and local infrastructure, particularly in the context of increased connectivity, is another essential consideration.

Embedding security throughout an organisation requires clear leadership and understanding of the practical ramifications of failure, and organisational culture is one of the biggest challenges. The Engineering Council's *Guidance on security for engineers and technicians*[26] and the UK Government's *Cyber Essentials*[27] scheme offer useful guidelines, but industry must also share lessons learnt if we are to keep a-pace with the evolving threat. *The Electronic Communications - Resilience and Response Group* [28] brings the telecommunications sector together creating a mutual benefit model where stakeholders cooperate and collaborate on common problems, and return to a competitive footing outside of that collaborative environment. Additionally, the CPNI and NCSC host information exchanges where threat issues are shared with all the industry players with strict rules on if or how information is shared thereafter.[29]

In May 2018 EU General Data Protection Rules (GDPR) and Network Information and Security (NIS) rules both come into force in the UK.[30] The NIS Directive is designed to ensure critical IT systems in core sectors of the economy, like energy and transport, are secure.[31] Infrastructure owners and operators will need to ensure they are prepared for the enforcement of these new regulations. GDPR is intended to bring existing data protection standards up to date and strengthen the rights of data subjects. Maximum penalties for mishandling data are now 4% of global revenue or £20m, whichever is greater. For many organisations in the UK, this represents a huge increase in the Information Commissioners Office current maximum penalty of £500,000.[32] Government has stated that these rules will be enforced and will not be impacted by the results of the EU referendum, although in reference to GDPR this may only be until 2020.[33]

The changing nature of how the infrastructure sector works means that as more people have access to great amounts of data, there is a greater risk of accidental or inappropriate information sharing. The construction and operation of major infrastructure projects involve large supply chains, involving hundreds of organisations and thousands of people. Crossrail, the Queensferry Crossing, and in the future, HS2; each of these have huge numbers of 'moving parts' and people that need to work together and share information to do so.

24. The government authority for protective security advice to the UK national infrastructure.

25. The Guardian (12 February 2017) UK hit by 188 high-level cyber-attacks in three months; Britain's new cybersecurity chief says Russia- and China-sponsored attacks are among those that have threatened defence and foreign policy.

26. Engineering Council. Guidance on security. Last accessed 13.03.17. Available at: http://www.engc.org.uk/security

27. HM Government (2015) Cyber essentials scheme: overview. Available at: https://www.gov.uk/government/publications/cyber-essentials-scheme-overview

28. HM Government (2014) Telecoms resilience**.** Available at: https://www.gov.uk/guidance/telecoms-resilience#the-electronic-communications---resilience-and-response-group-ec-rrg

29. CPNI. 3. Identify the threats. Available at**:** https://www.cpni.gov.uk/content/identify-threats

30. While the UK Government has identified that GDPR rules will apply in spite of the outcomes of the European Referendum outcomes, it is unclear whether the same decision will be taken for NI&S rules.

The roll-out of BIM means people have access to the information to do their job, but sometimes more than is actually required for their specific tasks. Clearly defining appropriate access for each individual, for only the required period of time, and ensuring the data trail is auditable will help balance the benefits from BIM[34] and other technologies with the necessary security considerations. Consideration should be given to making security-minded BIM the default option, with an opt-out approach rather than opt-in. Additionally, industry is beginning to make use of new technologies to deliver and operate infrastructure at lower cost. Some of this is cutting edge – like drones – but most involves well-established technologies – like sensors and mobile devices. These can be vectors for accidental data sharing, particularly where they store data between projects or 'talk' to other devices. These have to be considered as part of the wider security piece.

As industry and clients recognise the value of data, security considerations could become as important as price and could be incentivised through professional indemnity insurance discounts, or through Integrated Project Insurance.

Large projects in particular are a good opportunity to drive up security awareness and good practice through the whole supply chain. Clients can enforce cyber security awareness as part of the contract, and give it increased weighting during procurement, and primary contractors can also enforce it.

Ensuring resilience at every level

Local Government is subject to ongoing austerity measures, with spending cuts set to continue until at least 2020. Local Government funding is forecast to be reduced by 54% between 2015-2020, to just £5.4bn.[35] The situation is broadly similar across the devolved nations.

Better use of data and information can enable local decision makers to deliver core services with greater resource efficiency. However, this needs to be supported by appropriate local capacity building to enable best use of data. This will enable better management of local infrastructure, and informing how to deliver optimum user outcomes.

The economic and environmental costs of operating an asset over its lifetime are often higher than the initial capital investment. Ensuring asset resilience and optimum conditions for asset users helps to deliver best lifetime value, and can prolong the life of the asset. Digital transformation of infrastructure offers a mechanism by which to improve asset efficiency over the whole asset lifecycle.

Benefits beyond design and construction include:

- Preventative maintenance enabled by live monitoring of asset and component performance using sensors, preventing service disruption from component failure.
- Improved operational efficiency through access to all necessary asset data – e.g. component specifications.
- As-built data enabling a cradle-to-cradle[36] lifecycle where material reuse is maximised, and carbon impacts reduced.

Local decision makers face a range of challenges in realising the value of their data assets, which are in line with many of the issues uncovered during evidence gathering for this report:

- Data is poor quality.
- The lack of common data standards.
- Lack of familiarity with data-led innovation.
- Lack of staff technical capacity.
- Information governance.
- Resistance to, and lack of understanding about, open data.[37]
- Building a robust invest-to-save business case may not be possible.
- Data informed decision-making can be a bigger change than it appears at first.[38]

Addressing these blockers comes at a cost and has to be balanced against the competing demands of funding for core services – like education and social care. Strong leadership from policymakers is required if these challenges are to be addressed and the value of local authority data in better local asset design, operation and maintenance is to be realised with optimised outcomes for citizens. Government can support this through the provision of co-designed guidance to enable local decision makers to engage fully with the challenges and opportunities from their data assets.

City deals and devolution agreements offer an opportunity to create alignment direction across social and economic infrastructure strands at a local level in terms of digital uptake.

Infrastructure planning decisions are made at a range of levels,[39] so a coordinated, collaborative approach, enabled by digital technologies in design, construction, use and operation, will be key to maximising the benefits of a systems approach.

ICE's State of the Nation 2016: Devolution[40] called for regional strategies to be developed to identify infrastructure need, ensuring the devolution of infrastructure is most effective. With increasing interdependency and digital connectivity it will also be essential to understand and manage increased local risk in a more holistic way at a regional level. Greater collection and use of data created by increasing connectivity will enable this.

As local assets become more connected over time, it will be important for local decision makers to understand how this alters existing understanding of local infrastructure interdependencies, and security requirements.

Case study:
Digital and physical infrastructure interdependencies

In December 2015, Lancaster suffered a high-impact flooding event. Electricity supply to 61,000 properties was lost impacting homes, businesses, schools and hospitals. The loss of electricity supply, and flooding of connection boxes, meant that some areas suffered a complete fixed-line and wireless communications black-out. Schools and hospitals were forced to close, heating and cooling systems for housing and food supplies were lost, and electronic payment systems were impacted.[41]

31 Pinsent Masons (2016) Network and information security laws to be in force across the EU from 10 May 2018. Available at: http://www.out-law.com/en/articles/2016/july/network-and-information-security-laws-to-be-in-force-across-the-eu-from-10-may-2018/ Accessed 21.01.17

32. CGI. New European cyber laws GDPR and NISD. Available at: https://www.cgi-group.co.uk/systems-integration-services/cyber-security/nisdandgdpr Accessed: 24.02.17

33. Steven & Bolton LLP (2016) Brexit and data protection in the UK. Available at: http://www.stevens-bolton.com/files/9614/6840/3197/Brexit_-_Data_Protection_in_the_UK.pdf

34. BIM Task Group. PAS 1192-5 – Overview. Available at: http://www.bimtaskgroup.org/pas1192-5_overview/ Last accessed 08.03.17

35. Nesta (2016) Wise Council: Insights from the cutting edge of data-driven local government. Available at: http://www.nesta.org.uk/sites/default/files/wise_council.pdf

36. Cradle-to-cradle design maximises material and resource efficiency, and assets are designed with end-of-life in mind, and in such a way as to maximise reuse or remanufacture.

37. Data is generally refered to as being either open, safeguarded or controlled, depending on the sensitivity of that data. Open data is data that anyone can access, use or share, often when big companies or governments release non-personal data,

38. http://www.nesta.org.uk/sites/default/files/wise_council.pdf Nesta (2016) Wise Council: Insights from the cutting edge of data-driven local government.

39. UK, Devolved Nations, regional and local

40. ICE, State of the Nation 2016: Devolution ICE, State of the Nation 2016: Devolution ICE (2016) State of the Nation: Devolution. Available at: https://www.ice.org.uk/getattachment/media-and-policy/policy/state-of-the-nation-2016-devolution/ state-of-the-nation-2016-devolution.pdf.aspx

41. Lancaster University (2016) Learning from Lancaster's power cuts. Available at: http://www.lancaster.ac.uk/news/articles/2016/learning-from-lancasters-power-cuts/

Aligning digital connectivity and energy policy

The ICE-led National Needs Assessment (NNA) has highlighted not only the ever-increasing interdependencies between infrastructure sectors, but also the ever-increasing demands placed on our digital communications and energy infrastructure by the roll-out of ever-smarter, more connected assets.

The next stage of connectivity is moving from people to 'things' with Cisco estimating 500bn devices will be connected by 2030, up from 13bn in 2013.[42] The realisation of CAVs, IoT and smart cities will be heavily dependent upon getting connectivity right, and understanding the interdependencies with other infrastructure, planning and regulatory systems.

Big data requires significant electricity to power it. Last year, the world's data centres consumed 416.2 terawatt hours of electricity, far outstripping the UK's own total consumption (300 terawatt hours of electricity); a figure which experts forecast will treble in the next decade.[43] Data demand increased by 53% in the UK in 2014 alone;[44] managing the storage and sharing of increasing volumes of data requires national coordination, especially as the cost of storage declines overtime.

Of course, while new digital technologies and data can drive up energy requirements, they can also be instrumental in helping to manage them. Smart grid technology is already proving its ability to respond to real time fluctuations in energy demand, enabling effective supply side management. In turn, smart meters are already consumers with the information to use energy more efficiently, reducing consumption and energy bills.[45]

Meanwhile, the successful roll-out of CAVs will of course hinge on the timely installation of an open and accessible mobile telecommunication and backhaul network on our motorway system.[46] But it will also require us to address the electricity generation capacity and distribution across all our existing road networks, at a regional level.

The UK Government's newly published 5G Strategy[47] seeks to achieve this through use of commercial models, but with the possibility of funding live trails.

Other commitments include:

- Trials and testbeds for 5G in rural and urban contexts
- Building in the principles of interoperability, replicability and openness from the start
- Exploring removing barriers to infrastructure sharing for new communications
- A new national 5G Innovation Network to take 5G from R&D to commercial reality
- Government is establishing a new centre of 5G expertise in DCMS

Laying the groundwork for good connectivity for future communications technology now will be instrumental in delivering the smart and connected infrastructure that the UK needs to make best use of its existing infrastructure, adjust to an increasingly data-driven future, and ultimately deliver the best outcomes for infrastructure users.

42. Oxford Martin School (2016) Technology at Work v2.0: The Future Is Not What It Used to Be. Available at: http://www.oxford-martin.ox.ac.uk/downloads/reports/Citi_GPS_Technology_Work_2.pdf

43. Independent (23 January 2017) Global warming: Data centres to consume three times as much energy in next decade, experts warn. Available at: http://www.independent.co.uk/environment/global-warming-data-centres-to-consume-three-times-as-much-energy-in-next-decade-experts-warn-a6830086.html

44. The future of national infrastructure: A system-of-systems approach, edited by Hall, J.W., Nicholls, R.J.,Tran, M. and Hickford, A.J., Cambridge University Press, 2016, page 189.

45. Smart Energy GB (2016) "What is a smart meter?" Available at: https://www.smartenergygb.org/en/about-smart-meters/what-is-a-smart-meter . Energy suppliers are committed to installing around 50 million gas and electricity smart meters to all homes and small businesses by 2020.

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- Digital Catapult
- Digital Greenwich
- EE
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- Silverspring
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- Smart Energy GB
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- Telefonica
- Transport for London
- Thames Tideway
- Topcon
- Transport Catapult
- UBM
- UK BIM Task Group
- UK Collaboratorium for Research on Infrastructure and Cities
- Urban Big Data Centre

Individuals

- Regional workshop participants
- Data and security workshop participants
- Survey responders

ICE Expert Panels

- Transport Panel
- Structures Panel
- Energy Panel
- Infrastructure Systems Panel

About ICE

Established in 1818 and with over 91,000 members worldwide, ICE is the independent voice of infrastructure and the leading source of expertise in infrastructure and engineering policy. Under our Royal Charter, ICE has a public duty to provide advice to all political parties and work with industry to ensure that civil engineering remains a major contributor to the UKeconomy.

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46. NIC (2016) Connected Futures. Available at: https://www.gov.uk/government/publications/connected-future

47. DCMS (2017) Next Generation Mobile Technologies: A 5G Strategy for the UK. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/597421/07.03.17_5G_strategy_-_for_publication.pdf

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